

Günther Witzany

**Life: The Communicative Structure**  
a new philosophy of biology



Günther Witzany

**Life: The Communicative Structure**  
a new philosophy of biology

Gedruckt mit Unterstützung des Bundesministeriums für Wissenschaft, Forschung und Kunst in Wien.

Die Deutsche Bibliothek - CIP-Einheitsaufnahme

Witzany, Günther:

Life: the communicative structure: a new philosophy of biology/

Günther Witzany. Übers.: Michael Stachowitsch. - Bürmoos,

Vogelsangstraße 18c: G. Witzany, 2000 ([Norderstedt] : [Libri Books  
on Demand])

Einheitssacht.: Natur der Sprache - Sprache der Natur <engl.>

ISBN 3-8311-0349-6

Translation by Michael Stachowitsch

Cover photography: Immunoflourescence staining of PtK 2 cells (interphase stage)

G.Czihak/W. Schürmann, Institute for Genetics and General Biology, University of Salzburg

Dedicated to my parents, my wife and my son

The only elements that can interpret the genetic message  
are the products of the message itself.  
The genetic text makes sense only for the structures  
it has itself determined.

Francois Jacob

# CONTENTS

## Preface

<b>1. Introduction</b>	15
1.1. The need for a new understanding of nature	15
1.2. Schelling's <i>natura naturans</i> : „We term `nature as productivity` `nature as subject`“	18
1.3. The possibility and sense of an interdisciplinary dialog between biology and philosophy of language	21
1.4. The structural format of this study	22
1.5. Language and communication as a precondition and content of the interdisciplinary dialog	25

## PART ONE

<b>2. Language and communication - an approximation</b>	29
2.1. Language and communication in modern linguistics	29
2.1.1. The communication model in linguistics	30
2.1.2. The sign model in linguistics	30
2.1.3. Models of coding and decoding	30
2.1.4. The structure of the linguistic code in linguistics	31
2.2. Language and communication in semiotic pragmatics	31
2.3. Language and communication in universal-pragmatic communication theory	33
2.3.1. Several differences between the linguistic and the universal- pragmatic analysis of language and communication	34
2.3.2. Features of speech actions	36
2.3.3. Gaining the faculty for language and the possibilities of defining the ego	39
2.3.4. The communicative or the cognitive aspect of linguistic communication	40
2.3.5. Actions and behavior	40
2.3.6. Human communication versus animal communication	41
2.4. Language and communication - A working hypothesis	42
2.4.1. Three communication types in living nature	44
<b>3. Languages in nature</b>	45
3.1. Honeybees in the northern hemisphere	45
3.1.1. The sign-mediated communication process behind the finding of a new colony	46
3.1.2. The sign-mediated communication process of foraging	48
3.2. Further features of communication in honeybees	49
3.2.1. The types of dances: Their sign characters and their meaning	49
3.2.2. Forms of communication beyond dance	50

3.2.3.	Humans can understand the bee language	50
3.2.4.	Dialects of the bee language	50
3.2.5.	Language <i>and</i> communication in bees	51
<b>4.</b>	<b>Intraorganismic communication</b>	<b>53</b>
4.1.	Intracellular communication	53
4.1.1.	The sign-mediated communication process of protein synthesis involving two intracellular languages	54
4.1.2.	Proteins - products of intracellular communication	69
4.1.2.1.	Two intracellular communication processes in the regulation of enzyme protein synthesis	73
4.2.	Intercellular communication	74
4.2.1.	Hormones as linguistic signs	76
4.2.2.	Neurotransmitters as linguistic signs	78
4.2.3.	The organization of the cellular response	80
<b>5.</b>	<b>Disturbances in intraorganismic communication</b>	<b>85</b>
5.1.	Intercellular communication disturbance: Cholera as an example	85
5.2.	Disturbance of coordinated behavior between cell associations through disturbance of sign-mediated communication	86
5.3.	Intracellular communication disturbance	88
5.4.	Recombination of genetic texts through“jumping“ genes and retroviruses	91
5.5.	Electromagnetic fields as the communication medium of intercellular communication?	93
5.6.	Self-defence strategies of organisms: The immune response	94
5.6.1.	The identification of `self` and `non-self`	98
5.6.2.	The acquisition of interaction competence by thymus cells	101
5.6.3.	Viral camouflage strategies	102
5.6.4.	Communication disturbances involving damage to the genetic text and their repair by specific enzyme proteins	103
5.6.4.1.	Excision repair	103
5.6.4.2.	Postreplication repair	104

## PART TWO

<b>6.</b>	<b>Explanatory deficits in Manfred Eigen´s concept of language and communication.</b>	
	<b>From the logic of „molecular syntax“ to molecular pragmatism</b>	<b>109</b>
6.1.	Manfred Eigen´s use of the terms „language“ and „communication“	109
6.1.1.	Molecular recognition processes and their significance for genetic manipulation	109
6.1.2.	Self-organization and the logic of „self-reproducing automatons“	110



6.1.3.	Levels of self-reproduction: Eigen's implicit epistemology	112
6.1.4.	Structures of language	114
6.1.5.	The information concept: the constitution of meaning through syntactic structures as the logic of material reality	115
6.1.6.	The allocation of symbols and meaning in the human language	116
6.1.7.	Molecular semantics	117
6.1.8.	„The vector character of the speech flow from chromosome to organism“	118
6.1.9.	„Understanding“ (Verstehen) as a reversal of information generation	119
6.1.10	Molecular genetics and generative grammar	121
6.2.	Philosophical implications of Manfred Eigen's language and communication concept	124
6.2.1.	Language as a quantifiable set of signs	124
6.2.2.	Language as an algorithmic decision-making process	125
6.2.3.	Humankind as a learning machine	126
6.3.	Deficits in the depicting theory of language	127
<b>7.</b>	<b>Pragmatics of language (Sprachpragmatik) as a basis for a semiotically expanded language and communication concept in behavioral-, socio-, and molecular biology</b>	<b>133</b>
7.1.	Language as a medium of understanding. The apriori of the pragmatic situation of understanding	133
7.2.	No generative grammar without generative pragmatics	134
7.3.	From (privatistically conceived) generative grammar to apriori of pragmatic speech situations	136
7.4.	The constitution of meaning and understanding through real intercommunication processes	137
7.4.1.	The apriori of understanding situations for constituting meaning in the bee language	138
7.4.2.	No intra- and intercellular linguistic signs without real sign-users. The importance of cellular communities of communication	142
 <b>PART THREE</b>		
<b>8.</b>	<b>Types and forms of communication in living nature</b>	<b>149</b>
8.1.	One language of nature - many forms of communication	152
8.2.	Semicompatible forms of communication in nature. The classification of communication types and communication forms	153
8.2.1.	The arrangement of all known organisms into phylogenetically related groups	155
8.2.2.	Dating the origin of the 6 communication forms in nature	156

8.2.3.	Expanding modern biological systematics in the dimension of a philosophy of language	158
8.2.3.1.	The Prokaryotes	158
8.2.3.2.	The Protoctists	161
8.2.3.3.	The Animals	164
8.2.3.4.	The Fungi	167
8.2.3.5.	The Plants	170
8.2.3.6.	The Human beings	171
8.2.4.	The interrelationship of communication forms. The adaptation of Nicolai Hartmann's theory of levels in the philosophy of language sense	174
8.3.	Delimiting the communication forms from one another	177
8.3.1.	Precommunicative interaction level	178
8.3.2.	Communicative levels of interaction	180
8.3.2.1.	The Prokaryotes (bacteria)	180
8.3.2.2.	The Protoctists	181
8.3.2.3.	The Animals	182
8.3.2.4.	The Fungi	183
8.3.2.5.	The Plants	184
8.3.3.	The human communication level	185
8.4.	Using the semicompatibility of nature's communication forms to systematically define kingdom-specific, sign-mediated communication processes	186

## **9. The origin of novel entities in living nature:**

	<b>Evolution as generative linguistic behavior</b>	189
9.1.	Sign-mediated communication as an apriori for evolution	190
9.2.	Molecular evolution	193
9.2.1.	The macromolecular basis of bioevolution	194
9.2.2.	The difference between mutation and polycondensation	195
9.2.3.	DNA chain growth	198
9.2.3.1.	DNA chain growth through text-generative genes and enzymes	198
9.2.3.2.	Are structured biological languages potentially present in noncoding DNA sequences?	200
9.2.3.3.	The explanation of DNA chain growth through Serial Endosymbiosis Theory (SET)	202
9.2.4.	Back to Lamarckism?	
	or: forward to new concepts in development and evolution	203
9.2.4.1.	„Intelligent“ alteration of and retroaction on the genetic material?	203
9.2.4.2.	Molecular pragmatism: context determines meaning	204
9.2.4.3.	The concept of „downward causation“	205
9.2.4.4.	The concept of „adaptive mutation“	207
9.2.4.5.	Homeotic genes and evolution	208
9.2.4.6.	The importance of gene rearrangement in evolution	209

9.2.4.7. Informational transfer from protein to DNA	210
9.2.4.8. Back to Lamarckism?	211
9.3. Organismic evolution	212
9.4. Cultural evolution	212
<b>10. Nature as a norm subject</b>	<b>215</b>
10.1. The communicative relationship between man and nature	217
10.1.1. Intraorganismic communication in humans is almost exclusively a natural phenomenon	217
10.1.2. Interorganismic communication in humans is largely a cultural phenomenon	217
10.1.3. Cultural tradition plays an important role in orienting metaorganismic communication of humans	218
10.2. Remedying the human (metaorganismic) communication pathology towards living nature as a necessary step in cultural evolution	219
<b>11. Bibliography</b>	<b>223</b>



## Preface

The necessity for a new *understanding* of (living) nature is the driving force behind this book. The current relationship between humans and non-human nature clearly needs to be modified or improved if we are to master the escalating ecological crisis *in time*. The central idea is that living nature is structured and organized in a language-like and communicative manner, i.e., that all organisms, including humans, are members of a global community of communication. In this view of living nature, specific communication rules must be adhered to if the community of communication is to survive. This idea required an interdisciplinary approach combining philosophy, biology and semiotics.

It was clear to me that this would entail playing an intermediary role, i.e., explaining well-known (to philosophers) philosophical positions to biologists and well-known (to biologists) biological positions to philosophers. In any case, the point of departure would have to be mankind's understanding of itself (*Selbstverständnis des Menschen*) or, more precisely, the understanding of human language and communication as a precondition for formulating any kind of self-understanding:

*Referring back to the rules of communicative rationality provides an opportunity to answer questions of evolutionary logic and dynamics as questions of interaction logic and dynamics. Evolutionary history could then be understood as a developmental history of interaction semioses.* If we could further establish that the rules governing evolution are equivalent to the communication rules behind the history of interaction, then we could justify the view that rule-governed sign-mediated behavior is a factor not only in humans, but especially in non-human living nature.

A more detailed examination of research results in the biological sciences should yield structures that can unequivocally be interpreted as communication rules. Viewing living nature as a communication partner in a common shared, communicative world would establish it as a norm subject. Understanding nature would no longer be a metaphorical expression of reductionistic explanatory models, but rather would mean understanding interaction logic and dynamics in their regulative, constitutive, and generative (innovative) dimensions. If living nature could be comprehended as a global community of communication, then this understanding (preceded by an analysis of communication processes) might well extend to the pragmatic level, at least in the realm of human nature with its capacity for self-consciousness. The very behavior of this self-conscious nature should reveal that it has understood the rules of a linguistically and communicatively structured and organized living nature. Furthermore, it also adheres to these rules (inasmuch as it recognizes the validity of reasoned action), i.e., it acts in a manner conforming to norms and - when the need arises - in a manner constituting norms.

The current contribution provides a blueprint for a philosophy of biology in the light of pragmatics of language. It distinguishes itself from traditional natural philosophies in that its foundation in philosophy of language builds upon and unifies both empirical and transcendental-reflexive moments.

Such „preliminary remarks on a theory of communicative nature“ can go beyond a new perspective of non-human living nature to initiating a new understanding of human nature itself. If living nature is a global community of communication, humans could view themselves as members among many other (non-human) members in this community. Universal-communicative, normative rules can also be derived from such a membership. Their non-observance has led us into a historically unprecedented ecological crisis. In light of this ecological crisis, future adherence to these rules will probably become the greatest cultural and evolutionary challenge that mankind has ever faced. Should we be unable to master the ecological crisis in time by adequately complying with these rules, then our survival is as uncertain as that of most other biological species threatened by mankind's activities.

Viewed from this perspective, this book provides support for an ecologically oriented ethics. *It does not represent ethics in itself*; rather, by opening the way to a new perception of living nature, it wishes to provide the information we need to introduce and establish norms of ecological ethics.

***To this end, the book primarily aims to prove that it is justified to refer to a linguistically structured and communicatively organized living nature.*** This leads to a range of potential conclusions. It is beyond the scope of this book to treat this aspect in detail and such conclusions are only briefly outlined here.

I wish to thank: Wilhelm Vossenkuhl (University of Munich), Thure von Uexküll (Freiburg i.Br.), Manfred J. Sippl (Center of Applied Molecular Engineering, University of Salzburg), Ludger Albers (German clinic for diagnostics, Wiesbaden) for helpful discussions as well as a stimulating and critical correspondence. Michael Stachowitsch (University of Vienna) for translating this book, which is a revised version of „Natur der Sprache - Sprache der Natur“ (1993) .Wilhelm Hasenauer for Layout.

Günther Witzany, January 2000

# 1. Introduction

## 1.1. The need for a new understanding of nature

The development of human individuals and communities is accompanied or driven by crises. As a rule, such crises affect humans in a very complex manner, and the formal analysis of a „crisis“ as a decision structure that can principally be expressed and stored in a binary code is initially entirely irrelevant for those affected by the crisis: solving complex crisis situations requires wide-ranging consultations that cannot be reduced to yes/no answers. Crises must be mastered because they call for irreversible decisions without which a specific development would not be possible. From this perspective, they can be viewed as structural features in the social evolution of cultural communities.

Today we find ourselves confronted with an *ecological crisis*. Both quantitatively and qualitatively, this crisis transcends - in a unique manner - all those that have occurred in the past: No longer is merely the survival of mankind at stake, but the survival of most higher forms of life.

The existence of this ecological crisis is a fact that needs no further debate. Reports, studies, and research results outlining the details fill whole libraries. Never before has mankind been confronted with an ecological crisis of global proportions in which the future of human and non-human life is assured only if the problem is solved *in time*. Today, the ecological crisis is understood as an interlinked collapse of ecospheres that were previously largely self-regulating and self-stabilizing; it is a collapse stemming from specific human interventions into nature.

Up until these massive interventions, initiated by one of nature's own life forms, the biosphere produced an evolutionary dynamics and diversity having an amazing survival potential. Up until these interventions, the interlinked, highly varied functions of these ecospheres provided Earth with an ability to reproduce this variety that, although contingent, was compatible with the foreseeable life span of the planet. Initially, the social evolution of human cultures posed no threat to this ecological evolution.

The ecological crisis confronting us today is basically the result of a 100-year-long cultural development, with the escalation of the crisis having taken place only over the last 40 years. In other words, the quality of mankind's interventions in the past 40 years has created an ecological crisis that goes beyond merely disturbing nature, to potentially destroying the ecological balance developed and proven over millions of years.

The quality of this specific intervention reflects a form of human conduct that is based on a clear anthropocentric relationship to nature. More precisely: As opposed to cosmo- or biocentrically oriented cultural traditions, Western civilization adopted a world view that made humans the focal point and undisputed beneficiary of the nature around us.

Within Western civilization, and particularly in its modern form, i.e., scientific-technically oriented industrial society, non-human nature was degraded to a mere resource.

Moreover, people themselves and even society as a whole have, as „human capital“, become the object of a pervasive economic cost-benefit calculation; this is increasingly determining the system of values and norms of global cultural development.

The cultural specificity of this view of nature is discernible less in our conduct in and with nature, but rather in the fact that we set out to extract, exploit, utilize, and consume virtually every useful subject and object on the planet. Using the media power and money, Western culture and its proponents have, in fact, unleashed an entire series of successive (internal and external) colonization strategies over history and thus irrevocably drawn other cultures into their spell. The Western-Modern weltbild has come to dominate the lifestyles of these cultures in the realm of production, organization, distribution, and consumption, i.e., has increasingly penetrated the sphere of social and economic evolution.

This anthropocentric approach to nature, which is first exported and subsequently internalized by the affected cultures, pushes both the reproductive capacity of these societies as well as the capacity of exploited natural resources to their limits. At this point, Western-Modern society threatens not only the non-human nature in which it is set, but also every other culture that it has externally and internally colonized. The effect is global: the respective techniques, technologies, and strategies are primed for worldwide action.

How this situation came about and the reason behind the undeniable relationship between the scientific-technically oriented industrial nations and the current global ecological crisis is being systematically examined with varying success by a number of scientific disciplines.

I advocate a language-philosophical hypothesis: An ecological crisis of this dimension could only develop *because Western-Modern culture behaves **communicative-pathologically** toward (inner and outer) nature.* This culture's communication with nature is one-sided in its structure and therefore distorted. My underlying premise here is that *every form of rule governed interaction between living individuals*, within any behavioral context or set of actions, can be termed communication.

In the natural sciences, the term „rule governed interaction“ is defined as a behavior subject to the laws of nature. And, in fact, the weltbild of natural science underlies western civilization's relationship to nature. Worldwide, natural scientists accept the language of natural science as the universal communications tool in all matters dealing with nature. Precisely here, however, in the cognitive-instrumental representational concentrate of our modern culture, this linguistic-philosophical thesis (which upon closer examination proves to be a communication-theoretical thesis) is no longer amenable to discussion. The thesis that we communicate with nature and, moreover, that nature communicates with us cannot be the object of scientific research. The task of natural sciences is to study nature based on its inherent natural laws and to verify the obtained results in reproducible experiments. Nature, in such experiments, is forced to react; interpreting this response as nature's „answer“, however, is a very „imprecise“ formulation because „nature is incapable of speaking“.



„Man discovered the possibility of explaining nature as a series of events. In order to take advantage of this opportunity, however, nature had to be silenced. It was successfully silenced, and the door was thus opened for explanations. The result is that it is impossible to precisely determine whether nature is actually speaking: the very fact that it is not speaking is the prerequisite for the precise determination“. (KRINGS, 1982, p. 391).

In the face of the ecological crisis, a phase of contemplation and reflection on the relationship between the possible repercussions of human activity along with the non-human nature affected by such activity raises - in my mind - a key question: can we base suitable strategies to save and preserve the remaining ecological resources on explanatory models of nature handed to us by natural-scientific research institutions? Or, put differently, can we afford to reorient our relationship to living nature - and can we burden non-human nature - solely on the basis of knowledge stemming from natural-scientific disciplines, even if this knowledge is possibly incomplete, fragmentary, or of only limited value in coordinating appropriate rescue measures?

I contend that reducing the threat necessitates *a broader understanding of nature*, both with respect to the nature of humans and to surrounding (non-human) nature. Expanding upon my thesis on communication theory: we must learn to regard the rule governed interactions between living beings as a communication process, and to understand nature as *acting* in a communicative (*transcendentally reflective*) manner and *behaving* in a communicative (*empirical*) manner.

The methodology of those sciences that allow us to grasp nature in the technical-cognitive sense and that leave their results to be exploited by economic forces is incapable of viewing nature as anything but a resource in a cost-benefit calculation. This demonstrates that purely explanatory interpretations of nature, i.e., those that forego an explicit understanding of nature, construct a *monological* relationship between mankind and nature. In such a relationship, human subjects are pitted against non-human objects.

Based on its methodology, it is beyond the bounds of natural science to recognize that nature might be a co-subject of human beings, one with which mankind needs to deal and behave toward in a communicative manner if our access to nature is to go beyond explanatory models to true understanding (thus making nature a norm subject of moral-practical reason). Natural science has systematically excommunicated nature as a subject.

On the other hand, can nature be excommunicated as a subject? How does an excommunicated nature react? How does it respond? It unequivocally forces us to take up the „conversation“ again (in the form of rule governed, interactive action or behavior); moreover, the renewed conversation is enriched by the effort of re-communication, i.e., the effort invested to again raise the excommunication motives as well as the practical aspects of the excommunication. This is reflected in the treatment methods used in the field of psychosomatics (compare UEXKÜLL, 1982, 1984, 1986, 1989) and is further evident in groups of subjects who, in technocratically run businesses, have been degraded to numbered entities and who then use organizational skills to force management to deal with

them as subjects again (inner nature). This is equally evident for example in the willful or negligent disregard of ecological balances: the consequences of such an ecological imbalance can confront the community within the destabilized ecosystem so massively that there is no recourse but to repair the damage (external nature).

The ecological crisis, characterized by the destruction and subsequent collapse of mutually supportive ecospheres, forces mankind - as the perpetrator - to cope with a specific cognitive developmental deficit: the survival of all living nature has, at an incredible pace, become dependent not only upon *whether*, but rather *how fast* mankind will be able to develop and enter into a relationship with nature that can avert the worst consequences of the ecological crisis in time. This requires decisional qualities that have never been part of the decision-making processes in the reproduction of societies.

### 1.2. Schelling's *natura naturans*:

„We term ‘nature as productivity’ ‘nature as subject’“

*The flip side of a monological relationship to nature is a communicative one.* The complementary aspect of explanatory models about nature would be the understanding of nature, an understanding that orients rather than replaces the explanation.

„Understanding demands linguistic communication (text, speech, linguistically communicated action or interaction), demands the ‘co-subject’“ (KRINGS, 1982, p. 391)

Without recognizing nature as a subject, no transformation of the monological relationship is possible (on one side: the human subject, on the other side: the exploitable natural objects). A basic prerequisite for establishing and justifying such a recognition of nature as a subject is proving that a language of nature exists, i.e., that nature is structured and organized in a communicative manner.

*Such proof would provide the opportunity to understand nature by understanding sign-mediated, rule governed interactions and, subsequently, comprehending the signs and rules underlying the respective sign usage.*

This cannot be achieved without qualifying the strategic-exploitative perspective in favor of a more communicative thought process and conduct. The goal is not merely to understand the language and communication of man as a natural and cultural entity (although this is the most readily accessible starting point), **but to understand the languages and communication processes of non-human nature.**

The result, according to the present thesis, would be a better understanding of nature itself; besides overcoming the monological relationship to nature, this could also lead to the constitution of norms of conduct suitable for establishing a *non-parasitic*, evolutionary cooperation between human culture and non-human nature.

How can we establish, much less justify a premise such as the topos „language of nature“? Doesn't such an approach smack of an attempt to restore a metaphysical status, or worse yet, a (mystical) re-enchantment of nature?

No lesser a capacity than the philosopher F.W.J. Schelling devoted a major effort to the problem of „nature as subject“. Hermann Krings can be credited for taking up Schelling's interpretations of nature and further developing them in the framework of communication theory. Let us briefly examine his results.

According to Krings, Schelling's concept is a counter-concept to Kant's metaphysics of science. In Kant's concept, nature can be understood only indirectly: only by constructing the terms relating to corporal natural objects and, more so, the *representation of terms apriori to a natural object* does the possibility of an empirical and nomological science - as in the case of physics - become apparent. In this case, physics must be initially understood, and the comprehension of physics then leads to an understanding of nature - but only indirectly.

Schelling stands this concept on its head: nature itself is the subject, which, among other things, also scientifically constructs natural processes (e.g., mechanics). „Nature is the original constructor; science turns out to be a reconstruction“. (KRINGS 1982, p. 383)

Furthermore: *One and the same transcendental subjectivity is the empowering basis of nature and intelligence*. The phrase „nature as subject“, denoting nature that constructs, is *not a description* but rather an expression of a *geneticizing action* of nature itself. The original natural process is not the composition and dynamics (attracting and repelling forces) of matter in space, but self-consciousness. Schelling himself „constructs“ this as two originally opposed activities: One is absolutely productive, the other serves to limit this productivity, whereby the former always asserts itself against this limit or hindrance and thus dialectically reestablishes these opposing forces on a higher level.

„We term ‘nature as productivity’ (*natura naturans*) ‘nature as subject’ (this alone is the goal of all theory)“ (SCHELLING, in: HECKMANN R. (Ed.) 1985, p. 114).

That which is absolute *constructs* itself as nature, and philosophy reconstructs the geneticizing process of this absolute entity in a transcendental-terminological construction (KRINGS). Accordingly, the task of transcendental philosophy is to trace our existence back to an act of freedom and to regard its *actual emergence as a self-emergence*.

„The absolute activity constructs itself and the philosopher reconstructs the original self-construction of nature“ (KRINGS, 1985, p. 116). Schelling considers the organism to be the central phenomenon of nature. To him, non-living nature represents a still „enveloped“ organism and thus preliminary evolution. Humans, on the other hand, can be regarded as developed matter: while nature remains *unconscious awareness*, the mind represents *conscious nature*. In the present work, this topos - treated from the perspective of communication theory - will become a key point.

Schelling is convinced that „even that which we call reason is a mere interplay of higher natural forces necessarily unknown to us“ (SCHELLING, in: KRINGS, 1982, p. 384). Biology cannot be conducted according to the laws of biochemistry and biophysics, but

vice versa: physics and chemistry are subject to the principles of biology. Only by comprehending self-awareness can we understand the organism, and the comprehension of the organism is a prerequisite for understanding matter. „It is only ‘dynamically’ organized matter (in the sense of Schelling, not Kant) that enables us to understand reason as nature“ (KRINGS, 1982, p. 384). For Schelling, this conclusion stems from the premise that nature is unconscious mind, while mind is nature that has attained a conscious level.

From this point on, a hermeneutically oriented research program is called for. It is not meant to replace the explanatory sciences, but can provide them with the necessary orientation (in the normative sense as well), an orientation that they are unable to provide from within themselves, as we will see when we turn to Manfred Eigen. The way mankind perceives itself opens the door to understanding living nature. In Krings’ view, comprehending living nature enables us to understand matter. If nature that has become conscious (the human mind) wishes to understand both itself and nature that has remained unconscious, it can begin its inquiry with its own self-understanding (Selbstverständnis): ***nature as productivity is identical in all its forms, both in the mind inside us and in the nature surrounding us.***

Furthermore, it is fully compatible with the geneticizing acting of nature when humans, as natural beings, are dissatisfied with the claim of mathematics and physics to universal answers about nature, but instead grasp their freedom and behave toward nature from the vantage point of free reason. Mankind thereby transcends the position of explaining and technically exploiting, transcends the position of „standing opposite nature“ to attain a „together with“ and a „sharing with“ the common living world of nature and culture. *He elevates the freedom of nature to the same status as his own free reason.* „This, after all, is what distinguishes freedom: it can give rise to itself“ (KRINGS, 1982, p. 396).

This act of „dealing with nature“ or „sharing a common life-world (Lebenswelt) with nature“ points to a type of communicative relationship between human culture and non-human nature. Non-human nature becomes a co-subject in a world commonly shared between mankind and nature, i.e., man is able to recognize the same form of productivity in both. Man’s struggle for self-awareness is as much an expression of *nature as productivity* (and, in Schellings words, of „nature as subject“) as nature’s struggle to bring forth its diversity of forms.

This marks the point at which a systematic understanding of nature can begin. This beginning is therefore founded in the representation of human self-understanding (Selbstverständnis). Since human cognition and human activity is mediated through language, i.e., communicatively structured, and since mankind perceives itself solely as a linguistic being (in and with language) or as acting in a communicative manner, *a systematic understanding of a language of nature or of a communicatively organized and structured living nature* must be preceded by a systematic understanding of the nature of (human) language. This precondition - understanding the *nature of language* - is systematically anchored in the realm of *modern linguistics, pragmatic semiotics, and universal pragmatic theory of communication*. The scientific research in these disciplines can serve

as a key to understanding the nature of language (initially of humans) as well as a key for human self-understanding (Selbstverständnis) (which has always been linguistically mediated); this, in turn, provides the basis for understanding the language(s) of nature.

We can follow Schelling's lead and interpret the avenue of research leading via the nature of language to an understanding of the language of nature itself as a free act of conscious nature (which opened up as a possibility during the development from „nature as unconscious mind“ to „mind as nature that has attained consciousness“). In doing so, it would certainly be appropriate to learn more about the historical evolutionary process of this „conscious nature“. Efforts should concentrate on the stations of „conscious nature's“ search for an understanding of itself, i.e., where it has determined its relationship to its intrinsic and extrinsic nature. Such an approach to the *historical self-enlightenment of man as a natural being* would be quite an extensive undertaking and would go beyond the scope and aims of this contribution.

It could - programmatically - begin with the reconstruction of the relationship between man and nature, based for example on archaic cultural traditions handed down through history; these exist even today (albeit in very limited form) and their relationship to nature could be summarized and reconstructed under the topos „premetaphysical cultural paradigm“ (I). This would be followed by a representation of the „metaphysical cultural paradigm“ (II), whose origins would lie in early Greek philosophy of nature and might culminate in modern concepts in the theory of science such as logical empiricism or critically rationalism. This would then be followed by the current „postmetaphysical cultural paradigm“ (III) in which the human intellect *has gained access to the precondition underlying all cognition* - to language itself.

This point in the reconstruction (i.e., mankind's search for its relationship to its intrinsic and extrinsic nature) marks the onset of the present discourse. This book will initially discuss the terms „language“ and „communication“ as a prerequisite for all human self-understanding (Selbstverständnis), and then procede to an understanding of living, non-human nature.

### 1.3. The possibility and sense of an interdisciplinary dialog between biology and philosophy of language

In my study of current research in ethology, sociobiology, molecular biology, and biochemistry I came upon descriptions of observed structures and organizational forms of living nature that are based on the terms „language“ and „communication“, even though these descriptions and observations referred to non-human nature. Those biological fields of research that apply the terms language and communication mainly concentrate on interactive processes *between* biological organisms and on the description of molecular processes in biological organisms, whereby the ethologists and sociobiologists predominantly use „language“ and „communication“ in a linguistic-behavioristic manner, the molecular biologists and biochemists in the sense of information theory.

In my opinion, the very fact that the above disciplines use these terms to describe observations is interesting from the philosophy of language viewpoint. It raises the question whether the use of either term in biology can be satisfactorily justified from this philosophical perspective. Unfortunately, language philosophy has devoted little effort to this topic, and modern, actiontheory-oriented language philosophy recognizes the possibility of language and communication in the non-human realm - if at all - only in connection with the most simple signal languages in the animal kingdom.

Beyond reducing the definition of the terms language and communication to a linguistic-behavioristic and/or information theory context, the field of biology has neglected to make any significant attempts at establishing a firm basis for using these concepts.

Semiotics assumes a certain mediating role here; it by no means restricts its investigations of sign processes (semioses) to anthroposemioses (POSNER, 1990 c.), but takes up and examines sign processes in all forms of living nature. Clearly, an interdisciplinary dialog between biology and language philosophy could broaden the horizon of both disciplines. In the case of biology it would help to adequately reflect upon and subsequently justify the use of the terms language and communication. In language philosophy, it would help in recognizing that language and communication are not exclusively human capabilities, but can also be important in understanding non-human nature.

An interdisciplinary dialog between biology and language philosophy could also potentially contribute to epistemological progress in both fields, whereby the mere explanation of natural processes would be augmented by an understanding of these processes within living nature. *This book is my contribution to stimulating such an interdisciplinary dialog.*

#### 1.4. The structural format of this study

##### 1.4.1. Language and communication

In a first step, I attempt to define the terms language and communication in their broadest sense by briefly summarizing their current interpretation in linguistics (I), in semiotic pragmatism (II), and in the universal-pragmatic theory of communication (III).

Ultimately, the results of the universal-pragmatic communication theory represent the most relevant approach in the framework of the present study: these results can help avoid deficits of modern linguistics and semiotics in determining how *communication functions*.

Examining their meaning in these three disciplines should clearly familiarize the reader with the terminological background underlying research in the various realms of living nature. In the next step I formulate those paradigmatic realms predominantly affected by such research: interorganismic (I), intraorganismic (II), and metaorganismic (III) communication.

##### 1.4.2. Sign-mediated interactions in honeybees in the northern hemisphere

The actual investigation on whether living nature is linguistically structured and commu-

nically organized begins with the representation of inter-organismic communication. The example selected here is the sign-mediated interactions between members of a social animal community - the honeybees of the northern hemisphere. Karl von Frisch was awarded the Nobel Prize for his pioneering ethological studies in this field, and his colleagues considerably expanded upon the results of his research. Based on examples of this positive association and behavioral coordination, I attempt to show how critical the success of sign-mediated interactions is for the survival of this animal community. This approach revealed that the use of signs is inseparably connected with species-specific interaction logic and interaction dynamics. The evidence that the sign-mediated interactions of honeybees from warmer latitudes differ fundamentally from those of the northern hemisphere leads to a discussion about how certain capabilities and skills on the molecular level are genetically fixed, in the nuclei of the cells of organisms, culminating in the paradigmatic realm of intra-organismic communication.

#### 1.4.3. Sign-mediated interactions in and *between* cells

*One of the central research topics in this work* is the representation of sign-mediated interactions in cells of organisms (intracellular communication) and between cells (intercellular communication). The interest focuses on the constitution and structure of the so-called nucleic acid and amino acid language, which clearly bear features amenable to classification by sign theory. Both „languages“ have to a large extent been decoded, and mankind is on the brink of mastering the technology to use a language whose origin is not specifically human in nature.

The discussion of several examples of faulty intra- and intercellular communication underlines the complexity and reliability of sign-mediated interactions in the intra-organismic realm. The constitution and organization of natural defence mechanisms by the so-called immune system provides an insight into the mechanisms by which genetic sequences are duplicated, altered, repaired, or even generated. The demonstration of certain rules underlying sequence processing in the molecular realm shows that such processes are determined less by chance than by protein individuals that are competent in sequence processing and that are highly specialized for their respective task. This section of the present contribution strives to show that if we are going to talk about a universal „language of nature“, then the nucleic acid language - which is essential in constituting all forms of life - justifiably earns this designation.

#### 1.4.4. Critique of the language and communication terminology of molecular biology

I explicate the terms language and communication as they pertain to and define molecular biology and biochemistry by referring to one of the foremost proponents of this terminology, Manfred Eigen. After pointing out several deficits in Eigen's language and communication concepts, I attempt to expand upon this terminology using key research results from the field of *action theory-oriented pragmatics of language*. With this approach I hope to convince the reader that, both for language philosophy in the broad



sense and for the above-mentioned biological subdisciplines, one can justifiably speak of language and communication as the central structure and organizational form of living nature.

This *second, central research topic* in the present contribution is undertaken with the express intention of initiating the interdisciplinary dialog mentioned earlier; at the same time, it should also show that there is no adequate foundation for using the terms language and communication in a systems theoretical sense (i.e. information theory) to explain the phenomena of living nature.

#### 1.4.5. The apriori of pragmatic situations of understanding (Verständigungssituationen)

After depicting specific explanatory deficits in molecular biology by explaining and justifying (systems theoretically) the terms language and communication, I offer an approach that can lead to a semiotic expansion of these two terms in biology. I use two examples to exemplify the apriori of the pragmatic situation of understanding both for a (non-human) language in nature and for intra- and intercellular, sign-mediated communication processes.

Recognizing the *apriori of the pragmatic communicative situation* enables both an understanding and a plausible explanation of sign-mediated communication processes in living nature, from humans down to the simplest enzyme proteins. Under these prerequisites, language and communication become the ideally suited means to change, expand, or even fundamentally overstep existing rules.

#### 1.4.6. The representation of types and forms of communication in living nature

Based on the semiotic expansion of the terms language and communication, I attempt to arrive at a description of various forms of communication that affect living beings throughout their life. I attempt to systematize the basic forms of communication in living nature in a manner analogous to modern taxonomy, which defines 5 kingdoms of organisms into which all known life forms can be definitively arranged. Since these organismic kingdoms historically evolved in a certain sequence, the communicative relationship between them might well be described as being *semicompatible*: each successively developed kingdom of organisms always bears communication rules of the preceeding one, never vice versa.

#### 1.4.7. Evolution as generative linguistic behavior

The development of ever new biological species and, ultimately, their differentiation into distinct organismic kingdoms, confronts us with a phenomenon that evolutionary theory has largely explained based on a continuity principle. For the realms of molecular, organismic, and cultural evolution I attempt to show that, assuming a communicatively structured and organized living nature, *the origin of new entities* as well as the *incremental*



*nature* of this development process no longer represent a major problem; rather, they can be viewed as being downright typical, and the assumptions about the significance of „mutations“ for the evolutionary process can be discarded.

#### 1.4.8. Nature as a „norm subject“: living nature as a *global community of communication*

In the last section of this book I broach the possible consequences of the above theses: in a living world that is organized and structured in a language-like and communicative manner, humans - as cultural entities - would also have an interactive relationship with the entire living world. Seen holistically, such a world would have incredible powers of survival. Should mankind continue to cling to its monological relationship with living nature, my thesis predicts that we will not be in a position to develop, much less apply, those systems of values and norms necessary to master the ecological crisis *in time*. On the other hand, transforming this monological relationship with living, non-human nature into a communicative one would be evidence for the evolutionary capacity of culture; this step remains to be taken, but represents a positive alternative to the current *communication pathology* between man and nature.

#### 1.5. Language and communication as a precondition and content of the interdisciplinary dialog: a word on the suspicion of anthropomorphism

Investigating language and communication as central structural and organizational elements in living nature appears to be a promising mediating grounds between biology and the philosophy of language: neither discipline is capable of constituting its field of research - or of discussing language and communication - without language and communication. Cognition in virtually every field of inquiry is sign-mediated, and any attempt to formulate cognition outside the realm of language and communication is doomed to failure. Since we are unable to disassociate ourselves from our language or to reflect outside its realm, these two central terms are both a precondition and the content of the interdisciplinary dialog propagated by the present investigation. This exposes me to the potential accusation that I transpose essential elements of human self-understanding (Selbstverständnis) onto structures and organizational forms of non-human nature, i.e., that in representing living nature as a linguistically and communicatively structured and organized entity I have developed a new variant of anthropomorphism. Even a cursory glance shows that this is not the case: every conceivable statement about every conceivable object of cognition in non-human nature is open to such an accusation, and we have little choice but to accept the preconditions of language and communication for what they are.

*What we can do, however, is to define our (pre-)understanding (Vorverständnis) of these two terms at the beginning of every discussion about a specific cognitive realm. Then the reader will always be in a position to assimilate this level of reflection in his/her background knowledge.*

The accusation of anthropomorphism appears to be more accurately leveled at the use of

„language“ and „communication“ in the biological sciences and in medicine (f.e. neuroendocrinology, psychoendocrinology, immunology, etc.). They use phrases such as „communication between cells“, „faulty communication between cells“, „genetic code“, „genetic text sequence“, „chemical messengers“, „neuronal“ and „hormonal communication“, „transcription of the nucleic acid language“, „amino acid language“, „translation“, „letter pairs“ of DNA, „restriction enzymes that recognize palindromes“, etc. Or another example by James D. Watson: „But unlike other organs, in which cells exchange only a few signals, communication is the business of the brain, and brain cells employ a complex array of chemical and electrical signals“. (WATSON, 1992, p. 409)

Since no foundation and justification for the use of these terms has been forwarded to date, I attempt in this contribution to clarify the prerequisites under which this diction could be established and justified, while avoiding the pitfall of anthropomorphism.

# PART ONE



## 2. Language and communication - an approximation

Rather than being precise definitions, the description of the terms language and communication - as based on modern linguistics, semiotic pragmatics, and the universal-pragmatic communication theory of Jürgen Habermas - is a  *cursory*  approximation in order to apply the terms in the present study. Linguistic and semiotic-pragmatic interpretations are presented primarily to underline their differences vis-à-vis the  *universal-pragmatic communication theory*  in explaining and understanding communication. This is not meant to lessen the scientific achievements of these two fields of science, but merely to point out that Jürgen Habermas' theory currently provides the best explanation of  *communication processes* .

### 2.1. Language and communication in modern linguistics

Modern linguistics does not examine language in its historical context or in its interlinks with lifeforms (Lebensformen) and ideologies, but rather in the framework of an empirical-analytical explanatory model. Language is treated as an instrument of communication and as a system of signs agreed upon by social consensus (SPRACHE, 1973, p. 18). Modern linguistics has therefore focused its research on explaining and analyzing the instrumental character of language and defines the system of linguistic signs as a conventionalistic one.

It distinguishes between the research topic involving  *language as a system*  and  *language in its function* . The investigation of language as a system of signs concentrates on analyzing the relationship of the signs to one another and the rules governing the coupling of these signs. The investigation of language in its function involves studying communication processes. Interactions are defined as the „totality of communicative processes taking place between partners“ (ibid., p. 429).

Structural analysis in linguistics deals with the interrelationships of signs and the rules governing how these signs are coupled, yet orients itself according to usages of language in communication processes; the latter provides a framework for functional analyses of the utilized or utilizable sentence forms. Above all, the analysis of communication processes reveals a mastery of structure, i.e., in sentences expressed by sign-using subjects the words are not aligned in a structureless manner but are coupled according to specific rules.

In this field, language is investigated not only according to its basic elements such as  *phonemes, words, and sentences* , but also according to the rules under which these elements are structured and generated. Ultimately, linguistics strives to explain how language-using subjects gain and use the ability to form and understand the full range of correct sentences in a particular language.

A universal language  *as such*  does not exist, merely a series of different languages. In the case of humans, a distinction can be made between natural and artificial languages (i.e.,

scientific languages). Among the former, linguists are in a position to differentiate nearly 5000 different languages that are used as an instrument of communication.

### 2.1.1. The communication model in linguistics

The communication model in linguistics is built on the premise that a sender S sends a signal S' (expression) with a certain information I (content, meaning) to a receiver R via a communication channel C. „Coupling this signal with its meaning is achieved by the respective communication partners“ (SPRACHE, p. 35), whereby the common stock of signs is termed a „code“. Modern linguistics relies largely on the following definitions of communication:

- a) „Communication is the exchange of information between a sender and a receiver.
- b) A sender is the element in a communicative process that produced the signal.
- c) The channel is the material connection between the sender and the receiver.
- d) The code refers to the amount of signs that the sender and receiver use to communicate.
- e) The signal is the material condition of the channel.“ (SPRACHE, p. 36f.)

### 2.1.2. The sign model in linguistics

Signals distinguish themselves from other material conditions because they transport „information“ from the sender to the receiver. This transport is only possible because the signal is coupled with information. This coupling enables the sender to send a signal that corresponds with a particular information and enables the receiver to extract the information from the signal.

This provides the basis for the linguistic definition of the term „sign“: „A sign is that unit formed by the coupling of the signal with the information bound to that signal“ (SPRACHE, p. 34). Instead of „signal“ and „information“, linguistics also uses the pair of terms „expression“ and „content“ or „expression“ and „meaning“. The coupling between signal and information is „socially conditioned“ and is thus based on the „conventionality of the sign“. Such couplings must be learned before any communication with the signs is possible.

### 2.1.3. Models of coding and decoding

In the sign-mediated communication between sender and receiver (or, to emphasize the reversibility of the relationship, between speaker and listener), a coding-decoding process takes place in which the ideas stored in the brain of the speaker are first coded into language and are then decoded by the listener. This involves „the conversion of the speaker's picture into linguistic signs and the re-conversion of the linguistic signs into the listener's

picture“ (SPRACHE, p. 47). In linguistics, the capacity for this coding-decoding process is termed linguistic competence. If use is made of this capacity, linguistics refers to linguistic performance. Coding and decoding takes place in the framework of semantic, syntactic and phonological rules. The speaker's information is explicitly defined as „presemantic in the realm of pure imagination“ (ibid., p. 55).

#### 2.1.4. The structure of the linguistic code in linguistics

Coding and decoding takes place via a linguistic code that must exhibit certain structures in order to guarantee flawless coding-decoding:

- a) „The code must contain linguistic signs that impart the individual structural components of expression and content.
- b) The code must include syntactic rules which determine the relationship between the individual signs.
- c) The code must contain rules according to which the individual expressive units can be adapted to the respective context.
- d) The code must have rules by which the individual units of content can be adapted to the respective context“. (SPRACHE, p. 55f.)

The terms expression and content can be substituted by „signal“ and „meaning“. The more precise differentiation of the structural features of the linguistic code is the task of grammar „with its subdivisions semantics, syntax, and phonology“ (ibid. p. 56).

Special initiatives in this field of research have been developed by „generative“ grammar“ and „linguistic structuralism“, which have an effort to analyze the rules of coupling and usage. I will not delve more deeply into their results here. It suffices to say that research into communicative processes is mainly behavioristic in its approach: the observation and explanation of linguistic behavior is always a central element, even - or especially - in the case of humans.

#### 2.2. Language and communication in semiotic pragmatics

Ever since Charles Morris, semiotics has been based on the premise that every system worthy of the designation „language“ must be describable grammatically, semantically, *and* pragmatically. As opposed to linguistics, semiotic pragmatics bases its analysis on the relationship between the sign user and the employed sign. „Pragmatics studies the conditions an entity must fulfill, to be able to interpret signs as representing meaning in semiosis“ (POSNER, 1990 b; p. 2). The focus thus centers on the prerequisites under which a sign interpreter is in a position to identify signs in sign processes as bearing meaning.

Semiotics classifies basically all sign processes as semioses. In this sense, the sign interpreter can also be a system, for example a machine which reacts to a given sign - in a manner corresponding to the meaning contained in that sign - that it has received through a sign channel. Semiotic pragmatics distinguishes between a primitive use of signals and

true communication. The designation communication signs is only accepted when a „sender“ pursues a complex intention with its sign production and addresses a receiver. When the receiver notices and correctly interprets this intention, semiotics refers to a communication process.

Semiotics also recognizes simple, non-communicative sign processes, for example *simple* sign interpretation. If a bird on the wing can identify the shade of a tree, then the shade can be a sign that stimulates the interpretive behavior of the bird.

The term semiosis (sign process) combines the terms language and communication in a characteristic manner into a *processual* phenomenon that is expressly not limited to human language and communication. Thus, semiotic pragmatics recognizes various types of sign processes:

- a) „Something functions as a sign only insofar as it has an interpreter in whom it elicits some interpretant. Therefore all semioses are signalling processes. For some signals the interpretant consists in the formation of a belief in some message. Where this is so, the semiosis is called an indication of this message.
- b) Some signs are tokens of signifiers which are correlated with signifieds through a code. Where this is so, the semiosis is called signification.
- c) Some signs are not the result of natural processes but intentionally produced to cause certain interpretants. The resulting semiosis is called manipulation. Some manipulating signs are produced with the intention to cause an interpretant by means of a recognition of this intention by the interpreter. The resulting semiosis is called communication.
- d) Signaling, indicating, manipulative and communicative signs can, but need not, be signifying. Where someone intentionally produces a communicative sign which signifies something different from what he intends to communicate with it, the semiosis in question is called indirect communication“ (ibid. p. 9f.)

Semiotics shares, with linguistics, the sender-receiver model and the coding-decoding model: „The sender interprets the intended message through a signified, encodes the signified in a signifier and produces the signifier as a sign. The addressee receives the sign as a signifier, decodes the signifier into a signified, and interprets the signified as a message. The sender's and addressee's interpretation activities are pragmatic processes in a narrow sense“ (ibid. p. 15).

As opposed to linguistics, semiotics interprets sign process in a broader sense: Typically enough, one of the editors of „Semiotics - A Handbook of the Sign-Theoretic Foundations of Nature and Culture (Berlin 1990) is Thomas A. Sebeok, the founder of zoosemiotics, a field which has successfully dealt with the study of sign processes in animals. Beyond this, a discussion is taking place between ethology, sociobiology, and semiotics (for example in: Zeitschrift für Semiotik, Volume 8, „Zeichenverhalten der Tiere“, Tübingen, 1986). The proponents of biological subdisciplines apparently have no problem with using sign-theoretic terms to explain observations in the animal kingdom (TEM-



BROCK, 1971; TODT, 1986). Behavioral biology, sociobiology, and semiotics basically agree that sign processes in the animal kingdom are a key prerequisite for successful reproduction in biological species.

Furthermore, semiotics also recognizes codeless communicative signs; (ibid. p. 34f.). When a member of one culture is thrust into an entirely different culture and needs to communicate about something with local residents (for example about how to deal with a dangerous situation), then they must communicate through signs; semiotics does not consider such signs to be components of a commonly held stock of signs (code).

Semiotics does recognize signs outside of language and communication (codeless, non-communicative signs; ibid. p. 35f.). These describe a specific environment that, as a situation, can gain the status of a sign. For an automobile driver on a side road, for example, pedestrians crossing the main road can serve as a sign that there is only little traffic on the main road.

### 2.3. Language and communication in universal-pragmatic communication theory

*Neither* the analysis of the communicative process with respect to conveying information from a sender to a receiver through a transmission channel, i.e., the analysis of the information transmission process, *nor* the coding patterns of private ideas into signs and the subsequent decoding of these signs into the private ideas of the receiver, are the object of language and communication analysis by universal pragmatics.

Since linguistics and semiotics orient their language and communication analyses on observing behavior and on describing and explaining these observations, they find virtually no links to an actiontheory-oriented language and communication concept: the actiontheory-oriented researcher derives this concept both from the analysis of and from the context of direct and indirect *social interactions*, whereby the researcher is or may be a partner in that interaction.

The field of inquiry pursued by universal pragmatics is the analysis of the formal rules that underlie *every conceivable* sign-mediated intersubjective interaction. It is primarily concerned with the „general prerequisites for communication“. In this sense, it focuses its interest on the *metacommunicative ability of colloquial languages (Umgangssprachen)*, which permit a seamless transition between discourses on something about this world to discourse about these discourses. Rather than splitting the various functions that language can assume, such as calling, expressive, and representational functions, universal pragmatics attempts to combine these in an *analysis of universal rules underlying all possible symbol-mediated interactions*.

The universal-pragmatic communication theory considers the real, social life-world (Lebenswelt) of subjects (that share a common world) to be the basis of all language functions (including the signifying function); it therefore principally binds language as a sign system (in all its functions) to communication situations (HABERMAS, 1984, 1985, 1989).

According to Habermas, the conventionality of the signs does not reflect a conventionality of the rules underlying successful sign-mediated interactions. Before communicating with one another (a) about something (b), fundamental rules must be fulfilled; these rules predate *any* type of conventionality and are the focus of the universal-pragmatic analysis.

The real life-world (Lebenswelt) is what provides those situational contexts in which the acquired and innate competence (linguistic and communicative as well as cognitive) in applying an explicit or implicit consciousness of rules can be practiced, maintained, expanded and altered.

Universal pragmatics also lays claim to being able to explain the innovative, generative constitution of rules in both language and communication. It orients itself according to the *theory of the speech acts*, which is also anchored in the concept of the life-world (Lebenswelt). This theory investigates those situational contexts in which individual members of a social life-form participate in different ways, in which these members assume different perspectives in changing roles, in which they are coordinated according to divergent expectations and, based on these expectations, take on positions from which they articulate specific claims and intent. This explains the affinities of the universal-pragmatic communication theory to social theory and sociolinguistics as well as its recourse to the theory of science in its methodological discourse.

„Finally, communicative action is dependent on situational contexts, which represent in turn segments of the life-world of the participants in interaction. The connection of action theory to the basic concepts of social theory can be rendered secure by means of the concept of the life-world; this will be introduced as a complementary concept to communicative action via the analysis of background knowledge stimulated by Wittgenstein.“ (HABERMAS, 1985, p. 278 f.)

Thus, universal pragmatics is no longer interested in the universal rules of well-structured sentences, but rather in the ability of subjects - in communicative situations - to achieve a common, consensual understanding of the self and of the world. As opposed to the „action - reaction“ explanatory model, it attempts to define the relationship between language and communication based on the range of general communication prerequisites.

### 2.3.1. Several differences between the linguistic and the universal-pragmatic analysis of language and communication

One of the key differences is the following: The analysis of elementary units of language (sentences) in linguistics stands in contrast to the analysis of elementary units of communication (utterances) in universal pragmatics. At the same time, the universal-pragmatic communication theory distinguishes itself from earlier theories of communication (Ch. Morris): it combined the model of language behaviorism („the symbolically mediated behavioral reaction of the stimulated individual organism“) with the model of information transmission („encoding and decoding signals between sender and receiver for a given channel and at - least - partially - common store of signs“), and was thus unable

to fully answer the question regarding the general preconditions for possible communication.

„For example, the intersubjectivity of meanings that are identical for at least two speakers does not even become a problem (I) if the identity of meanings is reduced to extensionally equivalent classes of behavioral properties, as is done in linguistic behaviorism; or (2) if it is pre-established at the analytic level that there exists a common code and store of signs between sender and receiver, as is done in information theory.“ (HABERMAS, 1979, p. 6)

The linguistic approach to language and communication is, according to Habermas, poorly suited to reconstruct the preconditions for communication because the definition of its basic tenets hardly penetrates the „level of accidental contexts“ (I) and arrives at no assumption of binding prerequisites for language and communication (II). At the same time it attempts to fully grasp pragmatic relationships with the tools of logic and grammar, such as in the case of the „syntactic explanation of the performative nature of speech acts“. For example, the fact that logics of norms traces norms of action back to commands shows that basic concepts are being formalized; these, according to Habermas, have been thoroughly analyzed. According to Habermas, the „model of the isolated, purposive-rational actor“ is simply not suited to adequately reconstruct central elements of communication like „the common ground in understanding identical meanings“ or the „acknowledgment of intersubjective validity claims.“ (HABERMAS, 1979, p. 8).

Although linguistic expressions can, of course, be studied from various points of view, universal pragmatics does appear to be uniquely suited to substantially enrich our understanding of language and communication by systematically investigating one aspect - the establishment of an *intersubjective relationship*.

Theoretical Level	Object Domain
Linguistics	Sentences
Grammar	Sentences of an individual language
Grammatical theory	Rules for generating sentences in any language whatever
Aspects of linguistic analysis	
Phonetic theory	Inscriptions (language sounds)
Syntactic theory	Syntactical rules
Semantic theory	Lexical units
Pragmatics	Speech actions
Empirical pragmatics	Context-bound speech actions
Universal pragmatics	Rules for using sentences in utterances
Aspects of universal-pragmatic analysis	
Theory of elementary propositions	Acts of reference and predication
Theory of first-person sentences	Linguistic expression of intentions
Theory of illocutionary acts	Establishment of interpersonal relations

Fig. 1 Analytical levels (from: HABERMAS, 1979, p. 33)

„Phonetics investigates linguistic expressions as inscriptions in an underlying medium (i.e., as formations of sound). Syntactic theory investigates linguistic expressions with regard to the formal connections of the smallest meaningful units. Semantic theory investigates the meaning content of linguistic expressions. (...) General pragmatic theory, on the other hand, is occupied with reconstructing the rule system the underlies the ability of a subject to utter sentences in any relevant Situation“ (HABERMAS, 1979, p. 32)

Within his theory of pragmatics, Habermas describes three general pragmatic functions which „are the basis of all the particular functions that an utterance can assume in specific contexts“, i.e., especially (I) „with the help of a sentence, to represent something in the world, (II) to express the speakers intentions, (III) and to establish legitimate interpersonal relations.“ (ibid., p. 33)

The pragmatic theory expressly wishes *to avoid confusing the relational aspect with the information transmission aspect*, or the assignment of the former to the latter. It is thus one of the features of functioning everyday communication between communicating subjects that the understandability of expressions largely depends on an indeterminable number of assumptions that are not explicitly stated in the expression, i.e., that are unspoken; these assumptions are made both by the speaker and the listener and can perhaps best be determined by analyzing lifeforms (Lebensformen) in a commonly shared life-world (Lebenswelt). An approach that characterizes everyday communication by dealing with the coding of private ideas, the information transmission, and the decoding of syntactic-semantic information by a receiver appears to neglect essential aspects of intersubjective exchange.

This makes it imperative to differentiate between (a) linguistic and (b) communicative systems of rules and the respective abilities to use these. *While linguistic competence describes the mastery of a system of rules that allows sequences of language expressions to be produced, communicative competence describes the **ability to master a system of rules that allows intersubjective relationships** to be established.* The „grammar“ of language play (communication process) is not to be confused with the grammar of a language: language play refers to intersubjective relationships, while language refers to a system of signs.

### 2.3.2. Features of speech actions

Austin's *theory of speech acts* certainly provided a major impetus for the universal-pragmatic communication theory. In the framework of this theory, Austin attempted to investigate linguistic utterances as rule governed acts, within interactive contexts. The result was the differentiation of speech acts according to three aspects:

- (a) the locutionary aspect, or the verbal expression itself;
- (b) the illocutionary aspect, or the act that is fulfilled with this expression; this is closely related to the implementational aspect (performative act);
- (c) the perlocutionary aspect, or the effect that an act of speech has on the listener.

Here, focus is turned on linguistic utterances as acts carried out by interaction subjects in dialog situations.

The illocutionary aspect in particular - as the differentiation between the verbal utterance itself and the act by which it is expressed - has been the subject of detailed study: the relationship between the utterance and the act of utterance can decide which meaning the speaker attaches to the particular utterance, and this meaning may not even be explicit in the content of the utterance. *Illocutive aspects can therefore hardly be explained by analyzing the utterance syntactic-semantically because they gain their specific meaning primarily from common assumptions, expectations, and role interpretations.*

Everyday communication provides a never ending spectrum of differentiated illocutive aspects which, according to Habermas, can best be systematized by a *universal-pragmatic analysis of the conditions of possible understanding (Verständigung)*. In contrast, a nominalistic theory of meaning, which restricts the meaning to the intention of the speaker, is up against a difficult task: it can hardly satisfactorily explicate those intersubjective relationships that are central to illocutionary aspects, for example role playing, mutual expectations, or the claims raised and redeemed in communicative actions.

Habermas formulates 4 regions as the systematic site of language: „The“ World of External Nature (I), „Our“ World of Society (II), „My“ World of Internal Nature (III), and language itself (IV). „The „ World of External Nature is the subject of expressions dealing with objects and circumstances (from an objectifying perspective). These expressions lay claim to **truth**. The expressions dealing with „Our“ World of Society mainly involve a performative approach, whose claim lies in **rightness**. The main approaches themselves can also be altered: „We can replace this confirmative attitude with an objectivating attitude toward society; conversely, we can switch to a confirmative attitude in domains in which (today) we normally behave objectivatingly - for example, in relation to animals and plants.“ (ibid., p.66)

The expressions referring to „My“ World of Internal Nature are predominantly of a performative nature; these include the subjectively accessible experiences, the very personal intentions to which I have privileged access. The intention expressed lays claim to **truthfulness**. We refer to language by using language expressions, and it is a very feature of human language and communication that natural languages allow us to express ourselves metalinguistically about utterances: *in everyday communication, language and metalanguage are fully compatible with one another*. The approach can therefore be either performative or objectifying. Above all, linguistic utterances must principally lay claim to **comprehensibility** if they wish to be elements of comprehensible speech.

„The model intuitively introduced here is that of a communication in which grammatical sentences are embedded, by way of universal validity claims, in three relations to reality, thereby assuming the corresponding pragmatic functions of representing facts, establishing legitimate interpersonal relations, and expressing one's own subjectivity“ (67).

Domains of Reality	Modes of Communication; Basic Attitudes	Validity Claims	General Functions of Speech
„The“ World of External Nature	Cognitive: Objectivating Attitude	Truth	Representation of Facts
„Our“ World of Society	Interactive: Conformative Attitude	Rightness	Establishment of Legitimate Interpersonal Relations
„My“ World of Internal Nature	Expressive: Expressive Attitude	Truthfulness	Disclosure of Speaker's Subjectivity
Language	—————	Comprehensibility	—————

Fig. 2 The universal-pragmatic model of language  
(from: HABERMAS, 1979, p. 68)

In speech acts, various types of sentences are used to produce utterances about the three reference points mentioned above (and language itself). Accordingly, Habermas classifies various acts of speech:

- *constative speech-acts*: elementary declarative sentences are used to refer to something in the objective world;
- *expressive speech-acts*: elementary sentences based in experience are used to refer to something in the subjective world;
- *regulative speech-acts*: the speaker uses elementary sentences of declaration and intention to refer to something in the social, commonly shared world;
- *imperative speech-acts*: the speaker refers to a condition of the world that he/she desires and that he/she attempts to attain by influencing the decisions of others to bring about this condition;
- *communicative speech-acts* serve to organize speech;
- *operative speech-acts* serve to implement constructive rules, e.g., of logic, grammar, and mathematics. „They serve at the same time to describe what one does in constructing symbolic expressions in conformity with generative rules“.(HABERMAS, 1985, p. 326)

This classification can be meaningfully expanded to include *generative speech-acts* (H. Peukert terms these *innovative speech acts*; PEUKERT, 1978, p. 296f.). They serve to constitute new, never-before present sentences and acts and may well go hand in hand with the constitution of new language and communicative rules (to discover something,

invent something, compose something, think up something, to write something, etc.). New forms of action can be constituted with such speech acts.

2.3.3. Gaining the faculty for language and the possibilities of defining the ego

The universal-pragmatic communication theory attempts to explain the acquisition of communicative competence by adolescents through their increasing ability to define their ego.

„With training in the basic modes of language use, the growing child gains the ability to demarcate the subjectivity of his own expressions from the objectivity of an external reality, from the normativity of society, and from the intersubjectivity of the medium of language itself. In learning to deal hypothetically with the corresponding validity claims, he practices drawing the categorial distinctions between essence and appearance, being and illusion, „is“ and „ought“, sign and meaning. With these modalities of being he gets hold of the deceptive phenomena that first spring from the unwilling confusion between his own subjectivity, on the one hand, and the domains of the objective, the normative, and the intersubjective, on the other. He now knows how one can master the confusions, produce de-differentiations intentionally, and employ them in fiction, wit, irony, and the like.“ (HABERMAS, 1985, p. 332)

The acquisition of this capability is also the prerequisite for meaningfulness in generative speech-acts: their constitutive character only crystallizes vis-à-vis the established normativity in society, the subjectively experienced world, intersubjectivity, and the interpretation of the circumstances in the objective world. Generative speech-acts change, expand, or transform existing valuations and norms, establish new rules of a linguistic and/or communicative nature, and function to broaden horizons in the communicative constitution of the world, which is an intersubjective process.

With the acquisition of communicative competence and the ability to define the ego, one gains the ability to modalize one’s actions.

Mode of Communication	Type of Speech Action	Theme	Thematic Validity Claim
Cognitive	Constatives	Propositional content	Truth
Interactive	Regulatives	Interpersonal relation	Rightness appropriateness
Expressive	Avowals	Speaker’s intention	Truthfulness

Fig. 3 Modes of communication (from: HABERMAS, 1979, p. 58)

„Up until now, we have determined the system of ego definition through regions („The“ World of External Nature, „Our“ World of society, „My“ World of internal Nature and language itself) that can be experienced in a particular manner or that are „given“ (objectivity, normativity, subjectivity, intersubjectivity), whereby the corresponding language

use thematically accentuates certain claims (truth, rightness, truthfulness, comprehensibility). As soon as these claims are hypothetically formulated and negate, the individual regions become modalized.“ (HABERMAS, 1984, p.211)

According to Habermas, this can give rise to unintentional confusion, for example between appearance and reality, reality and the ideal, etc., along with the potential to produce intentional confusion („...we are also in a position to intentionally bring about modal confusion“, *ibid.* p. 213).

#### 2.3.4. The communicative or the cognitive aspect of linguistic communication

The universal-pragmatic communication theory differentiates between linguistic utterances (verbal utterances) and non-linguistic utterances (gestures, facial expressions, etc.). According to Habermas, linguistic communication is only possible when the communicating partners enter into two concurrent levels of communication, namely (a) the level of intersubjectivity and (b) the level of experiences and circumstances backed by commonly shared knowledge. From this perspective, linguistic communication is always communication (a) with one another and (b) about something. If linguistic communication concentrates on the level of intersubjectivity (communicative aspect), then, although the propositional content of the expression is mentioned, the main focus is on actions, such as warning someone about something, promising something to someone, inviting someone to do something, etc.

If the main focus in the linguistic communication is the cognitive aspect, then there is less emphasis on illocutive than on locutive aspects; the thematization of the expressive content and the interpersonal, intersubjective relationship have only peripheral status.

#### 2.3.5. Actions and behavior

The universal-pragmatic communication theory differentiates between actions and behavior based on a concept of adherence to rules, whereby something can be construed as action when the acting subject knows that it is following a rule and is perhaps even in a position to state which rule it is following. Here, Habermas distinguishes between human action and animal behavior:

„A private modification of this everyday pre-understanding allows us to interpret directed animal behavior according to the model of conscious rule-adherence, whereby we can attribute to the animal a fundamentally explicable awareness of rules (albeit one that is not explicable to the animal itself).“ (HABERMAS, 1984, p. 273)

Habermas considers mere behavior to be the correct term to describe observations when no implicit awareness of rules can be perceived, yet when the organism exhibits a minimum capability to act, for example to distinguish - in some way - between action and inaction, or action and suffering (*ibid.*).

Habermas differentiates three types of action, namely to act instrumentally (I), the manip-



ulation of objects; to act strategically (II), the exertion of influence on the decisions of rationally acting subjects; to act norm-regulated (III), the communication between subjects in a commonly shared social life-world (Lebenswelt).

### 2.3.6. Human communication versus animal communication

The distinction between action and behavior already provides the foundation for differentiating between human and animal communication. While the universal-pragmatic communication theory by no means principally denies the possibility of animal communication, it does largely reduce it to the realm of simple signal languages. The theory does, however, deny the possibility of using symbol languages in the sense of arbitrary sign systems whose signs have conventional rather than natural meaning. Nevertheless, some of Habermas' comments do also acknowledge the symbolic character of non-verbal communication (gestures, facial expressions, etc.):

„... Or, I can understand the actions of the other creature as a symbolic expression; in this case the coherence of the successive actions should adhere to rules that specify a system of symbols and that determine which physical characters function as signs and which meanings can be attributed to them under which situations of use“. (HABERMAS, 1984, p. 55).

Accordingly, the term *symbol-mediated interaction* can be interpreted broadly enough to also be applicable in non-human communication processes. Habermas clearly believes that the typical human, propositionally differentiated manner of speech is a separate entity:

„In this abstraction of propositional content from the asserted proposition, a fundamental accomplishment of our language is expressed. Propositionally differentiated speech distinguishes itself therein from the symbolically mediated interaction we can already observe among primates“ (ibid., p. 41)

The difference between human and animal languages is that, in the language communities of animals, the meanings of signs also constitute themselves in species-specific environments, yet „without them being grasped by the organisms as meaning. This, however, is precisely the condition that can be fulfilled at the level of communication conveyed through symbolic meaning.“ (HABERMAS, 1984, p. 349).

Another proponent of philosophical pragmatics freely relinquishes the investigation of non-human language and communication to behavioristic interpretations, even if it means abandoning suitable explanations of association processes, behavioral coordination, and at least sign-mediated interactions in species-specific environments and in animal communities.

„In the case of 'animal languages' it is useful to attribute the individual communicating partners with something along the lines of programming in the sense of an innate signal code. In both cases it is neither necessary nor reasonable to attribute them with anything

resembling metalinguistic and metacommunicative attendant awareness - basically an understanding of communication as a symbol-mediated interaction between partners. In this respect we are dealing here with „monologic“ communication models in the sense of Habermas. They can, in fact, be 'explained' by law-like hypotheses and peripheral conditions (i.e., based on the postulated signal programs and the particular storage and transmission conditions in or between the signal senders and receivers)“ (APEL, 1976, p. 298).

It may well be justified to assume the absence of metalanguage and metacommunicative attendant awareness here (or the absence of an understanding of communication as symbol-mediated interaction). Whether this is sufficient to relegate the communication forms in living nature - as they pertain to possible communications types - to the explanatory models of biology *alone* (within the framework of traditional natural science methodology) remains questionable: Apel, in his work, has repeatedly argued in principle against „monologic“ communication models, while conceding that they do present an opportunity to explain non-human communication. The possibility that more complex forms of language and communication, beyond those forms found in humans and animals, could exist is given no further thought; the same holds true for „understanding“ living nature. Modern communication theories concentrate almost exclusively on the realm of human interaction.

#### 2.4. Language and communication - A working hypothesis

Those descriptions of observations made on non-human living nature that rely on the terms „language and communication“ or „sign-mediated rule governed interaction“ appear to overwhelm communication theories that restrict the use of these terms to the level of human action.

Apparently there is no other option but to leave the analysis of „objective“ nature up to biological research and its empirical use of language; this research uses language and communication - based on the hypothesis of physically determinable laws of nature - as metaphors for a representation function on the one hand (language) and a „stimulus-reaction“ function (communication) on the other hand. This allows a postulated „Sein der Dinge an sich“ to be approached in an infinite approximation.

This image is contradicted by the fact that biological research also needs greater insight into its use of language in order to more precisely grasp the relationship: researcher - verbal description of the research objectives - the object of study - theoretical explanation.

Empirical research is expected to apply the empirical method to make reliable statements about the language that it uses, for example about the conditions of possible understanding in general. This leads to the *paradox that empirical methods need to be applied to discover fundamental language principles that are already preconditions for any empirical analysis*. To the extent that the biological sciences work with the concepts language and communication, one can recommend that this approach be supplemented by complementary methods that can analyze these two terms not empirically, but rather with regard to

the essential conditions of language and communication, as they reveal themselves to human self-understanding (Selbstverständnis) via the analysis of immediate and mediate intersubjectivity.

„I would like to advocate the thesis that we are unable to understand either causality itself or the differences between lawful interlinks and accidental regularities in nature without recurring to reflections on the effect of carrying out some act and some intended intervention into the course of nature“ (v. WRIGHT, 1974, p. 68).

Research in the behavioral, socio- and molecular biological disciplines (and ultimately in evolutionary theory and taxonomy) is called upon to orient our approximation of the terms language and communication in the sense of depicting their major features at the linguistic, pragmatic-semiotic, and universal-pragmatic/communication theoretical interpretation level. This approach must always bear in mind that

- (a) empirical discussions about observations in the biological realm can operate with a broader language and communication concept than can be substantiated within an empiristic scientific language;
- (b) linguistic discussion, in the case of syntactic/semantic analyses, will never fully clarify the terms language and communication;
- (c) semiotic discussions principally underline the significance of pragmatic analyses, but, in focusing on the information transmission process, reduce these to the framework of a coding-decoding model;
- (d) Input from universal-pragmatics and communication theory can contribute to our understanding of the preconditions for communication (an aspect neglected in the above-mentioned realms), yet restricts these to interaction processes between human subjects.

In the present study, which investigates whether living nature is structured and organized in a language-like and communicative manner, I therefore suggest defining language and communication such that

- (a) empirical observations whose explanations rely on terms such as language and communication are open to syntactic/grammatical, semantic, and pragmatic analyses;
- (b) principally all potential structures and processes that appear in interaction processes can be interpreted in the framework of sign processes (semioses) which bear syntactic/grammatical, semantic, *and* pragmatic features (that imply *real* sign users and sign interpreters).
- (c) **the discussion against the backdrop of universal-pragmatic communication theory must always keep in mind that the sign users or interpreters involved in a sign-mediated interaction do not represent monadologic, isolated individuals; rather, they are members of a species-specific life-world (Lebenswelt) that share an evolutionary heritage and whose behavior is subject to a commonly shared repertoire of rules.**

In summary, I forward a useful working hypothesis that understands language and communication as **(a) a system of signs and (b) sign-mediated rule governed interactions , that find use in real sign processes to coordinate behavior and to form associations between organisms, and that are represented by real sign users and interpreters sharing a common life-world (Lebenswelt).**

#### 2.4.1. Three communication types in living nature

Biological organisms are - according to my thesis - interwoven in three types of communication during the course of their lives.

- (a) Every organism consists of cells. The investigation whether sign processes (sign-mediated rule governed interactions) take place within the cell (intracellularly) or between cells (intercellularly) can be subsumed under the title „**intraorganismic** communication“.
- (b) The investigation of sign processes (sign-mediated rule governed interactions) between members of the same species can be subsumed under the title „**interorganismic** communication.
- (c) The investigation of sign processes (sign mediated rule governed interactions) between organisms belonging to different species can be subsumed under the title „**metaorganismic** communication“.

From this cursory treatment of the terms language and communication I will proceed to a description of sign-mediated interactions in the field of ethology (interorganismic communication) and subsequently to sign processes in the realm of molecular biology (intraorganismic communication).

Only after a quite detailed treatment of the various processes (especially in the case of intraorganismic communication) will I proceed to the next step. This involves analyzing which assumptions biology makes in its definition of the terms language and communication and how potential definitional deficits might be removed by reflecting on the results of the universal-pragmatic theory of communication. This would

a) enable biology in the broadest sense to employ the terms language and communication consistently (in the language philosophical and communication theoretical sense as well); this would contribute both to defining biology's own self-understanding (Selbstverständnis) and to explain biological processes that lie outside the realm of human self-understanding;

b) enable research in communication theory to not only understand human language and communication but also to grasp that non-human nature is also structured and organized in a language like and communicative manner.

### 3. Languages in nature

Communication serves to promote understanding and to coordinate action and behavior as well as to form associations between linguistic-competent individuals. The use of linguistic signs takes place in specific language media, whereby actions or behaviors (in sequences of actions or behaviors) can also assume sign-like character. This sign use takes place in regulative, constative and - less frequently - in generative linguistic action as well, or in linguistic behavior that is also characterized by regulative, constative and generative features. The rules that underlie or govern linguistic behavior or linguistic action stem largely from a social interaction process. The individual's genetic makeup gives it the ability to communicate in a species-specific environment. As I hope to show later, the entire realm of genetic imprinting can be understood as intraorganismic communication.

The interorganismic communication we will discuss here, i.e., the rule-governed, sign-mediated interaction between conspecifics is based on a genetically acquired ability. The increased skill in following these rules goes hand in hand with the improved ability to use linguistic signs within rule-governed interactions between individuals of a real, species-specific, life-world (*Lebenswelt*). Non-human individuals are unaware of these underlying rules, nor are they able to explicate the rules as rules.

In dealing with living organisms, behavioral biology is largely concerned with the investigation of rule-governed interactions in the animal kingdom. It has been able to discover a wide range of rules governing trans-specific and species-specific interactions. From the vantage point of language philosophy, the fact that rule-governed, sign-mediated interactions do take place is more interesting than how they take place. The language and communication of the honeybee, which has been studied in great detail, can serve as an example for non-human language (FRISCH, 1952, 1953, 1955, 1965, 1971; LINDAUER, 1975, 1981; SEELEY, 1982; HEINRICH, 1981). This can be illustrated by two cases in which communication, coordination of behavior, and the formation of associations are achieved through linguistic signs.

#### 3.1. Honeybees in the northern hemisphere

Honeybees originally stem from the warm regions of the Earth. The extension of their range into the northern hemisphere brought with it the problem of how to deal with longer cold periods. Winter requires the development of a specific survival strategy that was unnecessary at the geographic and phylogenetic origins of honeybees.

Searching for and finding suitable overwintering sites is critical for the survival of honeybees in temperate and more northern latitudes. The complex communication and behavioral coordination of individuals in this community requires correspondingly differentiated communication abilities and skills; without this, no suitable housing could be selected. A mistake in the selection of a hive leaves no opportunity for a second attempt: the correct choice is a life or death situation for the bee colony. Today we know that only one fourth of all newly established bee colonies survive the first winter (SEELEY, 1982).

Once the bees survive the first winter in a well-chosen site, the probability of surviving for another five years is high. How does the selection of an appropriate site take place?

### 3.1.1. The sign-mediated communication process behind the founding of a new colony

In the cold season, the bee colony forms a tight aggregation in its hive. A great number of bees join to form a type of outer shield; fine quivering movements of their flight muscles help maintain an ambient temperature of at least 10° C in the colony. Abundant supplies of honey ward off starvation. Spring marks the beginning of an intensive phase of brood rearing, and newly emerging bees lead to dense colonies and reduced space in the hive. Precisely this condition is a sign for the worker honey bees to construct queen cells in which a number of future queens can be reared simultaneously (*ibid.*). The old queen uses sound signs to communicate with the enclosed future queens. If one imitates the sounds of the enclosed future queens with the appropriate instruments, then the old queen answers these artificially produced sounds quite specifically. Although the queen is known to communicate with the future queens, the subject of the communication remains unknown. Before the replacements emerge and decide the future leadership of the colony in a stinging duel, the mother queen leaves the nest with half the original colony.

The initial flight is rather short, in any case less than 50 m (*ibid.*). The queen alights on a more or less suitable object and is immediately surrounded by a cluster of bees. As soon as the cluster is completed, a few hundred so-called scouts swarm out to search the terrain for a suitable new hive. These scouts are the oldest bees in the colony, i.e., those that have already collected food for the original colony and are therefore already familiar with the surroundings.

The selection criteria for the new home are quite differentiated (*ibid.*; LINDAUER, 1975, p. 49): The height of the entrance hole must lie at least 2 m above the ground in order to effectively rule out any disturbance of the colony by other animals. The opening of the hole should be no larger than 50 cm in order to permit reliable regulation of the hive's internal climate in winter, even if the temperatures drop to very low values. The hole should also face south: this enables the bees to swarm out and defecate at even the slightest outside temperature increases in winter. The volume of the entire hive should not be less than 10 l in order to provide sufficient room for the honey stores the colony needs to overwinter; at the same time, volumes in excess of 100 l make the regulation of the inside temperature difficult. The presence of old honeycombs is a positive criterion because it considerably reduces or even eliminates the time- and energy-consuming effort of honeycomb construction (*ibid.*)

Each of the scouts that has swarmed out returns to the colony as soon as she has found a site that seems suitable. She lands in the swarm and begins to carry out the characteristic movements that researchers have been termed dances (LINDAUER, 1975, p. 32). Such dances are displayed not only during the search for new hives, but also in locating suitable feeding sites. The dances have a communicatory character and represent linguistic signs

whose expression enables comprehensible information to be relayed to other bees. Because the scouts do not return with pollen or nectar, the dance is not a message about feeding sites but rather *about where and in which direction* a suitable place to build a hive can be found. These so-called waggle dance resembles a figure-of-eight in whose central section the abdomen is waggled. The waggle dance can be defined as constative linguistic behavior (ibid. p. 62): The direction of the central section of the danced figure-eight points into the direction of the new site in relation to the respective position of the sun (LINDAUER, 1975, p. 121f.; v. FRISCH, 1965, p. 333f.).

The greater the distance to the prospective site, the longer the wagging motion for that particular stretch lasts. Four other scouts observe the waggle dance from close quarters. Each scout advertizes her discovery with her own dance. The more suitable she believes her discovery to be, the more vigorous the dance. The greater a scout's doubt about her own discovery, the more subdued her dance. The latter are quickly attracted to the dances of their more agitated neighbors and follow up on the communication of one such dancing bee: they fly to the site indicated by the dance and inspect the so avidly promoted hive. After the inspection, these scouts return to the swarm: each scout that is more convinced of the new hive than of the one she originally found, begins an agitated dance to promote the new site. One after the other, all sites that were avidly promoted by scouts are visited by the other scouts. This consensus-building process gradually leads to agreement on one site (SEELEY, 1982)

It should be mentioned that the inspection of a potential hive site is a quite a precise process: the bee walks up and down the entire hollow, often covering a distance of 50 m (ibid.). This allows her to cover the entire inner surface of the cavity. When a scout gives up her original, first discovery and consensually agrees with the other scouts on another site, then the experienced scouts are in true agreement (ibid. )

The new bee hive can be up to 10 km away from the original site. The search lasts no more than three to four days. If no suitable place is found, then the bees begin constructing a hive directly at the first landing site and, since such hives cannot withstand the winter weather, the colony dies during the first cold spell.

If, on the other hand, the scouts have agreed on a new site, they force their way to the surface of the bee cluster in a zigzag course. At this point the entire colony begins to beat its wings in order to raise its temperature to 36° C (SEELEY, 1982; HEINRICH, 1981). This is a necessary precondition for the bees to be able to fly after this quiescent state. If the colony is knocked off balance before this temperature is reached, the whole swarm falls to the ground. When, after a few minutes, the correct temperature is reached, the scouts give the sign to take off: they force the aggregated bees apart in a series of so-called buzzing runs. The entire swarm disperses and ascends into the air, forming a cloud of bees with a diameter of approximately 10 m. Within this cloud, the scouts repeatedly take off into the direction of the new site, thereby showing the other bees the correct bearing of the destination. In the first 30 m the swarm makes only very slow progress, but it picks up speed dramatically over the next 200 m.



Upon reaching the newly selected site, the scouts emit a sign (v. FRISCH, 1965, p. 236 with a reference to Lindauer). The nature of this sign is still unknown. At any rate, the swarm reacts to this sign and comes to a standstill above the new hive. The scouts drop from the stationary swarm, alight on the entrance of the new home, and precisely mark it with a scent. Shortly thereafter the entire swarm takes over the hive. Within hours they remove all dirt, begin immediately with building the combs, and fly in search of pollen and nectar. This marks the end of this specific communication process until the following year.

### 3.1.2. The sign-mediated communication process of foraging

The second display of honeybee language that I describe here picks up where the first left off. It plays an equally important role in enabling the bee colony to survive over the winter.

So-called foraging bees are responsible for finding suitable food sources. Upon finding such a site, the forager returns to the surface of the hive and begins her own waggle dance. She brings along pollen and nectar, which not only informs the other bees that the dance refers to a feeding site and not to a new hive site (FRISCH, 1955, 1970), but also provides information on the quality and quantity of the food. The linguistic signs and the sequence of these signs are the same as in the first communication process described above (in which only scouts were involved). In this case, however, the waggle dance sequences are relevant to all encountered foragers, prompting them to collect food in the described direction and described distance. The constative linguistic behavior has changed into regulative linguistic behavior. *The linguistic behavior is different, the communication processes pursue different goals, yet the linguistic signs that are employed have remained the same.*

The above scenario refers only to information on feeding sites that are more than 25 m away. The bees again dance a figure-eight. The orientation of the central section of the „8“ signals the direction of the feeding site in relation to the position of the sun. If the dance takes place on a vertical honeycomb, the deviation in direction between the feeding site and the sun's position is accurately recreated as the deviation from the vertical (v. FRISCH, 1965). As in the case of the first communication process, distances are depicted temporally: the wagging in the central section of the „8“ lasts longer for longer stretches than it does for short ones. Thus, wagging for one second can indicate a distance of 500 m, while wagging for two seconds can indicate two kilometers. Other bees follow the waggle-dancing bee at close quarters, whereby certain odors provide additional information about the site. Rather than approaching such places directly, the individual bees take small detours. They orientate themselves according to distinctive landscape features. These orientations are determined in an arbitrary manner and are specific for the individual bee: they are not communicated to the others. If certain orientational features are experimentally altered, some bees can briefly become disoriented.



### 3.2. Further features of communication in honeybees

#### 3.2.1. The types of dances: Their sign characters and their meaning

To date, nine different dance types have been identified as linguistic signs (v. FRISCH, 1965):

- 1) The round-dance is a call to search for food in all directions within a radius of 25 m.
- 2) The waggle-dance describes the direction of the destination in terms of the respective position of the sun and defines the distance.
- 3) The Rumpel-dance describes a conspicuous type of movement made by successfully returning foragers. They hastily make their way across the honeycomb, bumping into colony members and informing them that something is going on, e.g., that food is available.
- 4) The Ruck-dance is carried out by foragers that are emptying their honey sacs and involves intermittent, directed tail wagging. It serves more to indicate a general dancing mood than to impart any specific message.
- 5) The sickel-dance has been observed in every bee species (with one exception) in the transition between the round-dance and the waggle dance (figure-eight). The opening of the „sickel“ in the dance pattern denotes the direction to the feeding site.
- 6) The buzzing run is the sign to disperse. Scouts barge through the interlocked bees in the swarm in an undirected, zigzag course and audibly buzz their wings.
- 7) In the Putzlauf the bee shakes its body from one side to the other.
- 8) In the vibration-dance, one bee takes up contact with another, whereby it rapidly vibrates its abdomen. The meaning of this dance has not yet been deciphered, although there is strong evidence that it involves a communication form combining dance and acoustic signals.
- 9) Finally, the Zitter-dance is an expression of neurotic behavior and is disregarded by the surrounding bees. Research has shown it to be a result of a traumatic experience such as severe impact, poisoning, injury to appendages, or extreme state of alarm.

The type of sign use that we designate as dances is a genetically acquired linguistic competence: even without prior socialization, i.e., the presence of older bees, juveniles develop the ability to collect food, to dance, and to communicate messages that others can understand and react to specifically. Nevertheless, subsequent social contact with bees of the same age is important: carrying out linguistic behavior and heeding the calls for specific action require some degree of practice and experience in participating in mutual interactions.

While the ability of bees to take their bearings according to the respective position of the sun is innate, the specific skills are gained and perfected in the course of a few days of fly-

ing experience. Interestingly, bees recognize the sun as having a 24-hour course, so that they can carry out their dance at the correct angle vis-à-vis the sun even in the dark (v. FRISCH, 1965; LINDAUER, 1975, p. 129f.).

### 3.2.2. Forms of communication beyond dance

Honeybees exhibit other forms of communication that are either combined with or separate from the communicatory dances themselves. Various wing-beating frequencies or abdominal vibrations can transmit movement frequencies on suitable substrates (KIRCHNER/TOWNE, 1994); other bees are able to identify their meaning. This is evident in the specific reactions to certain frequencies (v. FRISCH, 1965, p. 285f.).

Odors, which are actively employed, are apparently an even more significant form of danceless communication (v. FRISCH, 1965, p. 504f., p. 22f.). During her nuptial flight, the queen bee emits scents that attract the males (drones). The bees positioned at the entrance hole of the hive beat their wings to waft the smell of their scent glands toward the arriving workers and thus guide them to the entrance.

The scent glands are also used to mark certain food sources, enabling other bees to find these sites more easily. Bees that are threatened or attacked extend their sting and whirl their wings to exude an alarm scent which is not identical with bee poison. The alarm induces members of the colony to attack. This attack is generally directed at moving objects in the vicinity.

### 3.2.3. Humans can understand the bee language

Once one has understood the bees' linguistic behavior and their use of linguistic signs at the grammatic, semantic, and pragmatic level, it should be possible to identify the practical meaning of the information content. In fact, bee researchers, by observing the dances, were able to locate the feeding sites down to the meter! The only deviations pertained to direction, not to distance; humans are less adept than the studied bees at identifying the bearing in relation to the sun's position and potential sidewinds (v. FRISCH, 1965, p. 233f.).

### 3.2.4. Dialects of the bee language

Bee colonies form relative language communities that are distinguished by dialects. Experimentally mixed colonies of Austrian and Italian bees revealed clear differences in the interpretation of the dance tempo, which indicates the distance to the feeding site. When the Austrian bees communicated a suitable feeding site at a distance of 300 m, for example, the Italian bees executed the instruction in exactly the correct direction, yet over a distance of 500 m. Vice versa, a 200 m dance by the Italian bees meant a much shorter distance to the Austrian bees. Thus, despite applying identical rules to the same linguistic signs, distinct differences existed in the meaning of the signs (v. FRISCH, 1965, p. 292f.)

In stingless bees, the use of symbolic signs in regulative and constative linguistic behav-

ior to indicate direction and distance is not developed. These bees must accompany and guide inexperienced conspecifics to every discovered food site.

### 3.2.5. Language and communication in bees

Twenty years before Karl von Frisch received the Nobel prize for his research into the bee language, he was embroiled in a controversy involving so-called animal languages. He was accused of improperly using the term language to describe specific behavioral feats. His opponents argued that a very simple form of animal communication was involved, but certainly not language. In his response („Sprache“ oder „Kommunikation“ der Bienen?, 1953, p. 235f.), K. v. Frisch proves that it is justified to speak of the language of bees because a *system* of signs is involved.

In this chapter I have discussed only two of many sign-mediated communication processes that can serve as examples of rule-governed, sign-mediated interactions between individual bees in a colony. Each of these communication processes encompasses a series of characteristic sign uses and sign combinations, whereby the context of usage clearly determines the meaning of the utilized sign sequences. Furthermore, various forms of behavior evidently take on sign character and, when combined, can take on meaning and be understood as signs. The habitat specificity with which such language communities apply their stock of signs is reflected in the different dialects of bee communities.

The communication of honeybees (a) with one another and (b) about something is necessary to exchange information, coordinate behavior, and form associations between individuals of such social animal communities (LINDAUER, 1975, p. 145). Survival without the sign-mediated interactions described above would be impossible. At the same time, this example vividly illustrates how certain behavior can take on sign character within behavior sequences.

Beyond using linguistic signs in regulative and constative linguistic behavior, bees must originally have been able to perform generative linguistic behavior, thereby ultimately constituting new life-forms. In order to survive the winter, the swarm first had to have selected the correct overwintering site through appropriate communication. At some point, the rules underlying this communication were innovatively generated, much in the same way that the transition from signs with mere reference character (honey bees of warmer latitudes) to symbolic sign systems (northern hemisphere bees) must have been a marked innovative step. The ability to survive the winter eventually became fixed in the genetic text of these surviving bee generations. We know that this happened, but can only guess at how it happened.

The survival strategy of honeybees in colder latitudes clearly shows that communication experience in generative linguistic behavior, which substantially and permanently supersedes the originally innate language competence, can constitute an expanded communication competence. This competence is hereditary in an expanded (or at least modified) form; in the context of social animals, it can be differentiated as broadened language

play skills, for example through learning processes (LINDAUER, 1975, p. 138). How else can the set of criteria for an ideal hive be so differentiated if the genetic imprinting that orients the judgement on the potential of a new hive is not the result of rich, indelible experience by previous generations of bees. Communication experience by real life-forms can differentiate genetically imprinted and hereditary language and communication competence in a manner that expands and modifies the original genetic imprinting.

What, however, are the criteria behind the fact that certain experiences expand and change the genetic text, while others do not? A fruitful discussion of this question calls for prior examination of intraspecific communication. Examining the regulated interactions between and within cells of an organism brings us closer to the constitution of the genetic text.

## 4. Intraorganismic communication

After having presented an example of interorganismic communication (bee language), I would like to continue the investigation into whether living nature is structured and organized in a linguistic and communicative manner by focusing on specific interactions *in* and *between* cells. With the exception of the strictly unicellular organisms, all other forms of life consist of a smaller or greater number of organs - specific associations of cells - whose interaction enables the organism to function as a whole. Coordinated behavior between these organs is a prerequisite for the survival of the overall organism and enables it to interact with conspecifics as an individual in its specific environment. A closer examination of the communication between cells of an organism (intercellular communication) reveals that this, in turn, depends on successful behavioral coordination of key regions within the cell. A meaningful discussion of intraorganismic communication must therefore begin with an account of intracellular communication. A consideration of its basic principles is fundamental to understanding intercellular communication.

### 4.1. Intracellular communication

The range of interactions in and between cells of a living organism is the domain of molecular biology. Thus, the term „cell communication“ was coined primarily by molecular biologists to describe intercellular communication.

An initial analysis of living organisms shows them to be typically composed of a great number of different cells rather than of a single cell whose size is variable. This multicellularity, however, does not reflect the original condition of most organisms. At the very beginning of its life, each organism consisted of a single cell. In order for this cell to give rise to a multicellular organism required (1) a specific set of rules governing the production of ever new cells, (2) the association of these cells to organs and tissues and (3) the behavioral coordination between these cells. Reproductive capacity and metabolism are two such coordinated behaviors performed by the individual cells and, later, by the entire organism.

A prerequisite for a complex organism to develop from a single cell is the specific ability of the cell to reproduce in a coordinated manner. The rules underlying this behavioral coordination are contained in the nucleus of the cell, in the so-called genes. The cell's genes, in their totality, determine both the actual appearance of the fully developed organism and the course of the individual developmental stages. The totality of the genetic information of an organism, along with its developmental blueprints, is termed the *genotype*, while the fully developed organism itself is the *phenotype*. The genotypes of the various genera, species, phyla, etc. clearly differ from one another, and the variety of phenotypes provides visible evidence that the genetic codes and their ultimate expression are different. At the same time, the underlying structure of each living cell of an organism is basically very similar, as are its functions. The pathway leading from the genotype to the phenotype is *principally the same in all organisms*.

The manner in which the gene sequences constituting the genotype are formed, laid down, and expressed resembles the production and application of written texts, which are interpreted as transcripts of instructions, directives, as well as structural and production blueprints. One can therefore refer to a genetic code - a *symbolically* encoded text (functioning as linguistic signs) that defines the development and final configuration of an organism.

Chemical molecules are the building blocks in the sequences of linguistic signs. They are joined to one another like letters to words and words to sentences, the latter corresponding to concrete behavioral directives. How is this genetic language, which is equally valid for all organisms, constructed? What does its grammar, semantics, and pragmatics look like? Who or what are the sign users and what do the signs themselves really look like? What is their meaning according to which rules and in which situational contexts? Does something along the lines of communication processes exist here as well?

#### 4.1.1. The sign-mediated communication process of protein synthesis involving two intracellular languages

The genes of a cell consist of nucleic acids. These are themselves composed of nucleotides, each of which consists of a phosphate group, a sugar, and a base. If the sugar component is ribose, the nucleic acid is termed ribonucleic acid (RNA); if it is deoxyribose, it is termed deoxyribonucleic acid (DNA).

The nucleic acid language is almost exclusively composed of an alphabet consisting of 4 bases. DNA uses the bases A(denine), C(ytosine), G(uanine), and T(hymine), while RNA uses the first three bases and replaces thymine with U(racil). The nucleic acid molecules are strings of various lengths, without branches or interlinks. The bases are arranged linearly and are referred to as base sequences, which can then actually be recorded as written sequences (WATSON, 1992; FELSENFELD, 1985; DARNELL, 1985).

At the same time, however, the nucleic acids constituting the genetic code are not elements of the language constituting protein molecules. The production of protein molecules enables the cell to maintain and reproduce itself. The cell's entire metabolism is geared to this task. Proteins are formed by amino acid sequences. The amino acid language consists of an alphabet of 20 different amino acids which can further be differentiated into positively and negatively charged, into hydrophilic and hydrophobic (or lipophilic) types (WATSON, 1992; FELSENFELD, 1985).

Much like DNA and RNA molecules, proteins are linear molecules, whereby the sequence of amino acids defines a *protein individual*. Based on the physico-chemical features of amino acids and their interactions, a particular protein folds itself into a precisely determined spatial structure which is decisive for the function of that protein.

A short amino acid strand with few amino acids is known as an oligopeptide chain, while those with many are termed polypeptide chains. Proteins, in turn, are composed of 50 to

2000 amino acids. The rules underlying the structure of the sequences are determined in the DNA. How can DNA determine the structure of proteins when the latter are composed of amino acids? (DOOLITTLE, 1985)

The production of protein molecules, which are necessary for cell growth, metabolism, and reproduction, proceeds according to a stable set of rules. The central rule of complementary base pairs governs how the genetic code (as a text that defines the overall function and details of protein synthesis) functions: Thus, guanine shows a tendency to couple with the opposing cytosine in the double-stranded DNA or RNA and vice versa. Adenine has a tendency to couple with thymine in DNA and with uracil in RNA. This relates the grammar of the nucleic acid language

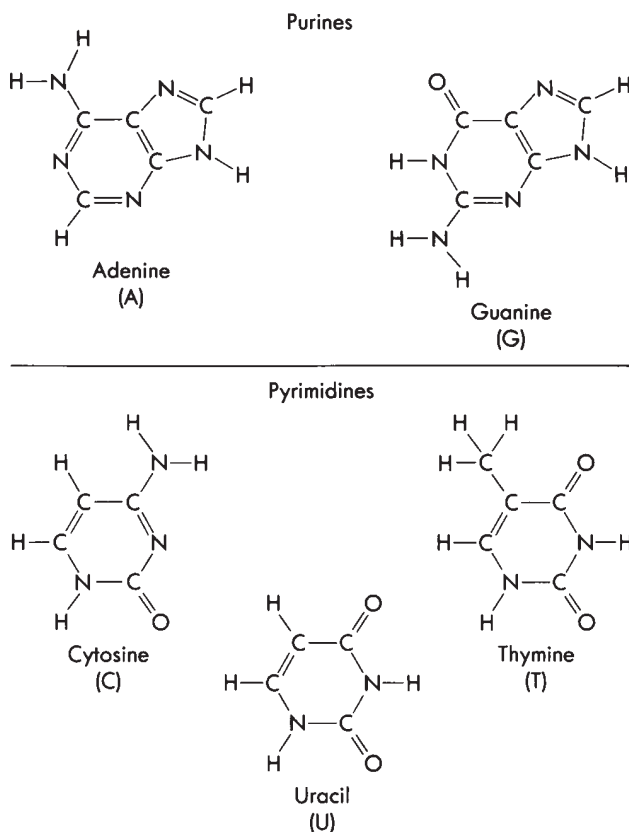


Fig. 4 „Bases of nucleic acids“ (from: WATSON, 1992, p. 14)

In the DNA or RNA, three successive bases always form a unit, a so-called triplet (or codon). Only in this form do the bases of the nucleic acids take on significance: as a triplet, each symbolizes exactly one amino acid. The potential number of combinations in the case of triplets is 64 variations. Of the 64 triplets, three serve as start and stop signals,

i.e., they determine the beginning and end of the protein chain. The arrangement of the remaining 61 triplets in the DNA regulates the sequence of amino acids in that each triplet codes one amino acid.

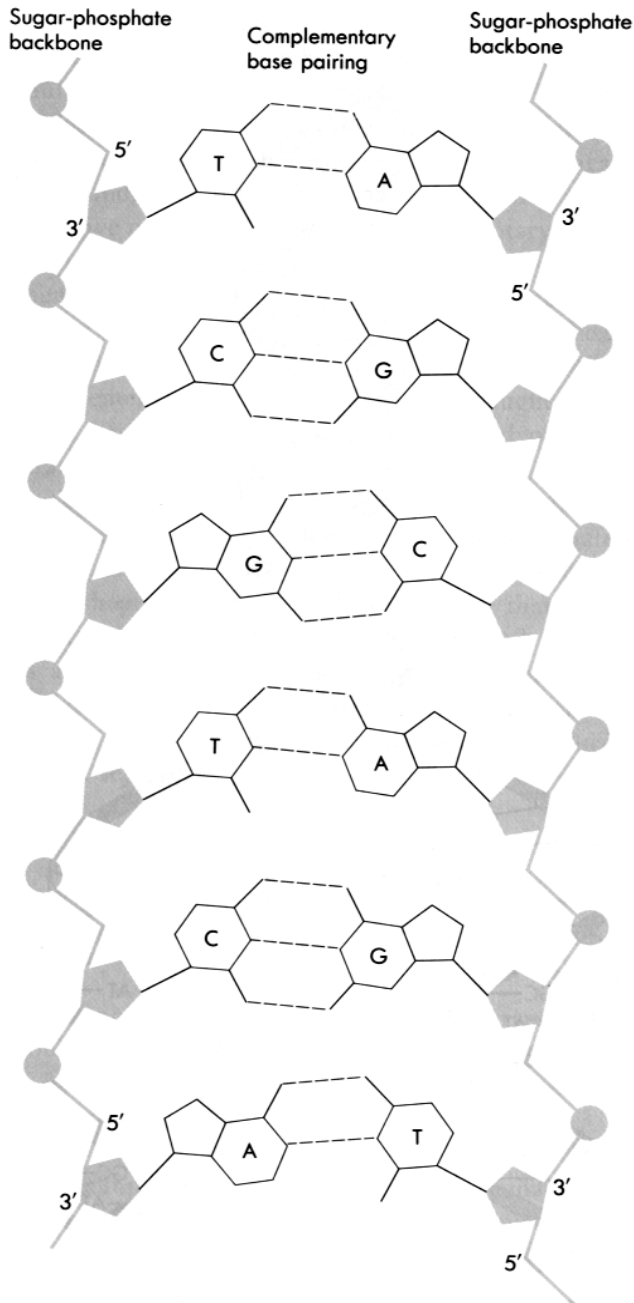


Fig. 5 „The base pairing of two DNA chains“ (from: WATSON, 1992, p. 21)



Each letter of the amino acid language corresponds to one or more „words“ formed by three letters of the nucleic acid language. Namely, the genetic code is redundant: 61 triplets determine 20 amino acids. In the present context, „word“ means: a structure (sequence of bases) that is meaningful for the grammar of the amino acid language. Semantically, it behaves like the word of a language.

AMINO ACID	THREE-LETTER ABBREVIATION	SINGLE-LETTER CODE
Glycine	Gly	G
Alanine	Ala	A
Valine	Val	V
Isoleucine	Ile	I
Leucine	Leu	L
Serine	Ser	S
Threonine	Thr	T
Proline	Pro	P
Aspartic acid	Asp	D
Glutamic acid	Glu	E
Lysine	Lys	K
Arginine	Arg	R
Asparagine	Asn	N
Glutamine	Gln	Q
Cysteine	Cys	C
Methionine	Met	M
Tryptophan	Trp	W
Phenylalanine	Phe	F
Tyrosine	Tyr	Y
Histidine	His	H

Fig. 6 The 20 amino acids in proteins (from: Watson, 1992, p. 4)

In protein synthesis, a protein-assembling entity must read the text of nucleic acid sequences that codes for the amino acids, i.e., it must correctly decode the text and act on this information according to a set of rules. This entity must begin with the first nucleotide, combine the first three into a triplet, and must deliver the amino acid corresponding to the triplet for the initial unit of the polypeptide chain, i.e., produce the initial unit of the amino acid sequence. If, for whatever reason, the protein-assembling entity neglects or fails to correctly read the first mononucleotide, then an incorrect sequence - and an incorrect protein - arises, even if all the subsequent units are correct. A reading error is a mistake in the grammar of the nucleic acid language and alters the semantic meaning such that the result of the sign process no longer corresponds with the original purpose. If, for example, the protein-assembling entity begins according to the RNA sequences AUG UCC AAG GCU etc. (these four sequences code for methionine, serine, lysine, alanine), and this entity fails to read the adenine of AUG in the first sequence, then

methionine will not be positioned at the beginning of the polypeptide chain. The result: the entire protein has another spatial structure that corresponds with other functions.

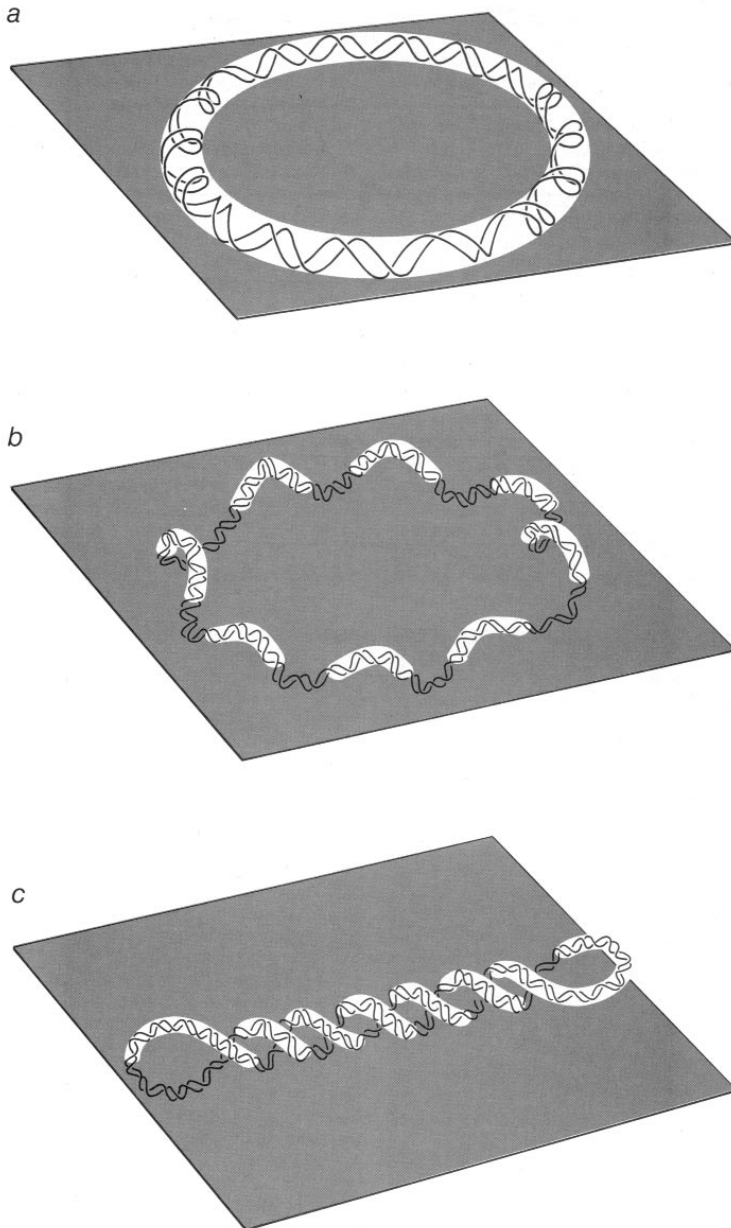
FIRST POSITION (5' END)	SECOND POSITION				THIRD POSITION (3' END)
	U	C	A	G	
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	Stop	Stop	A
	Leu	Ser	Stop	Trp	G
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G

„Note: Given the position of the bases in a codon, it is possible to find the corresponding amino acid. For example, the codon (5') AUG (3') on mRNA specifies methionine, whereas CAU specifies histidine. UAA, UAG, and UGA are termination signals. AUG is part of the initiation signal, and it codes for internal methionines as well. (From L. Stryer, *Biochemistry*, 3d ed., W.H. Freeman, 1988.)“

Fig. 7 The genetic code (from: WATSON, 1992, p. 41)

For the protein-assembling entity, the reading direction is irreversible: it can only read the nucleic acid sequence in *one direction*. Were this not the case, then the grammar and semantics of the nucleic acid language would have to have an entirely different constitution (WATSON, 1992). The nucleotide sequence UGA, for example, is coded as a stop-triplet in the correct sequence. If it is read incorrectly (AGU) it would code for the amino acid serine.

Molecular biology and biochemistry have interpreted this protein synthesis as a sign-mediated production process; they are therefore able to decipher the genetic code (the nucleic acid language) as a code, at least in the grammatic/semantic sense. They successfully determined which amino acids correspond to each of the 64 triplets. This led to the



„SUPERCOILING IN DNA changes the shape and stability of the double helix. When a helix is formed into a circle by a bond joining the ends (a), it lies flat in a plane because the DNA is relaxed. If the double helix is untwisted several turns before the ends are joined (b), it tries to resume its normal twist, and so the backbone can no longer lie in a plane. Here it has become a left-handed toroidal superhelix. A topologically equivalent form (c) is a right-handed supercoil that is probably closer to the shape supercoiled DNA assumes in a cell.“

Fig. 8 Supercoiling in DNA (from: FELSENFELD, 1985, p. 50)

establishment of a code table which defines the grammar/semantics of the DNA/RNA code in light of the protein/amino acid language. This „code catalog“ serves as a „dictionary“: any DNA strand can be read as the text for protein synthesis. While this allows the amino acid sequence that constitutes the protein to be predicted, predictions about its spatial configuration (a prerequisite for any analysis of the respective protein function) are currently possible only in a few cases (WATSON, 1992).

DNA consists of two complementary strands in which the respective codons and anticodons, i.e., the affine base pairs, bind via hydrogen bonds. Three-dimensionally, this double strand takes on a helical form, which serves to stabilize the structure energetically. This specific, spirally coiled DNA is packed into the cell nucleus.

The unique manner in which it is packaged serves to bring sequence elements that lie far apart on the linear DNA closer together spatially. This proximity enables specific forms of regulatory interaction which would not be possible at the distances involved on the linear DNA. The packaging is unique in that the basic coil is further folded into a supercoil (WATSON, 1992; FELSENFELD, 1985), whereby the angles attained are just sufficient to avoid damage to the basic coil.

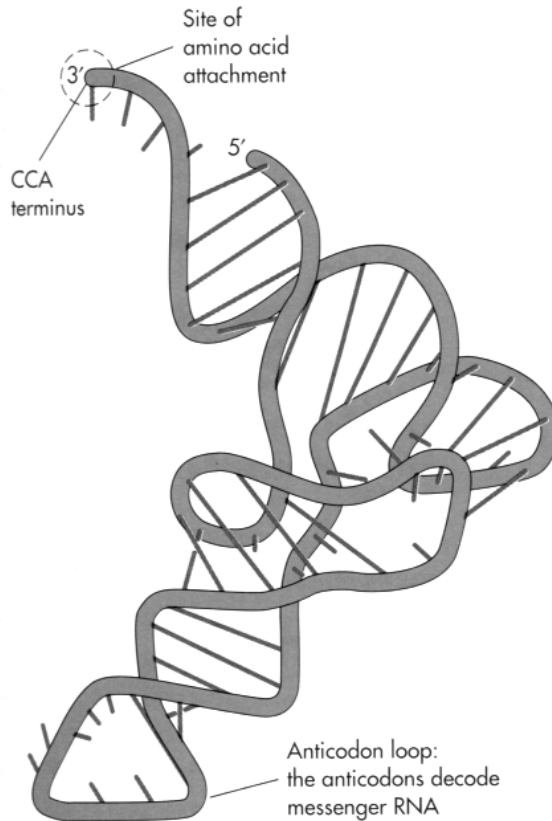
This double helix is split apart during protein synthesis. Ribonucleic acid is formed at the respective DNA strands. The DNA sequence is transcribed into an RNA sequence, which docks onto the free DNA sections in a complementary fashion. It is termed messenger RNA (mRNA) and serves as the template for the production of the protein. For this purpose, the message of the mRNA is transported from the nucleus into the cytoplasm.

The transcription from DNA to RNA is a complex process whose precision determines whether the information fixed in the genetic text is successfully implemented. After the mRNA is formed and transported out of the nucleus, it is attached in outstretched form to the protein-assembling entity (the ribosomes).

This is the only configuration in which the mRNA can serve as an operational text or is capable of delivering information. The amino acids corresponding to these codons of the mRNA, which dock onto the ribosomes, do not attach directly, but rather to the anticodons of the tRNA (transfer RNA) which are complementary to the codons. Each tRNA is charged with a corresponding amino acid produced by the cell and determined by the respective anticodons; they make their way toward the surface of the ribosome.

This explains the designation transfer RNA (tRNA). The tRNA molecules consist of ca. 80 nucleotides (some contain up to 120) aligned in a chain. The middle loop of the cloverleaf-shaped molecule is always the site of a triplet, for example CCA (cytosine-cytosine-adenine). This anticodon attaches to the complementary triplet, in this case AAC (adenine-adenine-cytosine) of the mRNA. Thus, the tRNA molecule wanders to the ribosome surface, bearing the amino acid that corresponds to its anticodon; there, on the outstretched mRNA molecule attached to the ribosome, it seeks the codon that fits its anticodon. Having found the codon, it remains in that position. Shortly thereafter, the next

tRNA molecule, with its own complementary anticodon, docks onto the directly adjoining codon of the mRNA. Terminally, it also bears the amino acid corresponding to its anticodon.



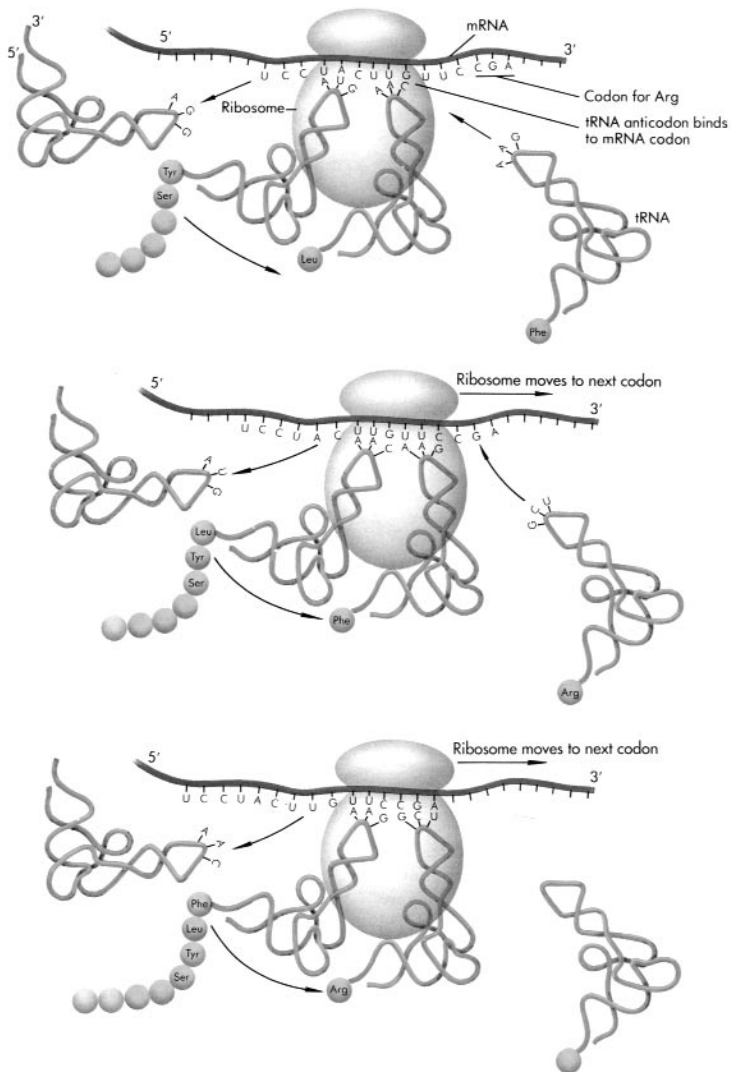
„The structure of a transfer RNA molecule. Base pairing within the single stranded molecule gives it its distinctive shape. The anticodon loop is the portion that decodes messenger RNA. An amino acid attaches to the CCA bases at the 3' end of the chain.“

Fig. 9 The structure of a transfer RNA molecule (from WATSON, 1992, p. 39)

Both amino acids are thus positioned next to one another and are joined by a peptide bond. The first tRNA has fulfilled its function, detaches from the ribosome, and is free to again pick up the same amino acid from the cell's amino acid stores. In the meantime, a third tRNA molecule with its anticodon and amino acid has arrived at the third codon of the mRNA and a peptide bond is formed between amino acid 2 and amino acid 3.

With the help of this rule-governed interaction the polypeptide chain grows progressively from one end until the stop codon appears, terminating the synthesis process.

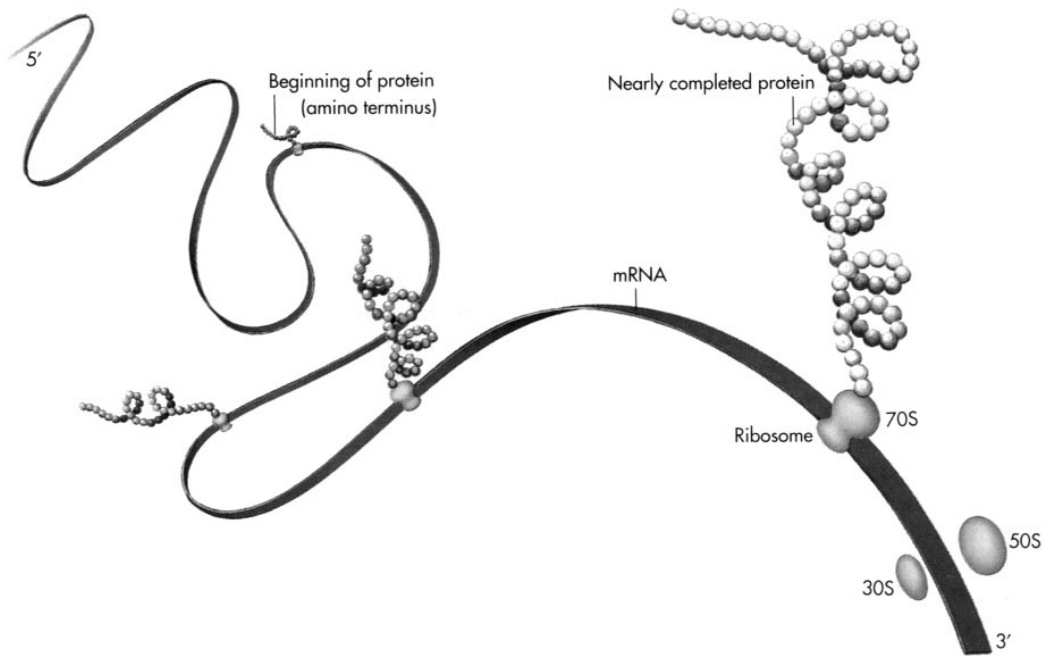
Error-free interaction processes in polypeptide chain formation are critical for the cell. The transcription and translation of the genetic text only makes sense if it is error-free. A single copying or translation mistake leads to insertion of a ‘wrong’ amino acid, resulting in a ‘wrong’ protein which is incapable of fulfilling its task, for example catalyzing a specific metabolic reaction. The protein with such an altered amino acid sequence (due to the transcription or translation error) is not incorrect in and of itself; within the rule-governed interaction, however, the altered steric configuration means a change in the original semantic content of the genetic information.



„At the ribosome, the codons of a messenger RNA molecule base-pair with the anticodons of transfer RNA’s, which are charged with amino acids.“

Fig. 10 (from: WATSON, 1992, p. 40)

The pragmatic aspect of such defective information lies in its actual effect on the metabolism of the cell or even of the entire organism. The molecular expression differs from that specified by the genetic text.

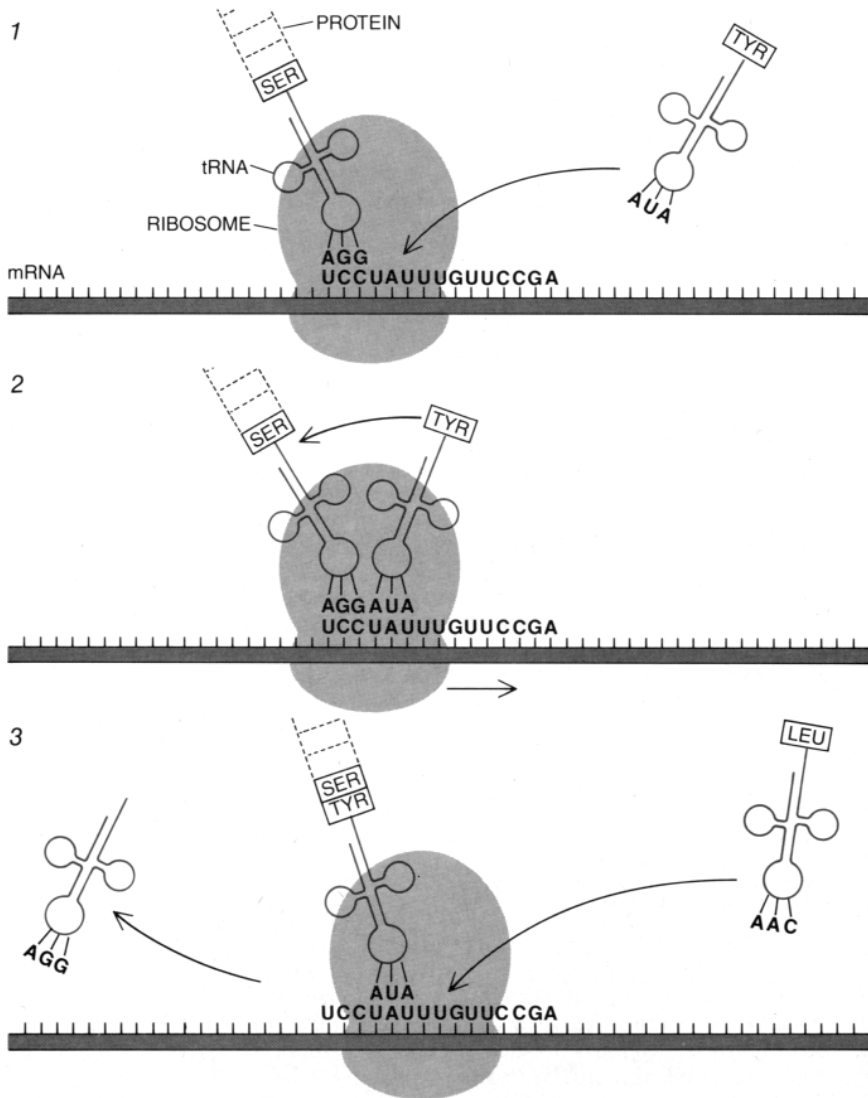


„Messenger RNA carries genetic information from the DNA to the ribosomes, where it is translated into protein. The polypeptide chains are elongated as ribosomes move along the mRNA molecules, with the 5′ends of the mRNA being translated first..“

Fig. 11 (from: WATSON, 1992, p. 38)

The entire translation process of a gene into the corresponding protein is termed gene expression. Generally spoken, all cells of an organism contain the same DNA, i.e., the full complement of genetic information. On the other hand, not all genes are active in all cells at the same time. This specific activation of particular genes is precisely what is responsible for the production of different enzyme proteins.

These very different enzyme proteins, in turn, are a precondition for coordinating both the production of very different cells and the interactions between these cells in a manner that justifies referring to associations. This very specific „reading“ of selected genes is what differentiates a blood cell from a liver cell, a nerve cell from a phagocyte in the immune system, etc. (GEHRING, 1984, 1985).



„TRANSLATION of mRNA into protein at a ribosome follows the same steps in both eukaryotes and prokaryotes. Each nucleotide triplet, or codon, on the mRNA chain encodes a specific amino acid. Each molecule of tRNA in turn binds only the amino acid corresponding to a particular codon. A tRNA recognizes a codon by means of a complementary nucleotide sequence called an anticodon. Here the addition of one amino acid to a protein chain is shown. An incoming tRNA molecule carrying the amino acid tyrosine binds to the codon exposed at a binding site on the ribosome (1). The tyrosine forms a peptide bond with serine, the last amino acid on the protein chain (2). As the ribosome advances one codon (3), exposing the binding site to the next incoming tRNA, the serine tRNA is released.“

Fig. 12 Translation of messenger RNA into protein (from: DARNELL, 1985, p. 58)



Differentiated cell types are an underlying feature of multicellular organisms; they produce the different proteins that ensure the specific activities and functions of an organ. The production process - as a rule-governed behavior - is the same in all cells. The production products, however, differ. Thus, liver cells for example produce ca. 50 proteins that are rare or absent in other cell types.

TYPE OF RNA*	FUNCTION
mRNA	Transfers information from genes to protein-synthesizing machinery
tRNA	Carries activated amino acids for protein synthesis
rRNA	Protein synthesis
U1, U2, U4/6, U5 snRNAs	mRNA splicing
M1 RNA	Catalytic unit of RNase P
Telomerase RNA	Template for telomere synthesis
Primer RNA	Initiation of DNA replication
7S RNA	Part of protein secretory complex
ATP	Carrier of energy-rich bonds
Coenzyme A	A key molecule in intermediate metabolism
* mRNA, messenger RNA; rRNA, ribosomal RNA; snRNA, small nuclear RNA; tRNA, transfer RNA.	

Fig. 13 „Some functions of RNA and ribonucleotids“ (from: WATSON, 1992, p. 436)

Let us briefly return to the transcription of DNA into RNA, i.e., to the copying process. The entire process begins when an enzyme, RNA polymerase, binds to a specific sequence of bases. This enzyme unwinds the DNA double helix, yielding two individual strands. One of them is copied, with the second one serving as a template: While the enzyme runs down the DNA, the respective, complementary RNA nucleotide is attached to the growing RNA chain. In fact, 3 different enzymes are involved in the copying

process: RNA polymerase 1 transcribes the DNA of those genes that code for ribosomal RNA (which goes on to form the ribosome as the protein-assembling entity) into rRNA. RNA polymerase 2 catalyzes the synthesis of mRNA. Finally, RNA polymerase 3 synthesizes tRNA and several small nuclear and cytoplasm RNAs. Thus, three enzymes are responsible for the production of three RNAs.

An error in this transcription process leads to formation of a protein that is orthless for the task it was designed to do.

The very first DNA copy, the mRNA, is not a one-to-one copy. *This copy is heavily modified by enzyme proteins in the nucleus* before it migrates into the cell's cytoplasm through pores in nuclear membrane:

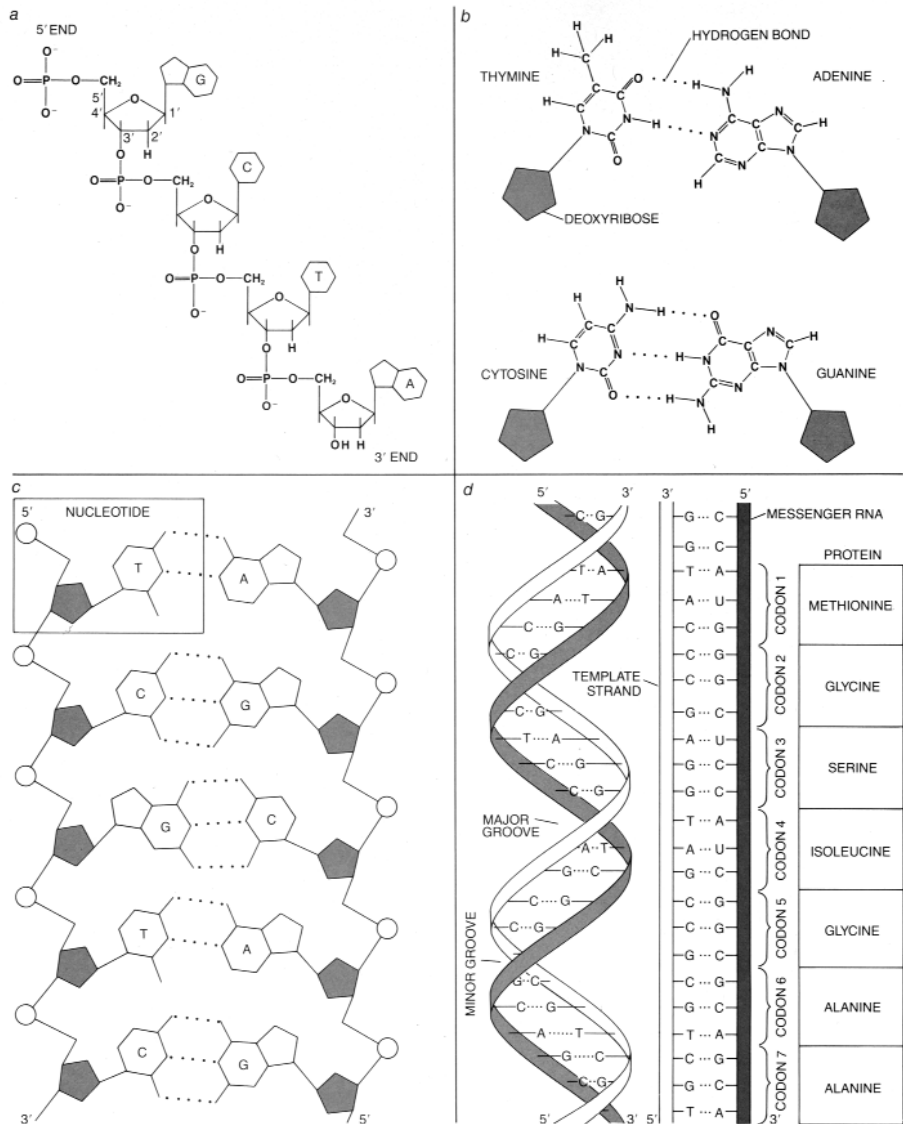
Rather than consisting of an uninterrupted unit, many genes of cells with true nuclei are composed of specific segments. Before mature RNA can form (i.e., an information sequence whose entire scope and content is actually useful), worthless segments of the primary copy are identified *as such* by enzyme proteins and cut out. This form of text processing already takes place during transcription rather than upon completion of the entire transcript.

Again, enzyme proteins are responsible for linking the remaining segments. Based on this *highly specific text processing activity*, molecular biologists concluded that stable information storage - such as that achieved in the DNA code - must have evolved later than the comparatively malleable RNA. Historically, the gene-regulated production of proteins by RNA presumably arose at the dawn of living cells; the reverse translation into DNA, which functions as a more stable storage for genetic information (stabilized irreversibility), apparently developed much later (DARNELL, 1985).

This not only considerably improved the density of information, but also the intra- and intercellular competence of cells (in implementing sign processes). The same holds true for the organisms that these cells constitute: even everyday social interactions, which must stand the test of experience, *can be genetically coded*. If crucial experience is gained over the history of an organism, a cell association, or cell, then the existing genetic text of the DNA can be expanded by additional, specific information contexts (in the form of nucleic acid sequences); this will lead from less complex to successively more complex and highly complex information structures.

Thus, every DNA bears a greater or smaller number of genes that are useless for the mRNA; these are spliced out to yield usable mRNA. This is the task of the so-called nuclear ribonucleoproteins: they *reliably identify as useless those sequences* that are in fact worthless in the specific application. The identification process underlies certain rules. If they are followed, the intended protein can be successfully produced. We now know that such identification rules for nuclear ribonucleoproteins actually exist, although how they can be formulated remains unknown (WATSON, 1992).

Enzyme proteins process the RNA text before it enters into the cytoplasm. This processing takes place during, not after, the transcription process. Since the tissue-specificity of



„STRUCTURE OF DNA has a backbone (a) made up of bonded sugar and phosphate groups, to each of which is attached one of four bases: guanine (G), cytosine (C), thymine (T) or adenine (A). The phosphate group is represented by the structures with the P at the center, the sugar by the pentagon with an oxygen atom (O) at the top. A phosphate group connects the 5' carbon atom of one sugar to the 3' carbon atom of the next. The combination of sugar-phosphate group and base constitutes a nucleotide (b). (The distances between atoms are not to scale.) The nature of the hydrogen bonding of the bases is such that thymine always pairs with adenine and cytosine always pairs with guanine. The structure that results is shown in two dimensions (c) and in three: the double helix (d). In conveying the genetic message of DNA the sequence of the coding strand is transcribed into a strand of messenger RNA, which serves to make a variety of proteins. The U in the strand of messenger RNA stands for uracil, the RNA counterpart of thymine.“

Fig. 14 „Structure of DNA“ (from: FELSENFELD, 1985, p. 46)

proteins typically necessitates a highly differentiated processing of the underlying texts, the decision regarding the prospective context must take place at this level. This decision is invariably correct. Molecular biologists are still in the dark as to the rules governing this decision.

Once the RNA strand has made its way to the end of the ribosome surface (this process is often referred to metaphorically in terms of a zipper action: McKNIGHT, 1991), the primary structure of the polypeptide chain has already been established. The mRNA strand can be reused. Upon full completion, the polypeptide chain folds into its so-called tertiary structure. In certain cases the fusion of such tertiary structures leads to so-called quaternary structures. The spatial configuration of the completed enzyme protein can then serve to produce the full range of substances that make up a complete cell.

The amino acid sequence, which constitutes a protein depending on species, form, and therefore function, is relatively simple to determine experimentally. The great number of protein-constituting amino acid sequences known today corresponds to only a fraction of the actually known three-dimensional protein structures. It is this three-dimensional structure, however, that decides the functional competence of the protein; this spatial configuration is also what enables a more precise analysis of its actual capabilities (RICHARDS, 1991; SIPPL, 1995, 1996). For example, it took 23 years to determine the structure of hemoglobin in detail; to date, we know the exact configuration of little over 100 proteins. *As much as we have learned about the grammar and semantics of this second, key intracellular language, all our attempts to decipher its pragmatic rules have been painfully slow. These rules clearly cannot be reduced to or deduced from the grammatic/semantic level, but rather constitute a complementary function.*

In any case, all three forms of RNA (mRNA, tRNA, and the rRNA forming the ribosome), along with the corresponding enzymes, represent the sign-mediated medium between genetic text and finished protein. RNA enables enzyme proteins to be produced in the precise sequence intended by the semantic text; in doing so, *it unites the essential sections of the text by identifying those that are unimportant, removing them from the text, and then splicing the remaining text sections* (DARNELL, 1985).

Humans, as linguistically talented beings, are unique in being able to explicate the rules they follow when they speak and to formulate these as rules; in extension of this, they are also in a position to learn and utilize the language in which the genetic information is coded, e.g., in genetic engineering techniques. In fact, humans selectively employ enzyme proteins for this process, enzyme proteins whose specific text-processing competence is known: this text-processing technique is much more precise and error-free than any other approach currently available to mankind.

Evidence for the universality of this language in the protein synthesis of all living organisms on this planet is that every organism investigated to date encodes its genetic text according to the same rules and, in doing so, (principally) uses the same code words. The mRNA, tRNA, and ribosomes of very different organisms are fully interchangeable in an

extracellular environment; they even respond to artificially produced mRNA. Recently, for example, a human growth hormone was successfully inserted into the genetic text of a mouse in order to double its growth (WATSON, 1992, p. 255 ff.).

#### 4.1.2. Proteins - products of intracellular communication

One can describe proteins as products of a behavior stipulated by the genetic text; the text definitively prescribes the sense and aims of this behavior and details its implementation.

Every living organism consists of proteins. They possess the competence to associate themselves or to interact with other molecules according to specific rules; the variability of their three-dimensional structure enables them to differentiate the various forms of life as defined in the respective genetic texts. They accelerate metabolic processes and code the behavior necessary for their own reproduction.

Proteins are subject to a behavior governed by rules. They can assume highly differentiated functions depending on which rule underlies the protein in which interaction:

- a) If the protein functions as a structural protein, its task is to associate proteins of the same type. They unite to form a larger structure such as an artery, a leaf, a specific tissue fiber, etc.
- b) If the protein serves as a messenger molecule, its task is to transmit information as a linguistic sign in linguistic behavior. It can serve to transmit messages between organs or between individual cells, where it functions as a sensory organ in the cell membrane, i.e., a so-called receptor.
- c) Proteins also serve as individual cell markers (to identify cells) for specific forms of communication between cells of one or more organs.
- d) Certain proteins enter into specific interactions with one another or with others (DOOLITTLE, 1985).

Other proteins interact with DNA and regulate the expression performance of the genes. Still others participate in copying and translating DNA and RNA into amino acids.

As briefly mentioned above, receptor proteins are embedded in the cell membrane and selectively identify specific messenger molecules that function as linguistic signs in information-transmitting linguistic behavior, for example as hormones or neurotransmitters. As we will see later, violations of these rules occur and errors can crop up: these can seriously impact the cell or even the entire organism.

The interactions between proteins and such molecules depends on the relative amounts of the substances involved and the strength of their bonds. Basically, this dependence describes how well the molecules fit one another spatially and which electrostatic interaction rules, such as attraction and repulsion, are in force between the charged sections at a given time.

The vast array of proteins is determined by the varying arrangement of 20 amino acids. This arrangement is itself determined by the grammar and semantic content of the nucle-

ic acid text. As indicated above, the actual characteristics of a protein molecule depend on how it is folded spatially; this configuration begins to take shape directly at the protein's point of origin, the ribosome (UNWIN/HENDERSON, 1984). The folding follows a pragmatic rule: the amount of free energy is held at the lowest level possible and the protein takes on its „most comfortable position“ (DOOLITTLE, 1985). This rule is constituted and regulated by the wide range of forces that affect the thousands of atoms in the protein molecule, by interactions with the adjoining molecules, and by the rules governing interactions between amino acids themselves (KARPLUS & McCAMMON, 1986).

In the past, protein sequencing, i.e., determining the particular amino acid sequences, was a laborious task. This changed when scientists realized that sequencing the nucleotides of a DNA molecule was a much simpler procedure. The new approach involved determining those DNA sections responsible for coding the proteins in question, i.e., determining the codons corresponding to the amino acids of the protein. This led to a host of new problems: each codon represents a very specific amino acid. Most amino acids, however, can be expressed by more than one codon.

*The role of proteins is not only a function of their specific spatial structure, but also of a structure that is flexible. The atoms of every protein oscillate rapidly around their central axis. This puts the entire protein into a constant state of motion and deformation, a prerequisite for it to execute the full range of catalytic processes, for example the enzymes' specific functions in protein synthesis itself or in the breakdown of energy-rich food.*

Proteins are composed of 50 to 500 amino acids, which corresponds to between 500 and 5000 atoms (KARPLUS & McCAMMON, 1986). The interaction between the atoms is important for the structure of the protein, whereby the forces acting on each atom depend on the momentary position of all the other atoms of the protein. The energetic interconnection of each atom with all the other atoms of the protein defines the rule which ultimately determines the spatial structure of that protein. This explains the difficulty involved in determining protein configurations despite knowing the underlying grammatic/semantic instructions in the genetic text.

The actual changes in the protein's position due to the constant motion of the atoms is limited. The combined effect of many small movements, however, can be considerable: individual, apparently undirected displacements can lead to coordinated movement. Such small, rapid movements are a prerequisite for large, coordinated protein movement.

Energetically, a cell relies on interactions with its environment. Specifically, it takes up energy-rich material, utilizes it for its own energy requirements, and excretes the energy-poor waste material. Enzymes are responsible for all these tasks, and the operational plans for these enzymes are in turn defined in the genetic text, in the DNA. This text ensures a continuous production of identical copies of itself and asserts its competence to express the bauplan defined in the genetic text by setting protein synthesis into motion and regulating it in detail. In their interactions, the components of the cell - the nucleus with the genetic text, plastids, mitochondria, dictyosomes, vacuoles and the endoplasmic reticulum - are all geared to optimize metabolism.

Every interactional element fulfils an important task that no other element can assume. This form of intracellular communication, as a rule-governed interaction, must function if intercellular communication (the exchange of information, the formation of associations, and the coordination of behavior between cells and cell associations of an organism) is to function. „Neighboring cells must be able to communicate with one another if they are to coordinate their metabolism and generally work together as a tissue“ (UNWIN & HENDERSON, 1984).

Intra- and intercellular communication are not independent entities. This is evident not only in successful communication, but even more drastically when communication fails. If intracellular communication is disturbed, then intercellular communication also becomes deformed and distorted; disturbed intercellular communication can distort and deform intracellular communication. Psychosomatics provides numerous well-documented examples for the latter condition (UEXKÜLL, 1989).

The organelles of a cell are surrounded by a thin layer of lipid and protein molecules (as is the cell itself) . These membranes are interactionally competent and allow only those substances to enter or exit that are important for the cell or the organelles and their function. A key function of such membranes is to segregate the individual interaction partners. In doing so, they prevent the rule - less mixture of substances from different regions that would undermine rule-governed interactions by the individual interaction partners. The membrane enables rule-governed interactions tailored to specific capabilities of the proteins enclosed within that membrane (UNWIN & HENDERSON; 1984; BERRIDGE, 1984, 1985).

Some proteins function as sensory organs by permitting the diffusion of specific molecules or ions. Other proteins have a specific interaction competence with hormones or with those substances that transport neuronal signals (SNYDER, 1985). They identify these substances from a wide range of irrelevant substances (with a negligible error rate) and identify foreign substances to which they also react very specifically. The proteins in the cell membrane enable the cell to react to messenger substances in a rule-governed manner, i.e., to interact communicatively with the cells emitting these messenger substances. The cell membrane is in principle an organ responsible for the sensory perception of the cell ( BERRIDGE, 1985).

Directly adjoining cells in a tissue or an organism must interact according to rules, i.e., communicate in a sign-mediated manner, if they are to coordinate their behavior (for example their metabolism). The corresponding contact sites are termed connexins (two successive proteins). Each connexon is anchored in its cell membrane and projects into the intercellular space, where it attaches to the connexon of the neighboring cell. These intercellular tubes enable chemical substances that serve as linguistic signs in communication processes to be exchanged and thus coordinate behavior. In living tissues, these intercellular connections open and close in reaction to changes in the cells. For example, this important feature allows a living cell to hermetically seal itself off from a dying neighbor and thus prevent the loss of vital nutrients (UNWIN & HENDERSON, 1984; BERRIDGE, 1985).



Proteins also serve in the overall internal organization of the cell, i.e., of its cytoplasm. A protein fiber, functioning as a cell framework, extends from the nucleus to the inner surface of the cell membrane and plays an important role in shaping the cell, its movements, and cell division (WEBER & OSBORN, 1985). One type of protein fiber, the microtubules, is important in cell division: at the onset of division, when the chromosomes begin to divide into two sets, these proteins alter their structure. The product is a fiber bundle consisting of parallel microtubules that extend from the opposite poles of the dividing cells to the chromosomes in the middle; they also directly connect the poles. These fiber bundles (mitotic spindle) then proceed to draw the chromosome sets to the poles and also generate the necessary forces of motion. The conclusion drawn from this is that the microtubules are probably the cytoskeletal factor responsible for precisely partitioning the genetic material of a mother cell into both daughter cells (*ibid.*). Experiments have shown that destroying the microtubules compromises the cell's structure, causing it to lose its form and function. The interaction with the other two cell types that form fiber frameworks collapses. The cell loses its functional ability as a communication partner in cell associations (*ibid.*).

As determined above, the production of enzymes is vital to the cell. The full complement of key enzymes allows the cell to convert food into the many substances it needs to fully develop its structure and to interact with associated cells in a rule-governed manner.

Multicellular organisms have quite different cell types with rather diverse functions and characteristics. For example, only red blood corpuscles possess the hemoglobin pigment; all others are colorless. The cells of the skeletal tissue are the only ones to secrete the rigid substances that form skeletal structures (*ibid.*). Certain digestive enzymes are produced exclusively in specific glands. At the same time, each cell holds the entire genetic text of the organism. What mechanisms and rules underlie the directed information transfer in the cell regarding the production of a required enzyme? How can one explain an information retrieval system that expresses the information of selected gene segments by neglecting all other functions and activities?

As rule-governed behavior, enzyme production proceeds according to specific information in the genetic text, information that defines how the correct enzyme is to be expressed and that it be expressed at the right place and at the right time. Only when these rules are broken can skin cells grow in the liver or can a leg replace an antenna on an insect's head (GEHRING, 1985). This information transfer is subject to the rules of economy, i.e., the cell produces only those enzymes that it needs at the time. The cell allocates energy reserves for this highly selective information retrieval for specific enzymes and thus improves its capacity to react to the specific demands of its environment. The ability to read specific information in order to synthesize specific enzymes is hereditary. There is even a special behavior coordinating gene that regulates these processes, the regulator gene.



#### 4.1.2.1. Two intracellular communication processes in the regulation of enzyme protein synthesis

When the cell stops building proteins yet maintains amino acid production, many unnecessary amino acids begin to accumulate. Since cell function is guided by the principle of minimal energy consumption, the cell can be expected to curb this overproduction. This is achieved by a rule-governed interaction of the intracellular type.

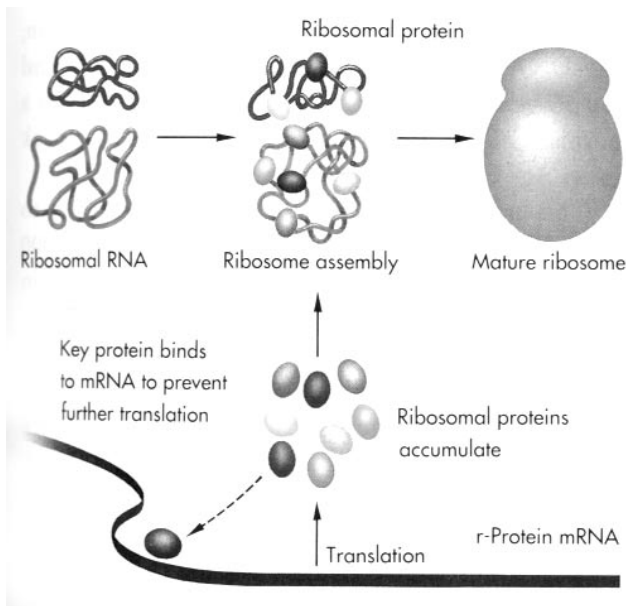
The production of a single amino acid, arginine for example, proceeds in 4 steps; each step requires an enzyme (i.e., for a total of 4) whose production is coded by 4 genes. The 4 enzymes work together, converting the raw product into the end-product (arginine). If a particular enzyme is present at adequate levels, the superfluous enzymes are immediately broken down. The genes corresponding to the amino acids lie next to one another in the same sequence as the required enzymes. The genes that code for the enzymes necessary to produce amino acids are termed structural genes. The so-called operator gene is positioned at the end of the chain of structural genes. It also codes for the inactivation of the structural gene and contains information on whether the structural genes are to be activated or not. The operator gene does not control its own status. If it is turned on („open reading grid“), then the structural genes can be transcribed; if it is turned off, transcription stops (WATSON, 1992).

The regulator gene is positioned some distance away from the operator gene and the corresponding structural genes. It regulates the operator gene. While the operator gene acts directly upon the neighboring structural genes, the regulator genes function by releasing a substance into the cytoplasm. There, this substance binds with a substance of low-molecular-weight, becomes activated, and shuts down the operator. This production-inhibiting process is termed repression (1), and both elements involved - the regulator gene and the low molecular weight substance - are termed apo-repressor and cro-repressor. This correspondence enables a tailored amino acid production (ibid.). In addition to this coordinated behavior in which the end-product itself, along with the regulator gene, regulates production volume, fine tuning also takes place: the end-product (the amino acid) acts directly on the first enzyme of the amino acid-assembling enzyme chain and turns it off. Overall, this production process is regulated by a directed enzyme production involving the regulation of information retrieval. This regulation follows very specific rules. By interacting with the enzymes that formed it, the end-product regulates overall production volume. Rough and fine tuning are complementary processes (ibid.).

As a rule-governed interaction, this intracellular, sign-mediated communication process that produces amino acids also finds use in other production processes of the cell, for example in the production of growth factors, in cell division, and in DNA replication.

The intracellular type of sign-mediated communication process includes not only the production, but also the consumption (2) of substances (ibid.). Energy-rich food must be broken down and utilized in order to release the energy that the cell requires to organize its life. This process is also catalyzed by enzymes. Again, only those enzymes that are actu-

ally needed are produced, and not all are produced at once. Here, the regulatory processes promote rather than inhibit enzyme production. Although this communication process pursues a different goal, the underlying rule remains the same, i.e., the production of the required enzymes is regulated by the same rules governing specific information retrieval, enzyme production, and the blocking of enzyme production via interactions between end-product and regulator gene (ibid.).



„Ribosomal protein levels control the translation of ribosomal protein mRNAs. When the rate of r-protein synthesis exceeds the rate of rRNA synthesis, free r-proteins accumulate. Some of them bind to the Shine-Dalgarno sequences on the r-protein mRNAs and prevent further translation. This mechanism ensures that r-proteins are not synthesized faster than they can be used in making ribosomes.“

Fig. 15 „Translational Control is the second means of Controlling Protein Synthesis“ (from: WATSON, 1992, p. 55)

The situation becomes somewhat more complex in the case of highly developed, multi-cellular organisms. Here, the temporal coordination of information retrieval is much more important: the ladybird beetle larvae don't need to develop the adult coloration, young elephants don't need mature tusks, and the human embryo doesn't require fully functional eyes. Today we know that specific chrono-genes regulate the temporal coordination of gene expression (GEHRING, 1985).

#### 4.2. Intercellular communication

A typical unicellular organism such as an ameba is fully capable of executing all life-sustaining functions by itself. Multicellular organisms, on the other hand, rely on the successfully coordinated behavior of numerous cell associations, tissues, and organs, which

may lie far apart. Such coordinated behavior would be impossible without a functioning communication between these components of multicellular organisms.

„The communication between cells or groups of cells is vital for the survival of every multicellular organism“ (SNYDER, 1985).

Intercellular communication (cell-cell- communication) also involves chemical substances that transmit specific messages in the form of linguistic signs; they have therefore been termed chemical messengers.

„The most important messenger substances in mammal cells are hormones, cyclic AMP (adenosine monophosphate) and calcium. Hormones serve primarily in the communication between cells, while cyclic AMP and calcium transmit messages within individual cells“ (CHEUNG, 1982).

Cells communicate with each other via such chemical messengers and, more directly and much quicker, via nerve cells. In neuronal communication, the linguistic signs are termed neurotransmitters (SNYDER, 1985; IVERSEN, 1979). Cells may also communicate with one another indirectly and in a slower manner. The linguistic signs in such hormonal communication are hormones.

There are no clearcut borders between these two types of intercellular communication, i.e., rather than being mutually exclusive, they are compatible to some degree. Evidence for this is the fact that one and the same linguistic sign can be used differently in either communication form („one messenger, several messages“; SNYDER, 1985). The pragmatic sign rule, or the relationship of the sign to the sign-using entity, follows the same rule: specific cells send information via chemical messengers to specific target cells (addressees). These, in turn, use their receptors (identification proteins in the cell membrane) to identify the messenger substances as such and to pass them on into the cytoplasm. Only at this point does the cell react to the particular semantic content of the message, i.e., it responds by a specific, rule-governed behavior tailored to the message and/or by producing specific substances.

These communication processes are also subject to misunderstandings and mistakes that induce the cell to disregard the rules. A common reason for such behavior is that the receptor in the cell membrane (the identification protein) either (I) confuses the semantic content of one messenger with that of another, (II) entirely fails to identify it, or (III) mistakes a substance for a messenger when this is not the case (RUBENSTEIN, 1980; HÖFER, 1977).

The result in any case is a disruption of intercellular communication. In autoimmune diseases, which we will discuss later, these misunderstandings play a decisive role that can severely impair the entire organism.

Nerve cells send messages to the respective group of addressees (target cells), e.g., to other nerve cells, gland cells, or muscle cells. The chemical messengers released by the nerve cells reach the target cells via so-called synapses and synaptic clefts (intercellular

space). The target cells identify these substances with their receptors and pass them on to the cell interior (LLINAS, 1982; BERRIDGE & IRVINE, 1984; BERRIDGE, 1985; CARAFOLI & PENNISTON, 1985).

There, a specific intracellular communication process ensures an intercellular response. „In intercellular communication via neurons, the signal is transmitted across a narrow gap at the synapse - the switching point between the nerve ends and the membranous region - to the postsynaptic cell“ (SNYDER, 1985). Nerve cells communicate with each other over relatively short distances within milliseconds.

Hormonal communication takes place via the internally secreting (endocrine) gland system. A gland releases hormones that are identified as messenger substances by the receptors of the target cells. The glands introduce the hormones into the circulatory system, where they are intercepted by target cells that transmit the message into the cell's interior. The fact that hormones are transported by the circulatory system means they can reach virtually any corner of the body. On the other hand, hormonal communication takes longer, and minutes or even hours can pass before the message triggers a response in the affected cell (SNYDER, 1985).

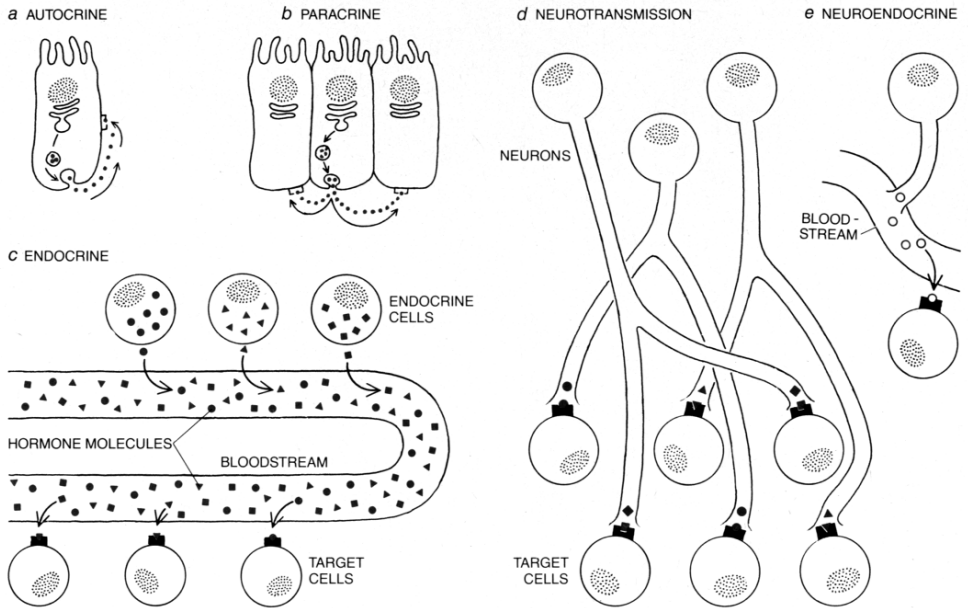
Two examples serve to illustrate how a chemical messenger can assume and ultimately represent *different meanings based on its different context in two different communication processes*.

*Noradrenaline:* Noradrenaline is a hormone secreted by the suprarenal gland. It promotes heart contractions, dilates the bronchial tubes in the lung, and increases the contraction force of the arm and leg muscles. If nerve cells of the sympathetic nervous system use the neurotransmitter noradrenaline as a messenger substance, it constricts the blood vessels and increases blood pressure.

*Vasopressin:* Vasopressin is secreted by the posterior lobes of the pituitary gland. As a hormone it increases blood pressure by constricting the blood vessels and inhibits urine production by increasing the kidney's water resorption ability. Used as a neurotransmitter by nerve cells, vasopressin is involved in memory formation in the brain (SNYDER, 1985).

#### 4.2.1. Hormones as linguistic signs

*Autocrine* hormones serve as messenger substances by acting on the very cells that released them. *Paracrine* hormones serve as messengers between directly adjoining cells. Most hormones stem from the endocrine glands; these secrete hormones into the circulatory system, where they are transported as messenger substances until the receptors of the target cells identify and bind them. In *neuroendocrine* communication processes the nerve cells transmit their message by secreting substances that function as hormones and that are released into the bloodstream. Nerve cells transmit their messages by releasing neurotransmitters directly to the respective target cells (SNYDER, 1985).



„METHODS OF COMMUNICATION employed by the hormonal system are generally less direct than those employed by the nervous system. Although autocrine hormones (a) act on the cell that releases them and paracrine hormones (b) act on adjacent cells, most hormones are in the endocrine system and act on cells or organs anywhere in the body. Endocrine glands (c) release hormone molecules into the bloodstream, where they come in contact with specific receptors on target cells. A cell's receptor recognizes the hormones meant to act on that cell and pull them out of the bloodstream. Neurons (d) communicate by releasing neurotransmitters meant to act on specific target cells. Neural communication is characterized by discrete messages sent over short distances. Some neurons, however, have a role in the hormonal system: in neuroendocrine action (e) a neuron releases substances that act as hormones directly into the blood.“

Fig. 16 „Methods of Communication“ (from: SNYDER, 1985, p. 116)

The endocrine glands of humans are primarily influenced by the hypophysis. It coordinates the functions of the other glands via hormonal communication, i.e., it releases hormones that subsequently stimulate other glands to produce and secrete their own hormones. The hypophysis itself is regulated by the hypothalamus (part of the diencephalon), which releases certain substances; these induce the hypophysis to release its hormones as messengers to the glands. In hormonal communication, glands function as linguistic sign users and hormones as linguistic signs in specific, sign-mediated communication processes.

Principally, one can distinguish two chemically different types of hormone molecules. The first include the steroid hormones, for example glucocorticoids, cortisol, corticosterone, but also mineral corticoids like aldosterone and sex hormones like progesterone, testosterone, and the estrogens; they regulate numerous metabolic processes, regulate the electrolytic balance in the entire body, and are responsible for sexual behavior and producing germ cells.

The specific substances with which the hypothalamus stimulates the hypophysis to secrete hormones, which in turn induce certain glands to secrete steroid hormones, are peptide hormones rather than steroids. One of the most important of these is insulin, which is produced by the beta cells of the pancreas and regulates the blood sugar level in nearly every cell of the body. It does this by inducing cells to take up glucose. Insulin also influences fat metabolism.

Some peptide hormones regulate the activity of the gastro-intestinal tract (gastrin, somatostatin), while others regulate the evacuation of the gallbladder into the intestine (cholecystokinin; it also serves as a neurotransmitter in the brain). As an intestinal hormone, the vasoactive intestinal polypeptide controls peristalsis and also functions as a specific neurotransmitter in the brain. The encephalins function like opiates in the brain; in the gut they regulate peristaltic movements (SNYDER, 1985).

The hormonal communication is the central field of investigation in neuroendocrinology, immunology, psychoendocrinology and psychoimmunology, because the communication processes by hormones between the central nervous system and the immune system are responsible for the efficiency of the immune response. (HELLHAMMER, 1992, KIRSCHBAUM 1999, BUSKE-KIRSCHBAUM et.al. 1999)

Both hormonal and neuronal communication use in part different and in part identical messenger substances as linguistic signs in the various communication processes. *The same messengers assume different meanings in different sign-mediated communication processes*; these are identified in their different meanings by the respective addressees.

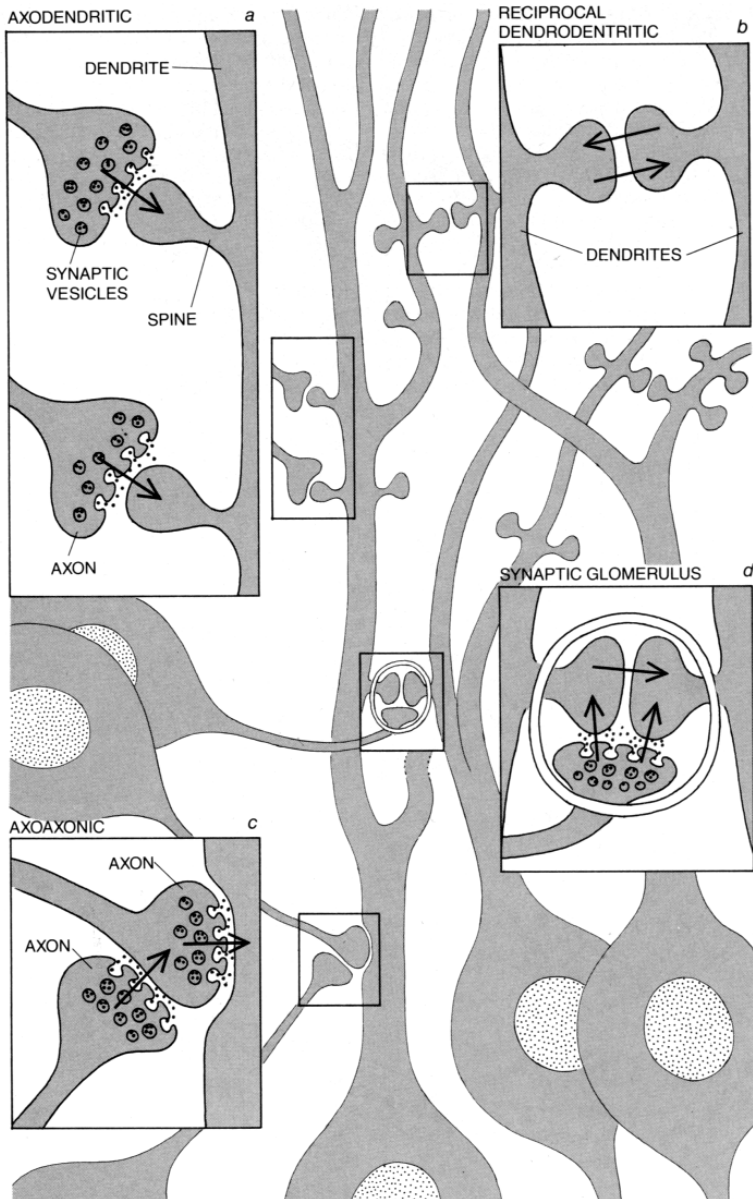
#### 4.2.2. Neurotransmitters as linguistic signs

Only 20 years ago, the number of neurotransmitters was believed to be very low. Since communication in nerve cells was interpreted as being solely inhibitory or stimulatory, two such substances with messenger function appeared to be sufficient. In the meantime, more than 50 neuropeptides that transmit very specific messages and thereby trigger complex interactions have been isolated.

The membrane of cells adjoining a nerve cell contains various types of canals. Neurotransmitters can selectively open or close these canals, enabling certain ions such as chlorine, sodium, calcium, or potassium to pass through. There is a special canal type for each ion, and a different signal is transmitted depending on the canal (BERRIDGE, 1985; CARAFOLI & PENNISTON, 1985; CHEUNG, 1982).

In neuronal communication, the interaction takes place between the end of one nerve fiber and the next nerve fiber. „The typical feature of communication between neurons is that they transmit directed messages over short distances“ (SNYDER, 1985).

The gap that serves as an intercellular communication space is termed a synaptic cleft. The terminal end of a nerve fiber bears vesicles filled with transmitter substances. The arrival of an electric impulse at the end of the nerve fiber signals the vesicles to release



„COMMUNICATION BETWEEN NEURONS takes place across gaps called synapses. In the classical axo-dendritic synapse (a) synaptic vesicles in the axon of one neuron release neurotransmitter toward receptors on the dendrite of a target neuron. It is also possible for a dendrite to pass a message to another dendrite; such messages are passed by way of dendrodendritic synapses. In a reciprocal dendrodendritic synapse (b) each dendrite passes messages to the other by way of a separate synapse. In some other synapses, called axoaxonic synapses (c), the axon of one neuron passes a message through the axon of another neuron to the dendrite of a third neuron. In a synaptic glomerulus (d) the axon of one neuron passes messages to dendrites of two others; the dendrites may pass messages to each other as well.“

Fig. 17 Communication between Neurons (from SNYDER, 1985, p. 120)



their contents into the narrow gap. The molecules cross the gap and are taken up by receptors in the membrane of the next cell. The receptors interact only with the transmitter substance released by the electric signal and react to no other substances (ibid.).

There are numerous rule-governed forms of interaction between nerve cells: an *axo-dendritic* synapse releases synaptic vesicles (the substance in the vesicles) at the end of a nerve fiber as a neurotransmitter. It docks on the receptors of a dendrite (plasma process on the surface of nerve cells) of the adjoining cell; this transmits the signal that triggers specific reactions within the framework of the rules governing a particular intercellular, sign-mediated communication process.

In the case of *dendro-dendritic* synapses, each dendrite relays a signal to the others via a separate synapse. This represents a reciprocal interaction.

In *axo-axonic* synapses, a message is transmitted from the axon of one nerve cell via the axon of a second to a third nerve cell.

„In a *glomerular* synapse, the nerve end relays messages to the dendrites of two other nerve cells. These dendrites can also communicate with one another“ (SNYDER, 1985).

Neurologists and psychiatrists, who have implicitly or explicitly interpreted these intercellular communication processes as sign-mediated communication and who have studied the rules underlying the process, can now themselves intervene in various inter- and intracellular communication processes, specifically with artificial hormones. In the past, all the medications used in neurology and psychiatry merely enhanced or suppressed the effect of a specific neurotransmitter (SNYDER, 1985). The recently developed peptide transmitters, on the other hand, can lead to the production of agents that influence the cell's own production and release of specific neuropeptides, including their receptor effects. This allows psychosomatic illnesses such as heart palpitations, asthma, angina pectoralis as well as endocrine depression to be more selectively treated. Such forms of treatment would not have been possible without insight into the rules governing the use of chemical messenger substances as linguistic signs in intercellular communication. This treatment involves using chemical substances that ultimately repair intercellular communication disorders by therapeutically intervening in this communication and taking advantage of the rule-governed use of the chemical messengers that act as linguistic signs.

#### 4.2.3. The organization of the cellular response

The information or message that reaches the cell as a messenger substance does not induce an immediate response from the cell. The receptors of the cell identify the special messenger molecule from among a wide range of other molecules. The receptor represents the cell's organ of perception. From the receptor, the external message is transferred into an internal signal transmission process (BERRIDGE, 1985). Once again, the information in one linguistic system is transformed into another language, i.e., the message encoded in one language is transformed into another one. Clearly, living nature as we define it is particularly successful in *creating different language systems and transforming them to communicate, coordinate behavior, and differentiate species*.



It is the rule-governed behavior behind the internal transformation of the external message that induces the targeted cell to initiate the correct response (e.g., secretion, contraction, metabolism, growth). After the external signal is transformed into an internal signal, a secondary messenger forwards that signal. This second messenger substance generally binds to the regulatory component of a protein kinase (enzyme), which then splits off its catalytic unit. This detached subunit transfers phosphate groups to specific proteins and initiates those processes commonly known as the cellular response (BERRIDGE, 1985; RUBENSTEIN, 1980).

Two main signal pathways are recognized in cells today: while the first proceeds via the secondary messenger cyclic adenosine monophosphate (cAMP), the second involves calcium ions together with two additional substances. In both pathways, the receptor molecule transfers the information from the cell surface through the cell membrane into the cell interior by means of a family of so-called G proteins.

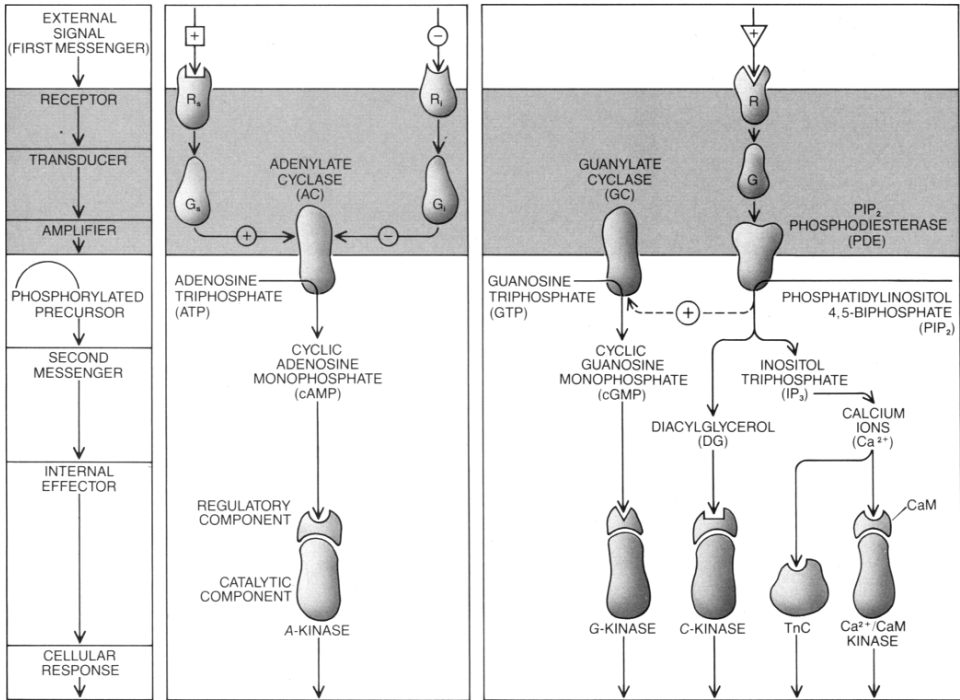
In both cases these proteins activate an amplifier enzyme on the inner surface of the cell membrane. This, in turn, transforms certain molecules into secondary messenger substances. These secondary messengers alter the spatial structure of cellular proteins: while the proteins remain inactive in one three-dimensional configuration, they trigger functions like secretion or contraction in another configuration. The message for the cell propagates itself in the cell in the form of a (chemically modulated) messenger substance.

The main effect of one signal path is to modulate the signal sequence in the other. For example, adrenalin in the heart influences the intracellular calcium content via this cAMP signal pathway. Thus, a brief calcium influx regulates the strength of the heartbeat. The cAMP signal pathway also regulates calcium transport in the muscle cells, secretory cells, and nerve cells. Little by little, calcium is proving to be the most important second messenger substance in cells (BERRIDGE, 1985; CARAFOLI & PENNISTON, 1985).

Cell reproduction occurs in various cycles. The cell growth necessary for this process is triggered by secondary messengers. The first phase involves only cell enlargement. In the second growth phase the chromosomes are replicated and prepare for cell division. In the next phase the chromosomes divide. Directly thereafter, the decision is taken as to which of two possible options will be adopted and carried out: the cell can divide again or become differentiated for a specific function in the tissue of the overall organism (until the late 90's scientists thought, that nerve cells lose their capacity to divide upon differentiation, but this was an error) other cell types can enter into a renewed cycle of division. This renewed activity is triggered by growth substances that are produced and released by specific cells. They bind to the receptors of the cell membrane and give the signal for DNA replication (BERRIDGE, 1985).

The fact that growth is a coordinated process clearly indicates successful cell communication. Uncontrolled growth leads to the development of tumors and shows that cell communication is disturbed. Our next task will be to examine forms of disturbed cell communication and to determine the role they play in various illnesses. This investigation will

lead us to yet another sign-mediated communication process, one that provides insight into a very special communicative faculty of organisms: the immune system.



„KNOWN SIGNAL PATHWAYS IN CELLS are few in number. In functional terms they share a sequence of events (left). External messengers arriving at receptor molecules in the plasma membrane (gray) activate a closely related family of transducer molecules, which carry signals through the membrane, and amplifier enzymes, which activate internal signals carried by „second messengers“. The pathway employing the second messenger cAMP (middle) has stimulatory receptors (R<sub>s</sub>) and inhibitory ones (R<sub>i</sub>), which both communicate with the amplifier adenylate cyclase (AC) by way of stimulatory and inhibitory transducers called G proteins because they require guanosine triphosphate (GTP) to function. Adenylate cyclase converts ATP into cAMP. The other major pathway (right) is not known to recognize inhibitory external signals. It employs a stimulatory G protein to activate its amplifier, a phosphodiesterase (PDE) enzyme. The enzyme makes phosphatidylinositol 4,5 biphosphate (PIP<sub>2</sub>) into a pair of second messengers, diacylglycerol (DG) and inositol triphosphate (IP<sub>3</sub>). In turn IP<sub>3</sub> induces the cell to mobilize still another messenger: calcium ions (Ca<sup>2+</sup>). Moreover, the path somehow induces the amplifier guanylate cyclase (GC) to convert GTP into the second messenger cyclic guanosine monophosphate (cGMP). In general the second messengers bind to the regulatory component of a protein kinase, an enzyme that activates a cellular response such as contraction or secretion by adding phosphate (PO<sub>4</sub>) groups to particular proteins. Calcium binds to a family of proteins including calmodulin (CaM) and troponin C (TnC). In turn CaM activates a protein kinase; TnC stimulates muscle contraction directly.“

Fig. 18 Signal Pathways in Cells (from: BERRIDGE, 1985, p. 126)

Before proceeding with our investigation into case studies of disturbed cell communication, I would like to present several examples of successful cell communication in which specific messages of specific nerves and glands trigger specific responses in specific tissues and organs:

EXTERNAL SIGNAL	TISSUE	CELLULAR RESPONSE
VASOPRESSION	LIVER	BREAKDOWN OF GLYCOGEN
ACETYLCHOLINE	PANCREAS	AMYLASE SECRETION
ACETYLCHOLINE	SMOOTH MUSCLE	CONTRACTION
ACETYLCHOLINE	OOCYTES(XENOPUS)	CHLORIDE PERMEABILITY
ACETYLCHOLINE	PANCREATIC BETA CELLS	INSULIN SECRETION
SEROTONIN	SALIVARY GLAND (BLOWFLY)	FLUID SECRETION
THROMBIN	BLOOD PLATELETS	PLATELET AGGREGATION
ANTIGEN	LYMPHOCYTES	DNA SYNTHESIS
ANTIGEN	MAST CELLS	HISTAMINE SECRETION
GROWTH FACTORS	FIBROBLASTS	DNA SYNTHESIS
LIGHT	PHOTORECEPTORS (LIMULUS)	PHOTOTRANSDUCTION
SPERMATOOZA	SEA URCHIN EGGS	FERTILIZATION
THYROTROPIN RELEASING HORMONE	ANTERIOR LOBE OF PITUITARY GLAND	PROLACTIN SECRETION

Fig. 19 „DETAILS OF SIGNAL PATHWAYS“ (from: BERRIDGE, 1985, P. 129)



## 5. Disturbances in intraorganismic communication

Any behavior of cells or cell associations that deviates from the rules can more or less seriously compromise the overall organism. Disrupted communication between and within cells can be triggered by a wide range of events ranging from psychological trauma to attacks on the overall organism by viruses and bacteria, including damage to overall intra-organismic communication competence through correspondingly severe defects in the genetic text. The organism as a whole is usually not defenseless against such communication disturbances: rather, it is capable of organizing appropriate counterstrategies to re-establish intraorganismic communication and ensure viable understanding (Verständigung), association, and behavioral coordination between the individual components of the overall organism.

### 5.1. Intercellular communication disturbance: Cholera as an example

Hormones and neurotransmitters serve as linguistic signs in sign-mediated communication processes between cells or cell associations (organs). Disturbances in intercellular communication occur when the addressee of the intercellular message cannot identify the signs in the sense in which the message was directed at the addressee by the sign user (for example a specific organ, gland, or nerve cell). On the other hand, the addressee can also interpret signs to be messages when these were never meant to be messenger substances. The addressee can also act as if it received a messenger substance without ever having actually received such a message. Alternately, a cell may lack or have damaged receptors on its surface which block or severely limit its capacity to receive certain messages and/or to respond appropriately. Finally, the receptors of a cell can confuse a particular messenger with substances that closely resemble the messenger. An example of the latter type of communication disturbance is the life-threatening disease cholera (RUBENSTEIN, 1980).

The small intestine of humans is the primary site of food digestion. It also releases the digestive products that the body needs into the blood stream. Specific enzymes that are produced and released by the pancreas and the small intestine break down the fats, carbohydrates, and proteins contained in the food. When food enters the small intestine from the stomach, a specific substance reacts with the receptors of the small intestine and induces - via intracellular communication - the production of cAMP (cyclic adenosine monophosphate) by these cells. This cAMP, in turn, induces the cells to excrete an alkaline fluid into the intestinal canal. The fluid creates the optimal conditions for digestion. As a rule, the cells involved produce two liters of fluid which are resorbed again at the end of the small intestine and partially in the colon (ibid.).

The presence of the bacterium *Vibrio cholerae* into the small intestine would, in itself, not elicit any reaction: it neither attacks nor in any way destroys intestinal tissue. The bacterium cannot penetrate or force its way between the epithelial cells of the gut and actually has no opportunity to reach the lymph ducts or enter into the blood stream. On the other hand, the bacterium produces the toxin cholera toxin. The receptors in the cells of the small intestine identify this substance as a messenger that signals the normal produc-

tion of cAMP. Cholera toxin, however, induces the cells to activate the enzyme adenylate cyclase (which converts adenosine triphosphate to cAMP) in such a manner that the cells release twenty to thirty liters of fluid into the small intestine versus the normal two liters. The cells are unable to resorb this amount of fluid, which is then lost in the form of vomiting or diarrhea. This severe fluid loss is life threatening and, in fact, 50% of all the infected, untreated cases die due to this intercellular communication disturbance (ibid.).

## 5.2. Disturbance of coordinated behavior between cell associations through disturbance of sign-mediated communication

Associations of cells into tissues and organs involve specific regulatory interactions. Successful regulatory communicative behavior between cells is a prerequisite for coordinated behavior in metabolic reactions or in specific interactions with other organs, glands, and nerve cells of the overall organism.

Many processes would be inconceivable without a highly complex communication between cells. This is especially true in the case of cell division and in protein synthesis during the growth of new cells, but is also valid for all the enzymes that these cells subsequently need (organ-specifically) in order to complete their full range of tasks. This includes the purely quantitative replacement of dying cells in a timely and precise manner. Communication disturbances here lead to variously grave adverse effects on the organism as a whole. We can distinguish three representative paths known to disrupt communication:

(a) environmental influences (e.g., chemicals, radiation, psychological trauma, etc.) can permanently disturb intercellular communication, thereby deforming intracellular communication and triggering abnormal cell behavior. For example, a cell that is unable to orient its own reproduction according to the rules governing coordinated reproduction within the organ may undergo unabated cell division.

(b) Environmental influences can directly alter the cell's genes so that, upon expression, a gene coded to coordinate growth will produce proteins in an uncoordinated manner. A change in the genetic text deforms the entire intracellular, sign-mediated communication involved in protein synthesis. This can be triggered by damage to or change in a single base of a single gene.

(c) The cell of an organ can be misused by being strategically conscripted by a virus or retrovirus (the difference will be discussed later in the text). The virus inserts its information in the cell's DNA. During the sign-mediated communication process of protein synthesis, the cell, rather than producing proteins for its own growth, produces viral proteins. These, in turn, strategically conscript further cells until the whole organism suffers from one or more tumors.

The resulting cancer cells are no longer bound to the rules of interaction inherent to a particular organ or organ complex, but exhibit abnormal behavior. They are permeable to chemical substances whose uptake would be blocked under normal circumstances, use

more energy than non-malignant cells, and also take on a somewhat different shape. As a rule, cancer is lethal not because a cell loses its capacity for regulated growth and thus develops into a tumor, but because such cells transcend their designated sphere of interaction, overstep their natural boundaries, and infest distant organs or tissues to form colonies of cancerous cells or metastases (NICOLSON, 1979).

Skin cells can serve as an example to elucidate the various ways in which cell associations interact with one another according to specific rules:

The outer layer of the skin is termed epidermis and consists of a layer of basal cells. This is overlaid by several layers of flat and scale-like cells. The epidermis undergoes constant renewal, with cell division taking place in the lowest stratum of the basal layer directly above the dermis (the latter represents an association of nutritive and skeletal cells). Due to the uninterrupted division in the basal layer, cells are continuously being pushed into the more superficial regions. There, they become differentiated according to very specific rules: they become flatter, produce the insoluble protein keratin, and lose their nucleus. They then form a layer of scales that eventually detaches from the epidermis surface. The relatively impermeable keratin layer is a first line of defense against our immediate environment (CHAIRNS, 1985).

The development of epidermis cells is the product of a regulatory, sign-mediated communication process between dermis cells. The dermis cells must signal the basal cells in order to initiate the division process. In the absence of such signals, the epidermis cells cease dividing and immediately begin to differentiate. The regions containing sign-transmitting dermis cells and sign-receiving basal cells are rather strictly delimited. Additional regulatory communication processes coordinate the arrangement of hair roots, sweat glands, and other structures in the epidermis. The sign-using dermis cells also specifically shape the surface features of the epidermis: if epidermal tissue is grafted from the upper arm to the palm of the hand, it gradually becomes thicker and develops the typical pattern of lines. If a patch of epidermis cells is lost due to injury, increased cell division in the bordering epidermis cells reclaims the damaged area. While the rules governing this regulatory, sign-mediated communication remain largely unknown, their existence is undisputed. Such intercellular communication involves numerous, specific communication processes that are more or less independent of one another. This leads to an increased potential for communication disturbance (ibid.).

Psoriasis is a disease that involves abnormal yet non-lethal cell growth. Here, the number of dividing basal cells increases far beyond the rate at which cells normally detach from the surface. Metabolic disturbance is one known cause, but even stress may be sufficient to disrupt the communication between dermis and basal cells and to trigger the symptoms of this communication disturbance. The common wart is also the result of such a benign communication disturbance between dermis and basal cells (ibid.).

Similar types of communication disturbance can also lead to cancer. In basal cell carcinomas, the cancerous cell leaves the tissue it is normally associated with and migrates into the underlying dermis. There, the basal cells no longer differentiate into their typical

form, but divide unabatedly. Once inside the dermis they lead to an ever-larger malignant growth. In this form of cancer, the cancerous cells rely heavily on the information flow from the dermis and rarely form metastases in other regions of the body. In prickle cell cancer, however, cells differentiate normally, albeit in areas outside the epidermis. These cells are less dependent on information from the dermis and the rate of metastasis formation is much higher. Both forms of cancer are frequently triggered by UV radiation, with the cells of each type showing a different behavior despite stemming from the same tissue. This is evidence for disturbances in more than one communication process between the dermis and basal cells.

„All four diseases are clearly the result of communication disturbances between the cells“ (CHAIRNS, 1985).

### 5.3. Intracellular communication disturbance

A malignant growth is an aggregation of cancerous cells which stems from a single cell that at some point lost control over its own growth. What causes a completely normal cell within a cell association to disregard the rules that coordinate normal cell growth?

Recently, special enzyme proteins were discovered that accelerate or even trigger such abnormal behavior. These enzymes are the products of specific genes. The conclusion was that certain genes code for such explosive cell growth and therefore enlarge tumors; they were termed oncogenes (BISHOP, 1982; WEINBERG, 1983, 1988; HUNTER, 1984). The transcription and expression of cancer-causing genes via the sign-mediated communication process of protein synthesis yields precisely those enzymes that accelerate the abnormal growth.

So-called retroviruses play an important role in the development of such cancer-causing genes. As opposed to normal viruses, whose genetic material is contained in DNA, the genetic text in retroviruses is based on RNA. It is surrounded by a proteinaceous envelope. Normal viruses conscript the cell strategically, i.e., after viral infection the activities of the cell no longer orient themselves according to the rules specific to the overall organism, but to those rules of behavior defined in the genetic text of the virus. In many areas, the cell's original genetic text remains effective, for example in the rules underlying protein synthesis, yet rather than maintaining the integrity of the overall organism, it serves solely to support the reproductive strategy of the viruses (WATSON, 1992).

When cells reproduce by cell division, the DNA is first transcribed into mRNA and then translated into the amino acid language. A virus inserts its information into this translation process, coercing the cell to produce viral proteins. Some of these proteins multiply the viral genome, other proteins attach themselves to the copies of the new virus particles, and still others serve as messenger substances for viral genes. Using these messengers, viruses induce normal cells to become tumors, i.e., to undergo unregulated cell proliferation.

Retroviruses can also unleash uncontrolled cell growth. They are the only viruses with an RNA genome. Retroviral infection involves transcribing viral RNA into double-stranded



DNA by means of a virus-specific enzyme (reverse transcriptase) and then inserting this into the genome of the host cell. Up until the discovery of this rule, no one had a clue as to how retroviruses reproduced. The hypothesis that RNA could also be transcribed into DNA - contrary to traditionally held belief that genetic information flows exclusively from DNA to RNA - enabled an understanding of reproduction in retroviruses through an understanding of the rules underlying this reproduction (ibid.).

The genetic text of retroviruses usually contains a cancer gene. The transcription into viral DNA and its insertion into the genome of the host cell will also involve the cancer gene. The subsequent transcription of the cell's DNA into mRNA by cellular enzymes naturally also gives rise to RNA copies of the viral DNA. Some of these copies will later form the viral genome of new virus particles. The remaining copies serve as mRNA, whose text the cell translates into the amino acid sequence of proteins in the course of the sign-mediated communication process of protein synthesis. These proteins are already subject to the rules of viral RNA, i.e., they already serve as envelopes for the genetic text of the retrovirus and thus in effect constitute new viral individuals. The enzyme of the cancer gene, however, attaches itself to the plasma membrane of the cell from the inside, where it alters certain proteins through so-called phosphorylation. Only at this point does the enzyme, which is coded by the cancer gene, induce malignant growth in the cell. Phosphorylation was long thought to be insignificant. Today we know that protein phosphorylation is responsible for cell growth. Its increase in the course of normal growth derails the normal regulatory process.

All forms of cancer involve communication disturbance of the intracellular type in that a group of cellular genes that code for growth and growth regulation becomes deformed or damaged. This can be triggered by chemical substances, viruses, or retroviruses. During the expression of such damaged genetic texts, i.e., in converting the genetic information into mRNA and the amino acid sequences of proteins, the pragmatic effect of the text alterations manifests itself as abnormal behavior and unhindered cell growth. In fact, the very genes that code for regulated growth in every cell also harbor the potential to form cancerous cells. The sign users are the same, yet the underlying rules can differ fundamentally.

Furthermore, viral strategies demonstrate that the overall organism's DNA, which is fully defined in each individual cell, is not a rigid genetic text; rather, the text components - those sequences that do or do not code for proteins - are subject to a certain variability which expresses itself in more or less clear variations of the semantic content and ultimately of the pragmatic phenotype or activity. This text variability enables the full range of text-processing procedures, from the insertion of viral DNA and the resultant conscription of the cell for intensified viral reproduction, to the vital adaptation of the organism as a whole to changing environmental conditions. Precisely this text variability makes it easier for entire populations to optimize the reproduction of their members. White hares in the northern hemisphere, for example, no doubt have a competitive advantage over brown hares, which potential predators can spot much more easily in the snow. In all likelihood, the reproductive success of a hare population whose genome contains a gene that expresses white fur when winter sets in, will be higher.

Genetic texts do not vary on their own, i.e., they are not autovaryable. Rather, text alterations - more commonly enlargements than distortions (e.g., through radiation damage) - involve the regulated behavior of specific protein individuals or coordinated behavior by a number of such individuals. While genes do code for proteins, no genetic text could be expressed as a protein without enzyme proteins. Specific enzymes identify precisely those sequences that mark the beginning and end of the particular gene that is to be expressed. To a certain degree, the sign users (that use the genetic alphabet and even the entire nucleic acid language, enzyme proteins, and other types of proteins) are at the same time the immediate goal of the sign-mediated communication processes undertaken by these sign users. On the pragmatic level, of course, each enzyme protein is used for a specific behavior sequence. The nucleic acid and amino acid languages enable protein individuals to reproduce themselves.

MICROORGANISM	ENZYME ABBREVIATION	SEQUENCE	NOTES*
<i>Haemophilus aegyptius</i>	<i>HaeIII</i>	5' ... G G   C C ... 3' 3' ... C C   G G ... 5'	1
<i>Thermus aquaticus</i>	<i>TaqI</i>	5' ... T   C G A ... 3' 3' ... A   G C T ... 5'	2
<i>Haemophilus haemolyticus</i>	<i>HbaI</i>	5' ... G C G   C ... 3' 3' ... C   G C G ... 5'	3
<i>Desulfovibrio desulfuricans</i>	<i>DdaI</i>	5' ... C   T N A G ... 3' 3' ... G A N T   C ... 5'	4
<i>Moraxella bovis</i>	<i>MboII</i>	5' ... G A A G A (N) <sub>8</sub>   ... 3' 3' ... C T T C T (N) <sub>7</sub>   ... 5'	5
<i>Escherichia coli</i>	<i>EcoRV</i>	5' ... G A T   A T C ... 3' 3' ... C T A   T A G ... 5'	1
	<i>EcoRI</i>	5' ... G   A A T T C ... 3' 3' ... C T T A   G ... 5'	2
<i>Providencia stuarti</i>	<i>PstI</i>	5' ... C T G C A   G ... 3' 3' ... G A   C G T C ... 5'	3
<i>Microcoleus</i>	<i>MsrII</i>	5' ... C C   T N A G G ... 3' 3' ... G G A N T   C C ... 5'	4
<i>Nocardia otitidis-caviarum</i>	<i>NorI</i>	5' ... G C   G G C C G C ... 3' 3' ... C G C C G   G C G ... 5'	6

\*,\* Notes:

1. Enzyme produces blunt ends.
2. The single strand is the 5' strand.
3. The single strand is the 3' strand.
4. The base pair N can be any purine or pyrimidine pair.
5. The enzyme does not cut within the recognition sequence, but at whatever sequence lies eight nucleotides 3' to the recognition site.
6. NorI has an eight-base recognition sequence and cuts mammalian DNA very infrequently."

Fig. 20 „Some Restriction Enzymes and Their Cleavage Sequences“  
(from: WATSON, 1992, p. 65)

Living nature, as a producing and self-reproducing entity, encompasses millions of different biological species. These have developed an equally diverse range of communication types and distinctly differ in the constellation of their genetic texts and in both their exter-

nal appearance and overall habitus. All of them are subject to the two central rules of reproduction and food uptake; in each individual, rule-governed interaction they underscore the variation of languages in nature. Common to all of them, however, is the language of protein individuals, especially the nucleic acid language: intraorganismic communication - more so in the intracellular than in the intercellular realm - makes use of a metalanguage that combines every conceivable language. Without its functionality, communication between discrete organisms would be impossible because no individual organism would be viable as a sign-using interorganismic species. Regardless of how different the individuals of a biological species are, the affect on intraorganismic communication disturbances is always negative. Communication disturbances that affect all the members of a population will jeopardize the survival of the population as a whole.

#### 5.4. Recombination of genetic texts through jumping genes and retroviruses

The investigation of so-called control sequences, i.e., genetic sequences of nucleotides that regulate gene expression, revealed that certain sequence elements are apparently variably inserted into and removed from genomes. These sequence elements were termed transposable elements („jumping“ genes) or transposons (WATSON, 1992). Subsequent research revealed that these sequence elements do not actually jump; rather, copies of these sequences are produced, and these are inserted into or excised from other sites in the genome by means of specific enzymes. A parent transposon is cleaved in a staggered manner and copied to form daughter transposons which are then inserted into other sections of the genome by means of similar restriction enzymes. The nucleases that function here as restriction enzymes and that cleave the genetic text such that the daughter transposon can be inserted are coded by the protein-coding genes of the transposon *itself*. The grammatic rule governing the insertion into the genetic text has been discovered:

In the affected chromosome, the sequences flanking the transposon are normally identical. The grammatic rules of complementary base pairs allow us to conclude that the host chromosome is cleaved in a staggered manner. The transposon itself is coded by so-called insertion sequences; they also include the gene that codes for the transposase, i.e., the enzyme responsible for the position change of the daughter transposons (ibid.).

This enzyme is flanked on each side by inverted repeats (IR) which are 24 base pairs long. The transposon itself consists of the identical insertion sequences, sandwiching a gene that is either inserted or removed. „Jumping“ genes add an element of variability to the genetic text because they can variably constitute the expression or repression of specific genes (ibid.).

The enzyme's staggered cleaving technique and the inverted repeats (IR), with the gene in between, are precisely the identification feature that seems to orient the retroviral insertion technique.

Let us recall the strategy of a retrovirus: once such an RNA tumor virus has infected a particular cell of the organism, DNA copies of the RNA original is synthesized by the reverse transcriptase contained within that cell. The viral DNA then migrates into the

nucleus of the host cell, where it is inserted into the chromosome by specific enzymes. During the production and insertion of viral DNA, certain terminal sequences are multiplied. They are distinguished by their 5' and 3' ends. This provides both ends of the viral DNA sequence with identically long terminal repeats (LTR). They are several hundred base pairs long. The base pairs of the viral DNA that directly adjoin the host DNA are termed tandem duplicates. The transposons have the very same features (in this case inverted repeats) (ibid.).

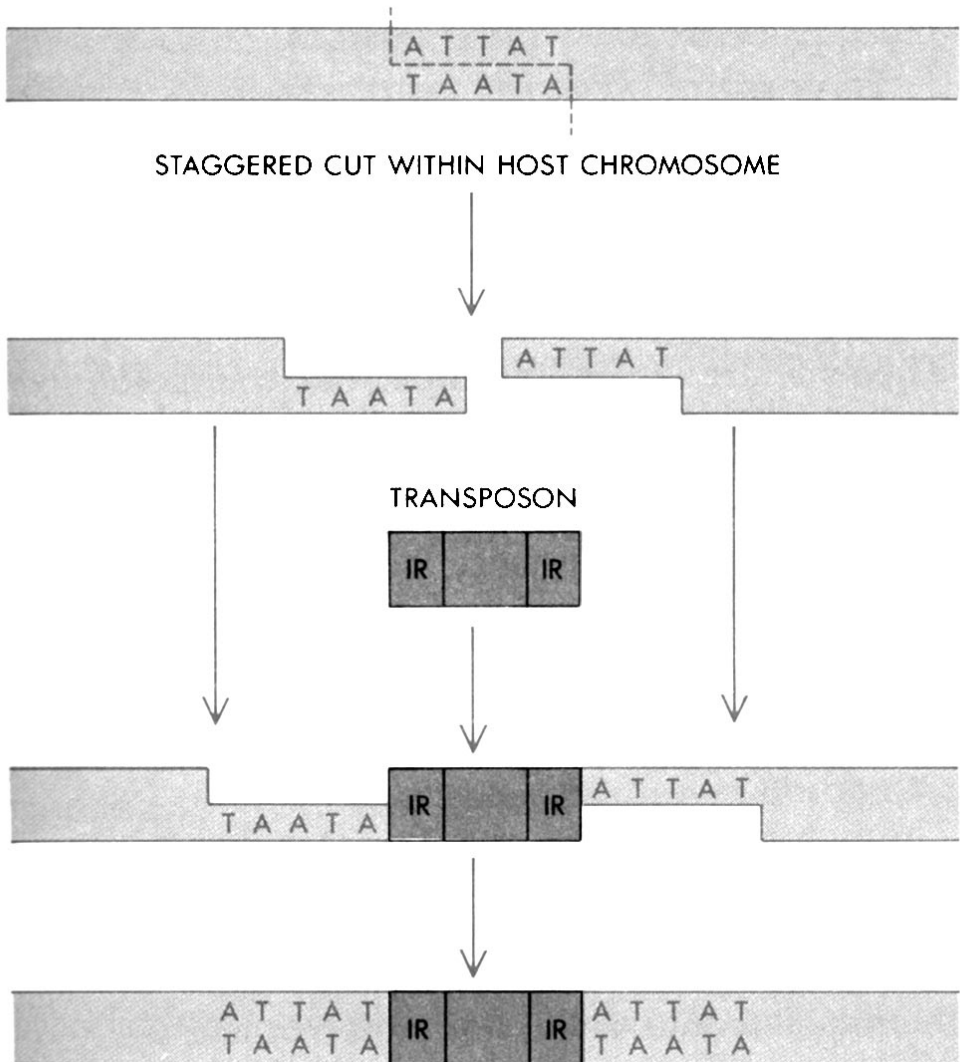


Fig. 21 „A model for transposon insertion. The host chromosome sequences flanking the transposon are usually found to be identical, implying that a staggered cut is involved in the insertion of the transposable element.“ (from: WATSON, 1983, p.141)

Both ends of the transposons and of the retroviral DNA bear identical sequences; they function as „recognition“ sequences (WATSON, 1992; I prefer the term identification sequences) for those transposase enzymes that cleave the host chromosome and insert either transposable control sequences or retroviral DNA. This precise process enables not only control genes (for example growth-regulating genes in the chromosome) but also the retroviral DNA to change their position in the chromosome or be variously inserted or removed (as copies of the original).

We are dealing here with a rule that governs the constitution of variable genetic text regions, a rule that was possibly learned or adopted by the retroviruses and subsequently used to promote their own reproduction. Uncontrolled cell growth may thus reflect the conscription of a host cell's genetic text through retroviral DNA in the region of those genes that code as growth regulation sequences; as a consequence, these become subject to the rules of retroviral DNA reproduction (ibid.).

#### 5.5. Electromagnetic fields as the communication medium of intercellular communication?

Up until now, we have referred only to chemical messenger substances and neurotransmitters as the signs used in intraorganismic communication. The possibility that other forms of sign-mediated communication and therefore other communication *media* exist alongside the chemical ones was indicated by an experiment conducted back in 1975 (POPP, 1976, p. 58-62):

In the laboratory, a cell culture was split into two by a normal pane of glass. One side of the divided culture was infected by a virus. In the course of the experiment, the second half remained entirely unaffected, even after a lengthier period. In the subsequent experimental setup, another cell culture was divided into two halves, this time with a plate of quartz glass. One half was again infected with a virus. After a certain period, the second half, which was separated from the infected half by the quartz divider, also began to grow uncontrollably.

The quartz glass is equally impenetrable for chemical substances and for viruses. How then does the viral information pass through the quartz glass and subjugate the growth regulation gene of the originally uninfected cell culture to the viral growth strategy?

Some sort of communication medium that is absorbed by normal glass yet can penetrate quartz glass must be involved. To the best of our knowledge, it could be UV radiation, which in this case would have to come from the cell itself. Within the cell it might be present in the form of infrared radiation, which would then be modulated into UV radiation. The presence of such radiation has been confirmed; this goes hand in hand with the recognition that every cell produces a weak electromagnetic field that is highly correlated with the energetic status of that cell. This radiation clearly plays a role in communication, specifically in regulating growth. The fact that the human body loses 10 million cells per second lends credence to such a scenario. This cell loss must be correctly compensated

for at the very site of the loss, i.e., in every part of the body. This requires that living cells in the various tissues rapidly and precisely detect their dead or dying neighbors and that this information be conveyed within the organism as a whole. *The detection of a dying cell by an adjoining cell must be more rapid than cell death itself.* Otherwise those cells responsible for compensating cell loss would be at constant risk of already being dead themselves. The communication speed necessary to compensate cell death in a coordinated manner exceeds the capacity of chemical messengers and must therefore lie in the electromagnetic realm.

The experiment shows that virus-infected cells can transmit the specific viral information to the uninfected cells through the quartz glass by non-chemical means. Or should we assume that the virally induced change in the genetic text (e.g., in the gene coding for growth) alters the entire energy field of a cell so systematically that its altered emission can also deform the energy field of the initially uninfected neighboring cell through the quartz, transforming the growth gene into an oncogene (cancer gene)? In the first case the viral information would assault the growth-regulating gene directly via an electromagnetically modulated path, while in the second case the attack would be indirect (ibid.).

This question cannot be answered definitively based on currently available research results. It is clear, however, that the uninfected cells, which were separated from the infected ones by quartz glass, showed abnormal gene expression. It is also clear that cells which heed the sign-mediated communication of the viruses can be classified as infected, i.e., subordinated to the reproduction of viral information (ibid.).

Disturbances in the communication medium of electromagnetic fields and radiation would be expected when carcinogenic chemicals distort normal communication processes, for example through partial absorption (e.g., of polycyclic hydrocarbons). The same holds true for radiation from outside the organism or when viruses so severely impair infected cells that distorted signals to the adjoining cell induce the latter to react in the same manner as the infected cell (ibid.).

Although this aspect of intracellular communication remains to be investigated in detail, it is mentioned here as a potentially important element in demonstrating intercellular communication and communication disturbances.

## 5.6. Self-defense strategies of organisms: The immune response

The organism as a whole is not defenseless against intraorganismic communication disturbance. It has numerous defense strategies at its disposal, some of which are innate, others which are acquired over the course of the organism's life. In humans these include the skin, which is impenetrable for both bacteria and viruses, as well as sebum and tears, which flush out foreign particles (much like the resin of trees), or gastric juices, which simply dissolve most foreign matter. Only after these innate protective functions are breached by infectious bacteria or viruses does a highly specific defense strategy termed the immune response kick in. It is the result of a complex behavioral coordination between cells that identify and those that destroy invaders, a coordination which can be mediated by cells that trigger alarm signals via chemical messenger substances.

In all, three types of cells mount complementary efforts to organize the immune response and to optimally coordinate behavior via very specific, sign-mediated communication processes. The quality of this coordinated behavior determines the success or failure of the overall immune response, i.e., whether the organism as a whole can defend itself against foreign substances. In the long run, any self-defense strategy that is not permanent means certain death by infection.

The cells responsible for organizing the immune response circulate throughout the body in search of foreign substances. They are capable of identifying a virtually unlimited number of such substances and can distinguish them from those occurring naturally in the body. The so-called antibodies are the best known identification proteins. Millions of these proteins (immunoglobins), which constitute themselves from a relatively limited number of gene sections, are known to exist. *Nevertheless, the virtually unlimited variability of these very restricted sequences gives rise to a wide range of antibodies. The cleaving and rejoining of genetic sequences is responsible for the pragmatic variance of the immune response as a sign-mediated communication process and guarantees its effectiveness.* Most of the diversity in antibodies stems from ever-new combinations and recombinations of DNA sections (TONEGAWA, 1985).

The surface of certain immune cells bears T cell receptors, i.e., identification proteins, that interact only with those cells that bear both endogenous and foreign identification characters. This specific feature enables immune cells with T cell receptors to act against virus infections in a very specific manner, because the surface of virally infected cells bears both natural and foreign identification characteristics.

The most important cells of the immune system are lymphocytes, white blood corpuscles formed from the stem cells of the bone marrow. In mammals, one class of lymphocytes, the B cells, mature in the bone marrow, while the second class, the T cells, mature in the thymus gland. Both cells are similar in appearance and size, yet play different roles in coordinating the behavior of the immune response (ibid.).

B lymphocytes produce antibodies. During its maturation in the bone marrow, each B cell is programmed to produce antibodies that can identify a particular antigen (foreign protein), even if this may have a variety of molecular configurations. As a rule, the descendents of such B cells retain this identification competence in slightly modified variations. The antibodies produced by the B cell remain attached to the outer surface of the cell membrane as receptor molecules. The docking of an antigen onto such an antibody is the signal for the cell to produce precisely those antibodies specialized in recognizing the triggering antigen. Because individual viruses or bacteria bear numerous identification features, a variety of different antibodies must be produced (ibid.).

After successfully warding off an infection, such specialized B lymphocytes retain their specialized defense competence; they remain in the body and form the so-called „immunological memory“, i.e., in the event of re-infection by the same antigen they ensure a rapid immune response (this conserves energy when one juxtaposes host life span and potential number of infections). The cells with such identification competence



have been termed „memory cells“. Since the rule behind this sign-mediated communication is known, the process can be strategically supported: vaccinations are designed to introduce small amounts of antigens from certain diseases into the body (albeit antigens whose virulence has largely been neutralized, yet which still retain the characteristics of the natural strains). This preventive measure induces the production of the above-mentioned antibody memory cells, ensuring a more rapid immune response of the body in the event of infection. The specialized B lymphocytes do more than merely form the immunological memory. Some of them differentiate definitively and completely, i.e., they no longer divide and do nothing but produce antibodies. At this stage they are termed plasma cells; they live for only a few days and produce large amounts of immunoglobulins, which they release to the body (ibid.).

The antibody molecules do not destroy the foreign invaders directly. Rather, by docking onto an antigen they mark the target for numerous other cells and proteins that contribute to the immune response. The macrophages, as feeding cells, devour and digest such foreign protein particles (ibid.).

The distinguishing feature of antibodies is their structure. It consists of four polypeptide chains, more specifically of two equal, low-weight chains with ca. 220 amino acids and two equal, high-weight chains with a length of 330-440 amino acids. These are combined to form a Y-shaped structure. Each polypeptide bears variable and invariable regions. Antibodies that belong to a particular type all have the same invariable regions, while the variable regions differ in each individual B cell reproductive clone. Each variable region bears three short sections in which the amino acids are particularly variable. At the end of both arms of the Y, these highly variable sections combine to form pouch-like depressions that serve as bonding sites for antigens. Depending on the shape of the pouch-like depressions, i.e., on which chemical groups line their walls, the antibody molecule is competent to interact with the specific antigene regions that bind to precisely those sites (ibid.).

The interaction competence of an antibody with an antigen is therefore determined by the amino acid sequence in the hypervariable regions. The overall functionality of an antibody is given by the specific composition of the invariable versus variable sections. Together, light and heavy polypeptide chains can produce several million different antigen-binding sites. As in the case of heavy chains, each light chain is coded by three different sections on the immunoglobulin DNA.

We are dealing here with nucleotide sequences of various lengths that code for the invariable regions, the variable regions, and the region joining the two. Furthermore, those genes that code for the variable regions of the heavy chains are provided with an additional sequence section. This yields a total of four coding sequence regions, the C(constant), the V(variable), the J(joining), and the D(diversity) regions.

An immunoglobulin chain that is suitable for the immune response therefore consists of an appropriately recombined DNA sequence. It is constituted in two steps. First, the V and J regions are combined in the DNA of the light chain, while the V, D, and J regions



are combined in the DNA of the heavy chain. In a subsequent step, the combined sequence regions are transcribed onto an uninterrupted RNA molecule. It incorporates the V and J regions of the light chain, the V, D, and J regions of the heavy chain, the C gene, as well as the intron (the term applied to the non-coding sequences between the coding ones: they serve like intervals between words or sentences). At this stage, the intron and a number of superfluous J elements are excised, and the mRNA is channeled out of the nucleus and translated into a protein (ibid.).

The initial step, in which DNA (not RNA) recombination takes place first, is thought to be limited *solely* to the sign-mediated communication process of the immune response. A group of highly specialized enzyme proteins fulfils the task of combining the sequence blocks of the V, D, and J regions, which lie some distance apart on the DNA, and to remove the intervening DNA. Only very few such enzymes have actually been found, although the corresponding DNA sequences that function as identification sequences for these enzymes have been localized: a characteristic sequence arrangement is located directly after every V gene of the light chain. It consists of (I) a group of 7 nucleotides (heptamere) followed by (II) a spacer and (III) a group of nine nucleotides (nonamer). An arrangement that is complementary to the above-mentioned sequence is positioned directly in front of the J sequence. This sequence region can serve as an identification sequence for enzymes that split the double helix, make it available for recombination, and then rejoin it (ibid.).

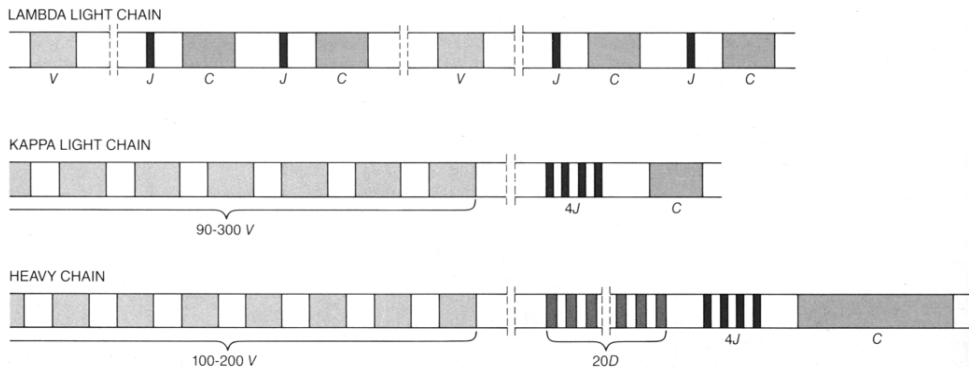
Similar identification sequences for such recombination enzymes have been found on the heavy chains.

On the other hand, the enzymes responsible for recombining the V, D, and J sequences are somewhat imprecise in that additional base pairs are inserted from time to time, leading to *slightly* different amino acid sequences from one immunoglobulin to the next. Therefore, each immunoglobulin bears somewhat different antigen binding sites. Beyond this recombinatory constitution of sequences, recombination is characterized by numerous spontaneous changes that follow no specific rules; this further significantly increases the diversity of antibodies. Such spontaneous changes are essential to maintain the necessary range of antibodies. In fact, they are so important that it is fair to assume that spontaneous changes are the rule rather than the exception (ibid.).

There are therefore two reasons for the diversity of antibodies: The first is rooted in sequence combinations, which proceed according to strict grammatic rules. The second involves spontaneous changes of individual nucleotide bases of a sequence which, as research has shown, can significantly improve the fine tuning of the immune response. Together, both increase the total number of potential antibody variations to over a billion (ibid.).

The B cells and their antibodies, however, represent only one half of the class of cells that contribute substantially to the immune response. The other half is formed by the so-called T cells which, despite their similar appearance, consist of three types that display differ-

ent behavior. The (a) killer cells kill their target cells directly by inflicting a lethal injury or using toxins; the (b) helper cells identify antigens as such and stimulate various other cells involved in the immune response; and the (c) suppressor cells weaken the activity of these cells, for example after a successfully completed immune response (their role is therefore antagonistic to that of the helper cells). The helper cells play an equally decisive role in identifying antigens as do the suppressor cells, which are responsible for neutralizing the B and T cells after the successful immune response (as these would otherwise attack the body's own tissue) (ibid.).



„GENES FOR ANTIBODIES are broken up into small segments scattered widely throughout the genome. Two kinds of light chain appear in mammalian antibody molecules. For the lamda light chain of the mouse there are two V genes that encode most of the variable region and four C genes for the constant region. Upstream of each C gene is a short segment of DNA designated J, for joining, which specifies the remainder of the variable region. Either V gene can be combined with any pair of J and C genes. For the kappa light chain there are a few hundred V segments, four J segments and a single C gene. The heavy-chain genes are similar, except that the DNA for the variable region is further subdivided: in addition to the V and J segments there are about 20 D (for diversity) segments. Each set of genes is on a different chromosome. The T-cell-receptor genes are organized much as the heavy-chain genes are.“

Fig. 22 4 coding sequence regions (from: TONEGAWA, 1985, p. 108)

The structure of the T cells consists of two chains of amino acids, the so-called alpha and beta chains, along with a third chain, the gamma chain, which also plays a role in identifying antigens.

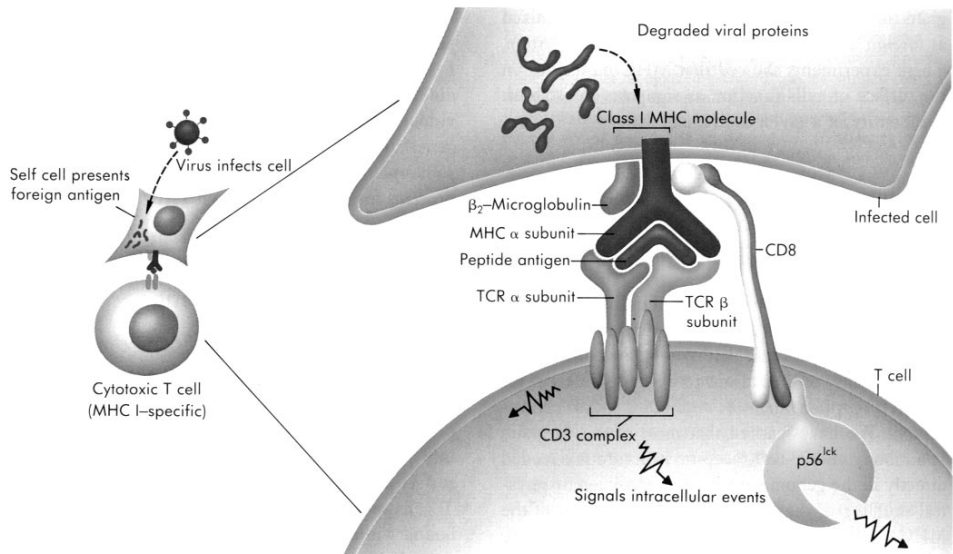
The sequence combination of the T cells is quite similar to that of the immunoglobulins, and the recombination techniques are governed by very similar or the same enzyme complexes.

#### 5.6.1. The identification of 'self' and 'non-self'

While B cells interact with antigens on their own, the T cells only become active when the antigen attaches to the surface of a cell which *also* bears features of the body's own tissue. Specific proteins, which are coded by a large number of genes termed the major histo-

compatibility complex (MHC), are responsible for this. When the tissue of a donor is transplanted to the recipient, the transplanted tissue is often rejected because the donor's MHC proteins trigger an immune response (ibid.).

Each and every organism, with the exception of identical twins, possesses a different group of MHC proteins. While antibodies and T cell receptors vary from cell to cell, the MHC proteins differ only from one organism to the other.



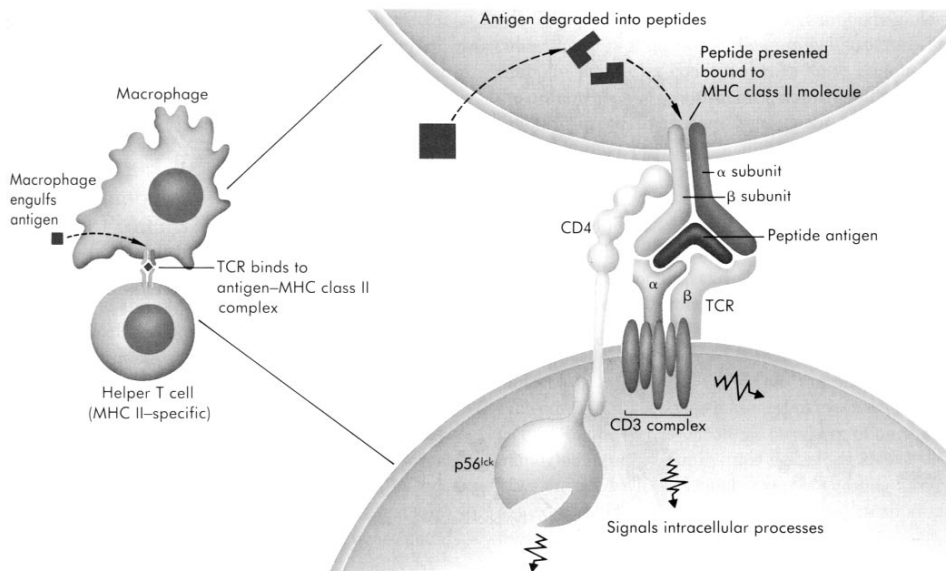
„Recognition of a virally infected cell by an MHC class I-specific cytotoxic T cell. Antigenic peptides derived from viral proteins appear on the surface of the infected cell in a complex with a class I MHC molecule. The class I molecule is made up of two polypeptides, the polymorphic  $\alpha$  chain and  $\beta_2$ -microglobulin, an invariant protein. The class I MHC-peptide complex is specifically recognized by a T-cell receptor (TCR), which is itself composed of two protein chains,  $\alpha$  and  $\beta$ . Another T cell-specific surface glycoprotein, CD8, binds to nonpolymorphic regions on the class I MHC molecule. The carboxy-terminal portion of the TCR is associated with a group of transmembrane proteins called the *CD3 complex*. The carboxy-terminal portion of CD8 is associated with an intracellular protein tyrosine kinase, p56<sup>lck</sup>. Formation of the TCR-antigen-MHC-CD8 complex relays signals to the interior of the cell and activates p56<sup>lck</sup> and proteins associated with CD3. In the case of cytotoxic T cells, the cells respond to these signals by synthesizing and secreting enzymes that bore holes into the infected cell.“

Fig. 23 Identification process by MHC class I proteins  
(from: WATSON, 1992, p. 306)

Two classes of MHC proteins have been discovered to date. T cells identify antigens when an antigen occurs *together* with an MHC protein on the surface of a cell. This is the only combination in which they are useful as an identification signal for T cells. Killer cells (cytotoxic cells) react to a combination of antigen and class 1 MHC proteins; T cells, on the other hand, react to a combination of antigens and class 2 MHC proteins. This combination rule is a highly specific identification signal for immune cells. They do not

react exclusively to foreign substances; if this were the case, then viruses would be able to reproduce unhindered once they have infected a cell, i.e., once they are shielded by one of the body's own cells.

Along with its own proteins, however, the surface of such an infected cell also bears surface proteins characteristic of the virus. Precisely this combination is the signal that induces killer cells, for example, to kill the entire infected cell along with its viruses before it can propagate any further (ibid.).



„Recognition of processed antigen presented on a macrophage by an MHC class II-specific helper T cell. Macrophages engulf an antigen and degrade it to small peptides. The peptides reappear on the cell surface in complex with class II MHC proteins, which are composed of two polymorphic chains termed  $\alpha$  and  $\beta$ . Class I-specific T cells express CD4 instead of the CD8 protein present on class I-specific T cells. The class II MHC-peptide complex is bound by the TCR and the CD4 protein present on helper T cells. Upon formation of the complex, the helper T cell synthesizes and secretes lymphokines that cause antibody-producing B cells to divide and differentiate into plasma cells, which secrete antibodies. Helper cell activation occurs through the CD3 complex and by turning on the p56<sup>lck</sup> protein tyrosine kinase.“

Fig. 24 Identification process by MHC class II proteins (from: WATSON, 1992, p. 307)

The class 2 MHC proteins on B lymphocytes and macrophages (killer cells) are the cue for T helper cells to signal alarm, i.e., to trigger the immune response, using specific messenger substances. Particularly in the case of virus infections, the specific interaction of the T cells with infected cells determines which combination of antigen and 'self' tissue surface triggers identification. This interaction determines success or failure of the immune response. A successful immune response will be organized by numerous communicating, associated, and behaviorally coordinated cells. Their successful communica-

tion is capable of repelling invaders that trigger intraorganismic communication disturbances, i.e., of repairing potential and actual communication disturbances by differentiating between foreign features and those of the body itself (ibid.).

#### 5.6.2. The acquisition of interaction competence by thymus cells (T cells)

The T cells' ability to interact with the body's own tissue in a rule-governed manner is vital, since virus-infected cells are not exogenous intruders but endogenous, strategically conscripted cells. T cells can either attack immediately upon identifying a virally infected cell, with the goal of destroying the target, or they can send messenger substances to those cells involved in the immune response (ibid.).

The body produces enormous numbers of T cells, in humans approximately 10 billion per day. Such quantities are justified by the great diversity of potential invaders. Initially, this mass of T cells remains inactive. Since they all have somewhat different receptors, no single, clear-cut rule would be capable of orienting their behavior, i.e., they would identify and attack most endogenous MHC proteins as alien (ibid.).

In the maturation phase of the T cells, which takes place in the thymus gland, the immature T cells are confronted with MHC proteins. This supply of different T cells is sorted into types that fit well with MHC proteins and types with suboptimal or no fit. The latter are destroyed. This initial selection process is followed by a second one for the remaining T cells. Among their many tasks, MHC proteins regulate the cells' uptake and release of metabolic products. In the thymus, the preselected T cells are confronted with MHC proteins that channel normal metabolic products out of the cell. Those T cells that react to normal waste products with „alarm“ (i.e., by releasing messenger substances that induce other cells to participate in the immune response), or that attack directly, are themselves destroyed. After all, their future task as mature T cells is not only to identify the body's own MHC proteins as such, but to recognize virus-infected cells as targets based on their MHC proteins (ibid.).

The identification features in this case are abnormal secretions of the virally infected cell; this may involve only a single foreign protein fragment based on the fact that the infected cell is producing viral components and is thus releasing modified metabolic products.

The interaction competence of the T cells is the result of rule conditioning during the maturation phase:

(a) only those cells that are compatible with the body's own MHC proteins can reproduce and mature unhindered in the thymus. The immature T cells must react to MHC proteins *without* foreign antigen. Once mature, they lose this ability and react *only* to the combination of antigen and endogenous MHC protein.

(b) Only those mature T cells are released into the body's circulatory system that do not react to the normal excretory products of MHC proteins, but that sound alarm or immediately attack upon encountering abnormal characteristics in excretory products (ibid.)

The rules behind this specific behavior are themselves subject to rule-governed interactions of the intracellular type, i.e., during the expression of the genes coding for T cells: immature T cells initially express the alpha gene only weakly, the beta and gamma gene more strongly. Their proteins are subsequently produced in greater numbers. Immature T cells bear receptors composed largely of gamma and beta chains (of amino acids) and that react exclusively to MHC proteins. The selected T cells can react in a rule-governed manner and are not destroyed, rather undergo further differentiation because they fit to MHC proteins; they subsequently suppress the expression of the gamma gene and, instead, express the alpha gene. The mature cells thus have alpha-beta receptors. This considerably reduces but does not entirely eliminate the reactivity with MHC proteins since the beta chain was, after all, present in the first selection process (ibid.).

T cells first react to the combination of antigen and the body's MHC proteins in the alpha-beta chain combination. This sheds light on why, in their first conditioning phase, T cells react exclusively to MHC proteins, while in the second phase this exclusive reactivity is lost and becomes differentiated into a combinational reactivity. Only the mature T cells *optimize* the immune response capability of the overall organism. (Red blood cells underlie a similar differentiation rule in converting the form they have within the unborn organism to that they take on after birth; ibid.).

The above response to disturbances of or threats to intraorganismic communication - in the form of the rule-governed interactions by cells responsible for the immune response - can itself be subject to disturbance; this can lead to disorders that are no less dangerous than those for which the immune response was developed in the first place. Thus, minor irregularities in the selection of suitable T cells in the first conditioning phase can lead to mature T cells that attack, destroy, or damage the body's own tissue. *Juvenile diabetes, rheumatoid arthritis, multiple sclerosis* and, above all, the ever-increasing incidence of allergies, stem from abnormal interactions between the cells that organize the immune response and the body's own tissue. The immune cells behave abnormally because they were already subject to abnormal conditions while gaining interaction competence. This can be genetically based but, as in the case of most allergies, can also be induced by environmental factors.

### 5.6.3. Viral camouflage strategies

The surface of virally infected cells typically bears specific protein molecules that are foreign and therefore termed antigens. They serve as identification features for antibodies and as a signal for defensive action known as the immune response.

Cells that have been conscripted by viruses in this manner develop strategies to camouflage themselves from cells that organize the immune response; these strategies fully conform with the aims of the infecting viruses:

- (a) a tumor consisting of few cells can remain undetected until it has reached a size where the identification mechanism of immune cells engages too late and the immune response is no longer capable of repairing the communication disturbance.

- (b) When attacked by immune cells, certain cancer cells are able to cast off their antigens or to shift them to the inside. Such cancer cells lack identifiable external features, i.e., they are no longer recognizable as targets by the immune cells.
- (c) Aggregations of cancerous cells can inundate the body with antigens. In doing so, they block so many immune cells that the cancer cells themselves can no longer be identified. This strategy has been termed „antigen blinding“ (ibid.).

These viral strategies, undertaken by cells subordinated to viral reproductive strategies, point to the potential existence of tumor cells that do without antigens altogether and thus principally circumvent detection by immune cells .

#### 5.6.4. Communication disturbances involving damage to the genetic text and their repair by specific enzyme proteins

The rule-governed interactions between cells and cell associations, as well as those between the components of a cell, guarantee a viable overall organism that is itself in a position to communicate on the inter- and metaorganismic level. Inter- and intracellular, sign-mediated communication processes are predetermined by the participating proteins and therefore by the DNA coding these proteins. Thus, all the essential conditions governing successful intraorganismic communication are fixed in the form of the nucleic acid language.

At the same time, the genetic text of a cell or cell association can be damaged by UV radiation, radioactivity, or chemicals. Such damage may prevent the expression of a gene necessary for a particular metabolic process, blocking its translation into a specific amino acid chain that would then yield the required enzyme protein. Processes such as DNA replication, the transcription of the DNA into RNA, and the subsequent translation into the amino acid sequence can no longer be executed according to the rules.

On the other hand, the genetic text of the cells within an organism harbors specific genes capable of repairing such damage. It does this by coding for enzymes that operate via two different, sign-mediated communication processes. Although the modalities of the rules governing these communication processes differ, their core rule remains the same: repair damage to the genetic text. Two key communication processes are involved in damage repair. The first is responsible for remedying minor damage and is permanently operative (HOWARD & FLANDERS, 1981). The second kicks in when the first becomes overloaded, i.e., when major damage needs to be repaired. Both strategies utilize the grammatic rules of complementary base pairs.

##### 5.6.4.1. Excision repair

Both strands of the double helix are typically held together by hydrogen bonds between the DNA bases. UV radiation, for example, can prompt 2 pyrimidines (thymine and cytosine) on one of the chains to form a bond. This shifts the two pyrimidines from their original position within the overall structure, breaking the hydrogen bonds between the com-



plementary bases on the other strand. The entire backbone of the DNA bends and the directly adjoining base pairs also lose their complementary bonds. If an enzyme involved in transcription were to come along at this time, it would have to interrupt the process at this site. The inevitable result would be a communication disturbance because the protein which was to be expressed could not be produced (ibid.).

Excision repair involves the removal of the damaged bases. Three enzymes are involved, each of which is coded by a gene, whereby a fourth enzyme also plays a role. The enzyme proteins *uvrA*, *uvrB*, and *uvrC* are responsible for excising the damaged sequence section. DNA polymerase I docks at this gap and adds new nucleotides according to the law of complementary base pairs. In a second step, the damaged sequence detaches entirely and completes the whole damaged sequence section using new nucleotides, whereby the original gap is shifted in the transcription direction by the length of the damaged sequence. The final gap in the reconstituted sequence chain is sealed by the enzyme DNA ligase. The original meaning of the damaged DNA is restored; it can now be read in the normal manner, be transcribed, and be translated into protein-constituting amino acid chains (ibid.).

#### 5.6.4.2. Postreplication repair

During DNA replication both parent strands unravel to form individual DNA parent strands, each of which normally gives rise to a new daughter strand. Two pyrimidines (thymine and cytosine) attached to one another in the parent strands can be corrected by the above-described excision repair. Should such a pyrimidine bond remain on a parent strand *after* the replication, then no complementary daughter strand can be produced in the immediate vicinity. The result is a so-called postreplicative gap. A delimited area of single-stranded DNA, which also bears the pyrimidine bond, lies opposite this gap.

A *recA* protein attaches at precisely this point and brings this single-stranded section next to the DNA region on the other, undamaged daughter double strand that has been formed in the meantime. There, both strands pair in a complementary manner. Thereafter, an enzyme cleaves the parent strand of the intact double structure. The *recA* protein guides the free end of the parent strand into the original gap, which thus becomes filled. The upper double strand is repaired by the DNA polymerase, whereby the *recA* protein shifts further to the right (in the reading direction), along with the crossing-over site of both strands (ibid.).

The original pyrimidine bond thus faces a correct base pair rather than the gap in the complementary strand. As soon as the *recA* protein has fulfilled its function, the pyrimidine bond can be eliminated by excision repair. A second enzyme removes the cross-over between the strands. The result is two intact double strands (ibid.).

Highly specific genes code for the enzyme proteins involved in this process. These genes are not expressed as long as the DNA remains undamaged. A transcription repressor blocks the operators of these genes engaged. In the event of more serious damage, the



recA protein binds to the single-stranded DNA opposite the gap. This event activates a protein-cleaving process which splits the repressor protein and allows all the previously repressed genes to be read, yielding repair proteins. This concurrently gives rise to numerous repressor proteins which, however, are immediately split by the recA protein that was activated by the single-stranded DNA. Once the repair has been completed, no additional recA protein is activated, and the repressor protein is no longer split. This allows it to again suppress the expression of the repair enzymes (*ibid.*).

Specific, rule-governed interactions enable components of this damaged cell to repair minor and major DNA damage, i.e., damage to the genetic text. Of particular interest in this respect are interactions between the genetic text sections that code for enzyme proteins, and between the enzyme proteins themselves, which not only regulate their own production but carry out all the individual steps.

By means of highly specific, sign-mediated communication processes, this variety of specific protein individuals gives rise to strategies designed to be successfully repair intraorganismic communication disturbances using a series of communication processes.



# PART TWO



## **6. Explanatory deficits in Manfred Eigen's concept of language and communication. From the logic of „molecular syntax“ to molecular pragmatism.**

Key biological processes could not be represented as sign-mediated communication processes that require rule-governed linguistic sign use by real sign users without the results of research in the fields of biochemistry and molecular biology. Superficially, the philosophical perspective of a „language of nature“ differs only imperceptibly from the scientific representation of such processes as rule-governed, sign-mediated interactions. The terms „Genetic code“, „nucleic acid language“, recognition sequences“, „translation process“, amino acid language“, „immune responses“, „intercellular communication“, etc. owe their status as irreplaceable core concepts in molecular biology not to an introduction into biochemistry and molecular biology by linguists, communication experts, or language philosophers. Rather, they were independently coined by molecular biologists to explain observed phenomena and were clearly invoked due to the strong analogy to processes of human communication.

Here, I attempt to show that the use of these key concepts in biochemistry and molecular biology - when viewed under the premises envisioned by these fields - is problematic. To exemplify this problem I refer to the terms „language“ and „communication“ as used by Manfred Eigen. His research has had a substantial and lasting influence on biochemistry and molecular biology as well as on evolutionary theory. Numerous researchers in these disciplines use the language and communication concepts in the same or similar context as Manfred Eigen.

### **6.1. Manfred Eigen's use of the terms „language“ and „communication“**

#### **6.1.1. Molecular recognition processes and their significance for genetic manipulation**

In the book he coauthored with Ruthild Winkler, „Das Spiel. Naturgesetze steuern den Zufall“ (EIGEN/WINKLER. 1975)\*, Eigen refers to a language concept which clearly leans on that of information theory, particularly John v. Neumann's idea regarding a self-reproducing, intelligent automaton. For Eigen it is beyond doubt that life in the biological sense originated according to the laws of physics and chemistry; it need only be investigated with sufficient rigor under these aspects for its function and therefore its genesis to be exactly defined. *The goal of this research approach is to provide techniques with which organisms can be created artificially.* In Eigen's mind, this artificial creation of life does not involve an entirely „de novo“ creation, but rather a distinct improvement of genetic manipulation techniques.

\* In the following text, page numbers in parentheses refer to this book.

The information concept is central to Eigen's position: it best describes and explains the storage of all the structural features of an organism in the chromosomes. According to Eigen, genetic information is laid down in the form of a molecular text which, in the case of humans, has the scope of a well-stocked private library (207). In the context of genetic manipulation, this very aspect of a genetic text encompassing the entire genetic information of an organism prompts Eigen to raise the problem of how to „track down and exchange“ (ibid.) the detailed information that codes the substructures of an organism.

The identification of such substructures poses no problem for Eigen, since „the relative arrangement of the individual genes, the gene map, as well as the syntax and semantics of this molecular language are (...) largely known today“ (ibid.). The problem to be resolved is one of „engineering“ (208), i.e., the techniques required to modify the genetic text. Eigen compares this with the problems in organ transplantations, only that molecular dimensions are involved and therefore the corresponding „micro-tools“ (ibid.) are required. On the other hand, „gene transplantations“ need not be specially developed, but merely discovered, since the entire instrumentarium has already been produced by nature. This range of tools need only to be isolated from living organisms in order to be applied. The naturally produced instrumentarium to manipulate the genetic text consists of restriction enzymes, which cut the genetic text at specific sites. „The site consists of a palindrome-like sequence of six letters of the genetic text“ (208f.). Eigen specifically lays down his conception of this identification process: „The restriction enzyme recognizes a palindrome-like symmetry of the genetic text“ (210).

*This capacity to identify specific text sequences* must be strategically applied by researchers who wish to carry out genetic manipulations. The restriction enzymes should be able to carry out their identification and text cutting techniques at any site.

„Since the genetic molecular language makes use of four different ‘letters’, one can envision a multitude of cohesive recognition characters, depending on the length of the symmetrical recognition zone“ (209). The exact nature of the recognition process by the restriction enzymes is not yet known. We do know, however, that the enzymes recognize the palindrome-like sequences as cutting sites and that this is the general rule „by which genetic texts are marked for the specific recognition by the executive function of the proteins“ (209).

#### 6.1.2. Self-organization and the logic of „self-reproducing automaton“

For Eigen, the principle of self-organization lies behind the organization of biological structures. He uses the human brain and its function to exemplify this principle. The brain consists of nearly 10 billion nerve cells, each of which develops approximately 10 000 to 100 000 specific contact sites with adjoining cells. The goal is to find the basic rule governing this complexity - that principle of hierarchic organization which enables cells to differentiate such a complex network.

Among the many explanatory models, Eigen sides with that of A. Turing: Turing postulated a universal computing device (similar to the human brain) which, upon exact instruction, „calculates the value of supplied functions“ (215) and is capable of independ-

ently discovering general mathematical procedures, so-called algorithms. The computing device would store these and use them as a basis for new operations, enabling it in principle to derive any calculatable function in a series of finite calculating steps. The device therefore stores all the initially entered computational rules along with all the newly derived ones and uses both in every algorithmic operation. The most significant advance of A. Turing's approach, in Eigen's opinion, involves John v. Neumann's concept of a „self-reproducing automaton“. Eigen describes Neumann's idea, which represents a „mathematically exact“ refinement of Turing's idea, in the following manner:

„Every machine consumes free energy - it either uses electrical current or is powered by an internal combustion engine; in short, it could not function without this metabolism. A specific operational task of the v. Neumann automaton is self-reproduction. The first model from the year 1950 was entirely realistic in its conception: The machine runs back and forth in a huge spare-parts warehouse and compiles the components necessary for its own replication. Most importantly, it also reproduces its own construction plan or blueprint. Its progeny should, after all, also be equipped with the self-reproduction capability. Herein lies the possibility to perfect the v. Neumann automaton, an idea that has long been taken up by theorists: selective alteration of the program enables continuous improvement and an expanded range of application in the sense of Darwinian evolution“ (216f.).

Eigen refers the *theoretical construction* of the self-reproducing automaton *to a reality in which these automata comply with Darwin's theory of biological evolution*. According to Eigen, v. Neumann achieves this by referring to the individual components of the automaton as cells and then assigning each cell a certain number of states which largely consist of relationships to neighboring cells. This simulation of the nerve cell network in the human brain would give rise to an optimal number of interconnections; these, in turn, would enable the quantity of calculations that the Turing machine requires to solve its problems. „In principle, the automaton is capable of carrying out any desired calculation“ (217). The cellular organization of the brain follows exactly this principle and is thus comparable to a cell automaton. Brain function, and thus speaking (thinking), are brain computations analogous to those of the self-reproducing automaton.

According to Eigen, an artificially constructed organism would require features resembling those of the above automaton. With this concept, Eigen has, in fact, set his sights on explaining the origin of life, or of organisms, through self-organization. This would require:

- a) a memory large enough to develop the algorithms;
- b) a number of adaptive capabilities permitting continuous changes in and expansion of the program;
- c) an intrinsic evaluation scheme within the machine.

Such an evaluation scheme is a prerequisite for the machine to be able to select the correct development from an array of theoretically possible variants. „Nature, through the development of receptors that register environmental signals and through the development of nervous systems that can process and store such signals, has found a more eco-

onomic way“ (225) than a machine whose construction is guided by the principle that improved construction plans benefit not the present, but only future generations.

Nature's more economic approach enables learning processes that impart significance even to important changes *within one and the same organism*. The learning process of such biological systems demonstrates how the reproduction, evaluation, and modification of the elementary processes in the learning system function as *selective processes*. Eigen does recognize the importance of „evaluation“ for his automaton model of life.

„The Turing automaton must therefore have an inherent, independently active evaluation scheme that ‘motivates’ it to do certain things and refrain from doing others. It requires a pleasure and a pain center; it would have to experience fear and delight. This, at least, is how an ‘animate’ being learns“ (ibid.).

Eigen views the evaluation function as a mental phenomenon. It thus ranks as a fundamental, computable function; one need only to definitively pinpoint the corresponding centers in the human brain to differentiate and reproduce the principles behind the operating mechanisms and, in Eigen's sense, to integrate them into a self-reproducing automaton. From the cognitive standpoint at least, no difference from humans would remain.

#### 6.1.3. Levels of self-reproduction: Eigen's implicit epistemology

The incredible variety that characterizes nature could not have been the result of a uniform principle of self-organization. Rather, various levels of self-organization must be assumed. In Eigen's opinion, Popper's 3-World-Concept, which J. Eccles applied to the organization of brain performance, is best suited for such a differentiation.

Accordingly, the world is divided into *World 1* - the objects - to which our questions pertain. This encompasses the energy of the cosmos, the structure and actions of all organisms and all human brains, but also includes the objects artificially created by humans along with material substrates of human creativity (works of art), tools, machines, books, etc.

*World 2* contains purely subjective knowledge, the experience of perception, thought, emotions, remembrances, dreams, creative imagination, i.e., the imaginative faculty. This world of the subjective is distinct from the world of objects and from *World 3*.

*World 3* harbors knowledge in the objective sense - the cultural heritage recorded on physical media and covering the fields of philosophy, theology, natural science, history, literature, art and technology, yet also including the theoretical systems of scientific problems and critical arguments.

Thus, Eigen envisions a world whose materiality can be found in *World 1* (including the materiality of the human beings that devised this system). His perceptive experience of this concept and the existence of the thinker as subjective „self-awareness“ corresponds



to World 2. Finally, World 3 encompasses that which the thinker thinks, as an intellectual substrate (insofar as it has been recorded in a book or other medium).

Eigen considers this interpretation model of the world to accurately reflect reality - a reality from which the rules governing the self-organization at the various levels (Worlds 1,2,3) should be able to be extracted.

„Organisms are formed from disordered, unorganized matter. This requires the development of a molecular language with which information can be ordered and transferred. This, in turn, presupposes a genetic memory enabling a program as complex as that of the human bauplan to develop in a *stepwise* manner“ (287).

These comprise processes of World 1. The quality of human thought and feeling would derive from the function of neuronal stimulatory patterns of the brain, which are the material expression of subjective feelings.

„The learning process in the central nervous system of (higher) animals takes place in an analogous manner. A communication medium, an ‘inner language’ for transferring and processing the environmental impressions received by the sensory organs, is necessary here as well. These are encoded in the form of electrical stimulation patterns in the network of nerve cells. The electroencephalogram is an externally inferable (weak) echo of the uninterrupted, highly diverse communication between nerve cells“ (ibid.)

The brain, after all, is the very instance that carries out the evaluatory process that decides on the efficiency of the information-processing system: it filters the „correct“ information from a wealth of potentially important information.

„The memory localized in the network of switch contacts or synapses is responsible for a selective evaluation of incoming information. The resulting continuous modification of the memory structure, the engram, determines the makeup of the subjective experience comprising World 2“ (287f.).

In Eigen’s opinion, subjective experience, or the totality of the relationship between subject and world, is based on the continuous change of existing rules by newly developed ones; this parallels the automaton model of calculating devices that function algorithmically. (*Here, Eigen provides an implicit transcendental foundation of the constitution of subjective experience*).

Finally, World 3 is reserved for the products of the human intellect, including the development of a language which can be employed to proceed independently in the automaton-theoretical sense.

„Among all organisms, man alone has developed a language built on logical principles; it serves to transmit, exchange, and recombine the rather limited subjective experience and thoughts conveyed by the sensory organs“ (288).

This considerably expands the horizon of traditional evolutive processes: human language liberates mankind from Darwinian constraints and enables him to partake of the cumulative experience amassed during cultural development. In lower evolutionary levels, on the other hand, new combinations always only benefit the following generation, never those who gave rise to the new combination. This world of information storage in books and other documents of the human intellect, this is World 3.

The central element in the competition between self-reproducing structures is the intrinsic evaluation scheme. The essentiality of this principle is not based on the principles of self-organization alone; it is also coupled with the „conditions forced upon us“ (289) by the real, living environment.

„The evaluation scheme of mental information, together with stimulus processing controlled by a nerve center, is a product of evolution. It was initially based solely on the selection of advantageous, genetically pre-programmed behavioral patterns. The development of evaluation centers in which pain, fear, and pleasure are localized expands the latitude for the directed response to environmental stimuli of all kinds. (...). Only in humankind does the evaluation scheme of mental information attain individual independence“ (ibid.).

The self-organization levels of the 3 worlds also correspond to the evolutionary levels. It is interesting to note that cognitive processes are the result of subjective brain processes, while the relationship between subject and external world can be interpreted as an input-output system from the standpoint of information theory. This is the opinion of Eigen.

#### 6.1.4. Structures of language

Eigen's explanatory model for the self-organization of intercommunicating organisms leans distinctly on the mathematical theory of communication - the information theory. He repeatedly presents both molecular and human language as a reflection of one reality and deduces the function of language from the material conditions of information-processing systems.

„The existence of `language' is equally important for the material self-organization of organisms, for human communication, and for the evolution of ideas. A prerequisite for the development of a language is an unambiguous symbol assignment. In the molecular language it involves defined physico-chemical interactions; in communication between humans it is based on phoneme allocation and its graphic fixation. The allocation of meaning to the symbol combinations as well as their mutual relationships stem from an evolutionary process based on functional evaluation. According to Chomsky, the inherent structure of all languages exhibits common features which reflect a functional logic based on the mode of operation of the central nervous system; this parallels the molecular mechanisms which gave rise to the genetic language“ (291).

Language thus becomes the product of language-producing organs. These organs are structured according to the principles of self-organization and form a functional logic of the network hierarchy of brain cells. Their logic, in turn, structures the language. The allocation of meaning to the symbol combinations, i.e., the sense of a sentence, arises

from evaluation criteria of a functional nature, that is, it develops from an agreement reached in the course of intersubjective information exchange; depending on the symbol arrangement, this agreement could have taken on a completely different form.

Language is a symbol arrangement formed according to physiological criteria, to which meaning is then attributed. It **clearly** mirrors - and this is one of the key points in Eigen's conception of language - *reality in its syntax, which obtains its structure from the organization of the nerve cell network*. Eigen's language model aims at a quantification and formalization, while the evaluation and allocation of meaning to expressions and contemporary usage represent marginal conditions or are merely supplementary, not essential constituents of language.

#### 6.1.5. The information concept: the constitution of meaning through syntactic structures as the logic of material reality

For Eigen, the information concept is closely allied with the concept of form or gestalt. Information is, so to speak, an abstraction of gestalt or its representation using the symbols of a language. „Just as the essence of a gestalt combines concreteness *and* functionality, information also has two complementary aspects: a quantitative, numerical one and a qualitative one examining the meaning and significance of the symbol arrangement“. (292)

Eigen shows special interest in the information concept, particularly as it pertains to the quantitative aspect, i.e., what is the minimum amount of information required to enable exact identification of the symbol arrangement. This measure of information is equivalent to the amount of „yes-no-decisions“ necessary to identify all the symbols of a sequence“ (ibid.). In principle, every wholly unknown text can thus be deciphered by quantifying its symbol arrangement. The text itself is irrelevant, e.g., in the event that speakers formulated it with different intentions or as an expression of various intents. Only the actual symbol sequence is of import.

Nevertheless, Eigen recognizes a differentiation between an „absolute, quantifiable“ and a „sense-providing, semantic information aspect“ (294). The latter is responsible for the complexity of language. This complexity, however, is itself the result of the complexity of the brain (Eigen, in accordance with Bar-Hillel): *the semantic aspect is thus the result of the syntax of the network hierarchy of brain cells*.

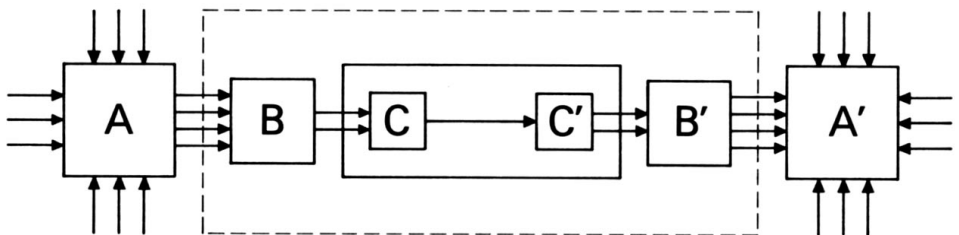


Fig. 25 (a) „Communication diagram“  
(from: EIGEN/WINKLER. Fig. 56; 1975, p. 294)

Therefore, according to Eigen, the „scheme of linguistic communication“ can be characterized by a flow diagram in which A represents a source of information of practically unlimited productivity.

This message is compiled in B. There, the „incoming environmental information“ (294) from the sensory organs - after „evaluation“ based on „programmed“ mechanisms - is combined with the experience stored in memory. Finally, the information from A, which is produced in B, is sent through C in the form of physical signals.

This user of a linguistic sign is mirrored by a receiver, who receives and evaluates this information in an analogous manner in the reversed sequence C', B', and A'. The key step in this communication model, the one involving the transfer of information, is that between C and C'. Actually, it only involves technical processes such as the coding of information to enable mechanical processing. The information theory is primarily concerned with this aspect along with the structural implications in the domain B and B'. The information theory clearly distances itself from the problems surrounding A and A' and relegates this topic to psychologists and philosophers. For Eigen, aspects such as sensory experience (= observation) and communicative experience (= comprehension) are processes which take place in the centers B' and A' as opposed to in A itself.

The question regarding the discovery of those laws governing the central nervous system of humans is, for Eigen, one of physics according to the rules of nature. Eigen remains convinced that the function of the central nervous system can, in principle, be quantified by sufficiently thorough research. It is erroneous to conclude that full quantification of brain capability is not possible since humans would simultaneously be the subject and object of such research, and that this would involve an apriori of understanding principally hindering quantification (296).

Specific powers of consciousness are, rather, interrelationships between the complementary halves of the brain, which are joined together through 200 million nerve fibers and which can transmit 4 Million Million electrical impulses per second. This quantity no doubt suffices to explain all functions.

#### 6.1.6. The allocation of symbols and meaning in the human language

The fixation of spoken language in symbols and letters also involves specific allocations. „Symbol arrangement in speech is clearly defined in every case. The reason behind the relatively large number of letters lies in the functional requirements of phonetically based everyday languages“ (298). In this case the letters of the alphabet have arisen from the abstraction of approx. 50 phonemes.

In standard computer languages it is more expedient to use only two symbols. „The mechanically relayed interrelationship between transmitter (C) and receiver (C') is based on the unambiguity of symbol allocation“ (ibid.).

If the allocation of symbols to individual sounds in speech is clear, then Eigen considers the allocation of meaning to the various symbol sequences to be equally unambiguous.

This process, however, is far from complete, as evidenced in the language of poetry, where new meaning is conferred through plays on phonemes. The combination of words into sentences is an allocation problem as well, with a sheer incalculable number of sentence combinations.

Eigen draws on Noam Chomsky's language interpretation, in which „sentence structures, if we disregard the specific peculiarities of the individual languages, exhibit parallels that indicate a universal regularity evidently originating in the organization of the human brain“ (301). Eigen (along with Chomsky) refers here to the structures of a universal syntax, a general syntax configuration „as may have underlain the acquisition of speech in evolution“ (ibid.). The intrinsic rules of Chomsky's generative grammar - the production and transformation rules - are of particular interest to Eigen. The fact that a consequent formalization of speech reveals discrepancies vis-à-vis colloquial usage is only a marginal problem for Eigen. The reality of the informal language that we normally deal with, however, is characterized by its open-endedness, whereas Eigen's formalization postulate presupposes a closed language system.

Eigen defines the relationship between language and reality such that *language reflects a formalizable reality*. The reality of objects is subject to the same laws as the materiality of our bodies and the self-organization of our brains. This brain is necessary to enable and determine both consciousness and language. Overall reality reflects a universal syntax which, in certain organisms, appears in the form of speech.

#### 6.1.7. Molecular semantics

Eigen illustrates the relationship between the linguistic symbols and the designated object (the semantic level of language) by comparing human language with the molecular language of biological organisms. He takes a cue from a quote by C. F. v. Weizsäcker („The relationship between chromosome and the developing individual appears to be such that the chromosome speaks and the individual listens“; 304). The conclusion: in the individual, the „communication channel“ from chromosome to organism is one-sided and can be more accurately described as an issuing of commands. Intermolecular communication - the „discourse“ (ibid.) between molecules - is restricted to the phenotypic level in the form of an „‘object language’ oriented toward functional optimum criteria“ (ibid.).

On this level, Eigen detects analogies between this „phenotypic, molecular functional language“ and „phonetically based spoken languages“ (ibid.).

The molecular language requires an equally „expressive alphabet“. Eigen refers here primarily to the 20 amino acids and their various functions, a protein alphabet which is to be compared with human language. The „words“ of the protein language, the amino acid sequences, represent all the executive functions within organisms such as reaction mediation, control, and transport. „As in linguistic word combinations, several - approx. four to eight - symbols combine to form a cooperative unit“ (ibid.). Eigen attaches importance to the circumstance that these functionally operating symbols in protein languages are not merely rowed linearly but are „arranged according to their respective chemical task in a

specific spatial coordination“ (ibid.). Specific chain elements between the amino acids are responsible for this spatial coordination. Enzymes themselves are word elements of the amino acid language.

„Although the active center - the actual three-dimensional word correlate of the protein language - comprises no more characters than the number of verbs in spoken language, the protein molecule must unite a total of between one to five hundred chain elements within itself in order to form such an active center. Each one of these molecules represents a particular task and one could describe the enzymes as the ‘verbs’ of the molecular language“ (305).

The detailed and functional coordination of all organizational and production processes within an organism is, according to Eigen, the result of the functionality of this language. Heredity marks the limits of this functionality.

„All words of the molecular language are combined to a meaningful text, which can be broken down into sentences. The transmission of this text from generation to generation and the information flow between the legislative and the executive branch within the cell cannot be accomplished with the protein alphabet, which is geared toward functional efficiency“ (305).

Eigen equates the legislative branch with the nucleic acid language; it is structured according to economical considerations, much as the alphabet of a computer „or some other type of mechanical information transmission“. This alphabet uses a codeword consisting of three nucleic acids for each letter of the amino acid. The allocation from codeword to letter is unambiguous; this is not true in the other direction: numerous amino acids have more than one codeword. Rather than using 2 characters as in the case of computers or telex codes, this language uses 4 characters because its construction was based not on logical criteria but on a natural process linked with the protein alphabet (ibid.). The manifold structures of biological species, their diversity and differentiation, could only have evolved through sequence combinations involving four letters; a simple pair of letters would have been insufficient. This nevertheless weakened the „‘teleonomic’ demand for a high level of economy in the transfer of genetic information and for a universal concept of the encoding enzymatic machinery“ (305 ).

#### 6.1.8. „The vector character of the speech flow from chromosome to organism“

In discussing the direction of this dialogue, Eigen refers to Arthur Kornberg and his tenet „DNA-RNA-PROTEIN-everything else“ (306). According to the above 3-World-Concept and Eigen’s 3-World-Language Model, the Kornberg equivalent can be stated as follows: DNA is the storage site, the memory for genetic information. RNA transmits this information, and the protein is the executive form of the information. „Everything else“, the life process itself, is a subsequent development.

„Speech, communication, reading, and comprehension on this level merely means binding (= recognizing) the complementary molecular building blocks (=language symbols) and linking them into a macromolecular ribbon (= text)“ (307).

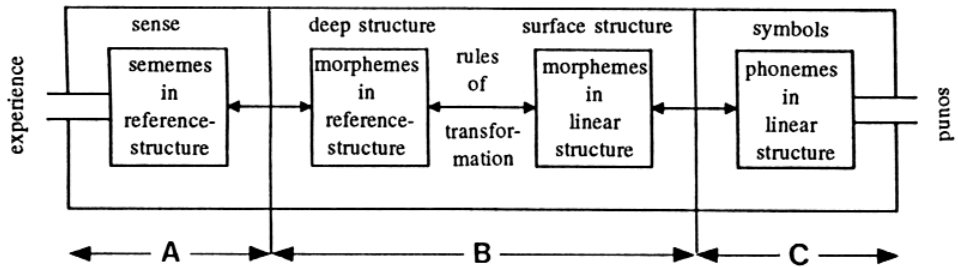


Fig. 25 (b) „In the above diagram, William G. Moulton characterizes the communication system of human language. Its relationship with the formal representation in Fig. 59 (i.e. Fig. 25 (a); the A.) of this paper is indicated.“ (Figure and text from: EIGEN/WINKLER. 1975, p. 300)

As a rule, the information transfer in the outlined language model of Moulton flows from A to C and in the present case also from the DNA to RNA: At the same time, reversals of this direction have been recorded, for example in retroviral infections where RNA sequences develop first and are subsequently copied into DNA sequences. Since DNA is the more stable form, it has been speculated that RNA sequences are evolutionarily older.

Accordingly, they would have contributed substantially, as a language, to the genesis of the nucleic acid language; DNA would thus represent the more stable, reliable form of fixing RNA creations and using them in reproduction (specifically, in hereditary transmission). In Eigen's words, „initially, in the phase of de-novo synthesis, a great many phantasy products apparently develop. Under selection pressure, however, only the best adapted sequence becomes chosen (...). The best adapted sequence is that which can be reproduced the quickest and most accurately and also has the greatest stability“ (308).

In Eigen's opinion, „a clear divergence of roles between geno- and phenotype“ took place, especially in the differentiation of the translation mechanism from DNA to RNA. Eigen answers the question regarding the subject of the translation - the subject of the linguistic sign usage in the production of those phantasy products in the de-novo synthesis - both holistically and materialistically: Molecular semantics provides language signs with meaning according to physical laws.

„The representation of phenotypic reality in the genetic language (in an analogy to the memory capacity of the mind we can refer to it as 'genetic reflection') is a consequence of evolution in toto. We are dealing with the generation of information. This applies to information in our brain as well: it can only arise in an evolutive manner, i.e., on the basis of selection. In this case, however, the underlying elementary processes we are dealing with involve time scales of milliseconds“ (310).

#### 6.1.9. „Understanding“ as a reversal of information generation

Eigen then poses the question of whether information reveals itself to us as something already in existence or whether it is an actual creation. In his opinion, information is both creation and revelation. These features provide the process with its evolutive quality.



„A message that is received is meant to be understood. It must therefore ‘reveal’ its meaning, i.e., relate to existing experience or conventions and reproduce these. At the same time it can also enrich our experience. The subsequent establishment of a connection, the integration, the understanding becomes an act of creation“ (310).

Eigen’s distinction between the absolute aspect of information (i.e., the logical depiction of reality through clear symbol allocation) and the semantic aspect (the symbol’s actual meaning) could be eliminated „as soon as one could consider and express all the factors in the probability distribution that are important for its meaning“ (ibid.). The reversal of the information generation process would guarantee an adequate and comprehensive understanding of information: all of the individual factors contributing to its development, and their interrelationships, could be reconstructed. Understanding in this sense would mean systematically narrowing down the probability distribution of semantic alternatives until only a single alternative remains. This would represent both the absolute and the semantic aspect of the respective information.

This type of information gain - information as a message clearly understood to convey information - has been quantitatively defined by Shannon and Rényi, who, in Eigen’s words, „started out by considering the probability distribution before and after the arrival of an additional piece of information and calculated the median information gain by comparing the modified individual probabilities“ (ibid.).

Understanding an information-containing expression would involve a process in which all the possible alternative meanings of that information, *with one exception*, could be „attributed a probability of realization equal to zero“. Narrowing a probability distribution down in this manner can be achieved physically only through irreversible processes.

„A sudden event causes an initially conceivable condition, characterized by a certain probability, to become unstable; it collapses. A new situation, leading to the exclusion of previously conceivable alternatives, arises“ (311).

Eigen’s communications model has its basis in formalizing criteria and would not be possible without the maxims of the depicting theory of language. Even the reflection on thought (described in philosophy as transcendental reflection) is considered to be a process of self-organization that is principally quantifiable and, through the construction of learning machines, qualitatively modifiable as well.

Nature develops a brain based on mathematical and physical (obeying an inner logic) natural laws; this brain derives the lawfulness within itself from a universal syntax and functions according to this syntax. Phoneme allocation enables a correct depiction of reality in a formalized scientific language. *The brain mirrors its own principles of organization in this language.* This is merely the endpoint of a biological evolution which began on the lowest molecular level and thus, from the evolutionary point of view, was initially defined by the nucleic acid language.



„A selectively advantageous mutant arising from a reading error (i.e., from a statistical fluctuation) in the genetic program can lead to the irrevocable collapse of a previously stable population. The ‘new’ information owes its genesis to an irreversible event; it stems from an „evaluation of meaning“ (this is , after all, what selection represents). One can concur with Karl Popper in saying: Certain alternatives which were previously possible become falsified. An analogous process must take place in the brain when an observation is made or a message is read“ (311).

At this point, Eigen draws an analogy between molecular information and human communication: both have a common process of information generation in which symbol allocation is subject to a selection, i.e., evaluation, process where possible meanings are irreversibly eliminated until only a single one remains. In his view, the understanding of meaning on both the molecular and human level involves a reduction to zero of all possibilities of realization, with the exception of one alternative. Molecular semantics and the semantics of human languages (at least in the case of formalized scientific language) are based on a selection process, a falsification process.

*For Eigen, Popper’s falsification criterium in science theory, originally designed to decide on the quality of quantifiable theories, is itself not amenable to theoretical discussion and does not represent a falsifiable evaluation model; rather, it is an expression of a reality in information-perception in which the brain lends expression to its own form of organization along with the underlying logic.*

#### 6.1.10. Molecular genetics and generative grammar

Eigen also draws attention to the discrepancies arising from the „juxtaposition of molecular and phonetic language“ and which reflect „the different nature of function“. This no doubt indicates that Eigen does not entirely dismiss the pragmatic aspect of the linguistic sign usage, although he attributes only marginal importance to the user of linguistic signs. „Each language primarily reflects the characteristic features of the respective, underlying communication machinery“ (313f.).

The term „communications machinery“ is used by most of the top researchers in the fields of biochemistry and molecular biology; it can also be encountered in connection with terms such as „protein synthesis machinery“ (DARNELL, 1985) or in slightly modified form as „evolutionary mechanism“, „communication mechanism between molecules“ (PRIGOGINE, 1980, 1984), and „enzyme machinery“ (DELBRÜCK, 1987). This demonstrates a broad consensus that v. Neumann’s automaton theory, or the mathematical theory of communication, can serve as an undisputed basis for the explanation of all living phenomena.

Let us return to the differences between the molecular and phonetic language. The respective language structures differ much in the same way that the different functions in the molecular and phonetic fields lead to a different „communication machinery“.

„The expression form of genetics are sentences whose structure is determined by control functions. Thus, in the operon segment of the bacterial genome, numerous functionally interrelated structural genes are united by control units, so-called operators. The entire genetic description of the bacterium, the genome, consists of such sentences, which are interconnected within a single giant molecule. The chromosomes of more highly developed organisms have a highly regionated structure which is clearly visible even under the electron microscope; the details of its ‘syntax’, however, remain largely unknown“ (314).

Here, Eigen clearly expresses what biochemists and molecular biologists interpret their observations to be. He describes the biological structures that code the organism’s structure and developmental plan as a genetic message „fixed in sentences“. The form of the genetic information corresponds with control functions.

The sentence construction of phonetic languages also exhibits general structural principles. As determined by Chomsky, the inherent structure of phonetically articulated sentences reflects structures of a universal grammar „which are intimately related to the ‘generative’ organ of language, the brain“ (314). New sentence combinations, formed to promote understanding in the discourse between members of a social environment, are the result of generative, syntactic operations of the brain. When human beings reflect on their cognitive abilities, the brain forms syntactic sentence structures using these underlying, universal syntactic rules. *Accordingly, self-knowledge in humankind is a depiction of brain functions through generative syntactic operations of the brain.*

The analogy between molecular genetics and phonetic languages, coupled with the universal generative grammar common to both (as a manifestation of the logic inherent in the material) leads Eigen to the conclusion that:

„At any rate one can say that the prerequisite for both great evolutionary processes of nature - the origin of all forms of life and the evolution of the mind - was the existence of a language. The molecular communication system of the cell is based on the reproductive and instructive features of nucleic acids as well as on the catalytic efficiency of proteins“ (314f.).

At the same time, the similarities and dissimilarities of molecular genetic and phonetic languages go beyond this. Memory capability, in particular, clearly demonstrates these differences in forms of communication and language usage: While antibody formation in the immune system takes place independently in each individual, memory involves regulated interactions between antibody molecules and learned features. Memory takes place on the molecular level.

„Each individual immune system therefore has its own language. The ‘vocabulary’ is determined by the spectrum of antibody-producing cells. The correct usage of this language emerges from a learning process and is subject to constant modification“ (328).

The organization of the immune memory is a regulated interaction process between all protein individuals (enzymes) involved in the immune response. Even minute deviations from these rules endanger the efficiency of the immune response and consequently the

survival of the entire organism. It is the network of these interactions which enables an immune response flexible enough to adapt to new requirements, to modify itself, and to build upon and expand the stored memory of previous immune responses. The immune response can thus always incorporate the stored experience and improve its efficiency.

Brain cells, as the epitome of the evolution of the central nervous system, form a similar structural network to organize memory capability. As opposed to the indirect interaction of protein individuals in the immune system, the cells of the central nervous system are directly interconnected - via synapses as switch contacts - and interact by means of electric impulses and chemical substances. The interaction is more complex and is considerably more rapid.

„Naturally, electric communication over greater distances can be effected at much greater speeds than chemical communication involving material transport. Learning processes which require hours or days in the immune network take place in fractions of a second in the brain. At the same time, the fixation of that which is ‘experienced’ or ‘learned’ is again a material process“ (329).

The junction between the nerve cells, the synapses, are extremely adaptable. „They develop, vanish, and constantly change their contact features as a result of the communication“ (329).

In the central nervous system, memory and recollection, learning capacity, and imagination are fixed as specific stimulatory patterns and can therefore be rapidly recalled as information or informational context; the process of reading and transcribing genetic information involves entirely different mechanisms. Only the stable storage takes somewhat more time because complex information can only be recalled through a specific circuitry and this requires organizing a functional network of synapses and specific (informationally adequate) network structure.

„Neurons have the highest metabolism of all cells in the body; that is, they continuously produce ribonucleic acids and proteins, yet not to store the information *within* these molecules, but to employ them in developing a modifiable, *functional* network“ (331).

For Eigen, this description and interpretation of observed phenomena through the information theoretical model is self-referential. It is obvious to him that these conditions for potential self-organization in the various networks - both molecular, molecular-cellular, and intercellular types along with all their functions in the realm of genetics, in the immune system and in the central nervous system - are the same as the conditions of their scientific description.

*Eigen can make no distinction between the language of the observation of events and the language of the theory about the interpretation of these observations. The preconditions for self-organization „mirror themselves in the uniform structure of the theoretical approaches used in their description“ (331 ).*

## 6.2. Philosophical implications of Manfred Eigen's language and communication concept

The comparison between the molecular and human language, as undertaken by Eigen, is problematic because Eigen believes he is able to fully explain human language and language in general by means of an implicit depictional theory. In his interpretation of language and communication, the pragmatic aspect, i.e., the relationship between linguistic signs and the user of these signs, is reduced to a marginal condition in the theory of language, while the semantic aspect is reduced to rules of a universal syntax.

When viewed in this light, Eigen's usage of the terms language and communication takes on a *purely metaphorical character* that can only be avoided if these terms are understood and used in their broader sense. Summarizing Eigen's language concept reveals the following features:

### 6.2.1. Language as a quantifiable set of signs

The world behaves according to physically determinable natural laws. These can be expressed using the language of mathematics. The formal, technical language of mathematics is alone capable of realistically describing these natural laws. Language in its fundamental sense is language as a formalized sign language. The „natural laws“ are explications of an implicit logical order in nature. Language depicts this logical order through the logical structure of the linguistic sign system. The essential element of a language is therefore its syntax. Only through the syntax does the *logical structure of a language as a depiction of the logical structure of nature* come to light. Language as an image of lawfully structured reality is principally quantifiable because it is mathematicizable. Scientific research must concentrate on this aspect if it seeks to claim exactness.

The semantic aspect of language initially comprises an incidentally developed or combined symbol sequence which only gained significance in the course of specific selection processes. Here, substance in meaning corresponds to natural substance because the selection processes have evaluative function.

We merely need to study and explain all the possible criteria in the genesis of natural substance in order to *unmistakably* understand the substance of meaning. In Eigen's language communication model, language as a communication medium between communicative subjects remains an event of private and monologic character: language as an arbitrary sequence of linguistic signs whose meaning is derived from selection processes does not convey substance but merely structure. These structures can be expressed in binary codes (yes/no decisions). The linguistic signs are variables whose syntax is subject to laws governing the linguistic sign-using organ or the macromolecules. The brain of humans, for example, is endowed with these variables and combines them to reflect synapse network logic. The variable sign syntax of the brain must be filled with experiences of a personal nature and thus constitutes an individualized evaluation scheme.

In messages between communication partners, one side encodes the news he/she wishes to convey in phonetic characters; the receiver must then decode and interpret the message based on personal experience. Understanding messages shared between transmitter and receiver is principally possible since a uniform logical form - a universal syntax - lies hidden behind every language. Messages are therefore apriori intersubjective in form and structure, while the interpretation of content remains a purely private matter. The formal structure of species-specific languages is intersubjectively identical; therefore, only scientific formal languages, such as those used in mathematics and physics, can be properly designated as languages capable of accurately representing conditions of reality.

#### 6.2.2. Language as an algorithmic decision-making process

The function of that organ which syntactically combines the language symbols according to its own structure most closely corresponds, in Eigen's opinion, to cybernetics, i.e., the theory of information-processing systems (while abstracting the manner of its realization). The functional units „central nervous system“, „brain“, and even „macromolecule“ consist of a definable, limited number of elements and a limited number of interrelationships between these elements; these make up the structure, the so-called systems structure, of these units.

Since we are dealing with living systems, active systems are present as well, i.e., there are elements in systems which mutually exert or endure active influence. The relational structures can be of a chemical-particulate and energetic nature or purely informational. Some of these systems will regulate themselves and react to particular environmental influences with greater or lesser success. Those reacting more successfully optimize their probability of reproduction. In the course of evolution, precisely those biological species which have best adapted to altered environmental conditions have prevailed. Certain types of systems create irreversible processes through self-organizational behavior, leading to the preservation rather than the degeneration of successful structures; these structures continue to attract other evolutionarily successful structures, which enhances the complexity of the system and in turn optimizes its adaptability.

These systems, along with their description by means of language, are depictions of a reality structured by natural laws. Since both the logic of the describing and that of the theory-forming language corresponds with the logic of the system, the relationship between the elements of the system can be represented in an abstract, formal, and unambiguous manner. It is important to determine the relationship among the linguistic signs, as their relationship reflects the relationship of order in the realm of nature.

The quality of the syntax is evident in the concept of information. Since messages based on reality can be formally represented, they can be coded with 2 characters (0 and 1). This unit of measure enables the information content of a particular message to be determined with regard to the available number of available characters. This furnishes a calculatable, average information content of a letter of an alphabet below which one cannot drop without rendering letter identification impossible.

A receiver decodes and privately interprets the received information (albeit according to intersubjectively identical rules of an underlying logic common to all languages). Information theory therefore also involves information processing, i.e., various transformations of particular messages into other sentence structures according to specific transformation rules as determined by a machine.

Dynamic, self-regulating and information-processing cybernetic systems are considered to be the realization of algorithms. An algorithm defines that method by which, in a *finite* number of steps, a problem can be solved. Machines can calculate those functions for which an algorithm exists. Since reality is structured by a logical order subject to natural laws, the logical form of language (mirroring the logical form of reality) must be expressible in binary codes. Every message, every information, is calculatable and every problem is solvable algorithmically. Principally, an optimally constructed machine would be equipped with a more optimal syntax than humans.

### 6.2.3. Humankind as a learning machine

From the viewpoint of man as a machine, humans clearly represent an optimal model: they fulfil all those preconditions for the algorithm development that a conventional machine cannot deliver, i.e., criteria for information evaluation based on the real, social environment. Humans, and all other biological systems, resemble a learning machine capable of internally producing a syntactically correct image of the environment by interacting with this environment, of correcting this image through repeated interactions, and thus of changing the behavior toward the environment. Such learning systems are able to continuously optimize their adaptability. The learning efficiency is mirrored in a history of advantageous selections. This type of selection history is the history of the optimal realization of algorithms.

Processes of human consciousness can be best represented cybernetically because the brain - as the „learning machine“ in this model - understands itself best.

*Reflection on reflection is a self-reproducing, dynamic, self-regulating behavior; a (transcendental) reflection of the machine; language, the common logical form of reality and reflection medium, is the precondition for its existence.*

Ultimately, processes of consciousness are learning machine functions based on the input-output principle. Decoding the rules governing brain organization makes the decoding of all conceivable conscious processes possible. This approach transforms consciousness into an observable, accurately and unambiguously describable and quantifiable problem-solving behavior. The brain is structured in such a manner that it can transform the syntax inherent on its molecular level up into the phonetic level: The constitution of a formal language by the brain enables this „learning machine“ to recognize itself as a constitution of reality and to reflect on itself.

Here, Popper's theoretical viewpoint becomes relevant for Eigen. Accordingly, scientific research must be viewed as being analogous to the adaptive behavior of organisms to

their environment: one can therefore refer to the (biological) evolutionary character of knowledge gain. The self-reproduction of the learning automaton is reflected in all levels of biological reality. Popper's 3-World concept enables Eigen to explain language in every sense, from the nucleic acid language to that of human reason.

The differences between these two languages stem from the continuous development process of biological structures, based on the model of a self-reproducing and self-regulating automaton *that functioned as a realization of algorithms*. This enabled the steady optimization of problem-solving strategies in organisms, eventually leading to the constitution of a central nervous system, a precursor ultimately giving rise to the brain and its enormous storage and information-processing capacity. Language enabled implementation of this evolutionary plan (from the amoeba to Einstein): this medium forms, transforms, stores, expands, and combines information.

*This explains why* Eigen sees language as the prerequisite for the development of all forms of life, as well as for the evolution of the mind. A uniform fundamental structure, the logic of the universal language, lies behind all living phenomena as well as behind the construction of the formal language which exactly reproduces this logic of reality (comprising both being and the discourse-on-being). Thus, the structure of information-forming and -processing systems such as the brain, the central nervous system, or the immune system mirrors „in its uniform basic structure, the theoretical approaches applied in its description“ (331).

### 6.3. Deficits in the depicting theory of language

Even formal systems are not closed, as Eigen purports, nor are they principally fully determinable. Furthermore, language is the result of communicative interactions in dialogue situations rather than the result of constitutive achievements of the individual persons. Communicating with one another, sending messages, understanding expressions is not a private coding and decoding process, but rather an interpretation process arising from a mutual adherence to rules by communicating partners who agree on the rules.

The ability to abide by these rules is innate, the skill in complying with particular rules is acquired through interactions and relies on norms of interaction to utilize words in sentences. Information cannot principally be quantified as message content: statements made by social individuals in situational contexts are not closed and thus are *principally* not fully formalizable. The attempt to construct a purely representational language is *doomed to failure* because formal artificial languages do *not exclusively* contain terms that are unambiguous. This pertains to terms that cannot be confirmed through observation. **Specifically, scientific statements are not attributable to immediate sensory experience, i.e., the language game used to describe observations does not mirror the brain activity during the perception of reality.**

A world-depicting standard language must remain a mere postulate because it cannot logically substantiate itself. Too many theoretical concepts, too many scientific criteria that



are principally not formalizable (e.g., „progress in the cognition process“, „practicability“, etc.), point to the limits of formalizability. The very identity between artificial language and its form renders it incapable of reporting on itself, something that presents no problem when using informal speech. Language is an intersubjective phenomenon in which several individuals can share, alter, reproduce as well as renew the rules of language usage. The basis and aims of this usage are defined by the real social environment of interacting life forms. The user of a linguistic sign cannot be comprehended according to the speaker-outside world model. Rather, this requires reflection on the interactive circumstances to which the user has always been bound, circumstances which provide an underlying awareness enabling him/her to understand statements made by members of the real environment. The user of formal artificial languages - before appreciating the purpose of the usage - has also developed this prior awareness in the course of interactive processes with members of the real social environment.

Speech is a form of action, and I can understand this activity if I understand the rules governing the activity. This means I can also understand an act that runs counter to the rules. Everyday language usage reflects everyday social interactions of the constituent individuals. The prerequisite for fully understanding statements is the integration of the understander in customs of social interaction and not merely a knowledge of formal syntactic-semantic rules. A *prior condition* for all formalizations in scientific artificial languages is a factual, historically evolved, communicative experience. This very precondition becomes an object of empirically testable hypothesis formation in Eigen's language model. At this point, however, Eigen's model becomes *paradoxical* because he seeks to theoretically grasp language with tools that are themselves linguistically predetermined.

Even Chomsky's attempt to reconstruct universal systems of rules within an empirical theory of language (rules that have developed over the course of evolution, are genetically transmitted, and then „awakened“ through social interaction) is founded on a „generative grammar“ which itself is based on the mathematical analysis of formal systems (CHOMSKY, 1964 a, 1964 b). He attributes the rules governing sentence construction to the level of syntax, semantics, and phonology. To him, these rules are rules of a formal system. Chomsky himself, however, concludes that formal systems are principally incapable of doing justice to the complexity of sentence structure: sentences do not appear to be produced linearly, which should be the case in formal systems. According to this model, the generating system of rules must exclude real communicative acts and interactions and, with it, precisely the apriori of practical language usage.

Eigen's language model, which is rooted in information theory, clearly reveals that Eigen equates the form of theory language with the form of language used to describe reality (experience). This implies the equation of formalized scientific languages with the language used to describe observations. Previous attempts to specify all the rules governing the translation of every term in theory-language into terms of observational languages have been unsuccessful. Not all concepts of theory language can be transposed into concepts of the observational language.



A similar situation is encountered in the attempt to absolutize mathematics as that pure formal language whose every ramification might become fully transparent. This led Gödel to formulate the „Unvollständigkeitssatz“ („incompleteness theorem“) in his work „Über formal unentscheidbare Sätze der principia mathematica und verwandter Systeme“ (GÖDEL, 1931).

Gödel investigated a formal system by applying arithmetic and related deduction methodologies. His aim was to convert the metatheoretical statements into arithmetic statements by means of a specific allocation procedure. More precisely, he strived to convert the statements formulated in a metalanguage into the object language S by using the object language S. This led Gödel to two conclusions:

- a) Under the assumption that system S is consistent, then it will contain one formally undecidable theorem, i.e., one theorem is inevitably present that can be neither proved nor disproved within the system.
- b) Under the assumption that system S is consistent, then this consistency of S cannot be proved within S.

The question of decidability and computability is closely allied with the algorithm concept, whereby Eigen seems to postulate that algorithms are not only concepts of theoretical language, but also depict (decision-) behavior in the realm of biology and therefore are amenable to empirical analysis. Indeed, he is convinced that everything can be represented in the form of algorithms and can thus, in principle (after sufficiently thorough analysis), be decided. Yet Eigen never puts this to the test, i.e., he never states the conditions under which a branch of mathematics would be undecidable. Namely, a field of formalized artificial language is undecidable when no algorithm can be provided to help decide - for a particular formula of a formalized artificial language and involving a finite number of steps - whether this formula is universally valid or not.

Today, several branches of mathematics are considered undecidable. Herein lies the consequence of this undecidability theorem for the automaton theory of A. Turing and J. v. Neumann: a machine can principally compute only those functions for which an algorithm can be provided. *Functions lacking an algorithm are not computable.*

Every cybernetic, self-controlling machine is the realization of a formal system. Eigen assumes that the evolution of self-reproducing and self-organizing organisms represents the realization of the syntax of a universal language underlying the order of the world. This universal syntax, as a representation of mathematically expressible reality, is also the formal basis for the evolution of these organisms. For every one of these machines, as in the case of every organism, there must be an undecidable formula.

It is precisely by means of a *non-formal* language that this formula can be shown to be true or false; this non-formal language is the very tool that enables the language itself to be discussed. The machine is unable to do this because no algorithm is available with

which a cybernetic machine can get to the bottom of its underlying formal system. Systems theory is *principally* unable to fulfil the demands that Eigen places on it.

The fact that the paradoxes arising within an object language cannot be solved with that language led to a differentiation between object language and metalanguage. Nonetheless, paradoxes can also appear within metalanguage; these can only be solved by splitting into metalanguage, meta-meta language and so forth in an infinite number of steps. This unavoidable gradation of metalanguages necessitated resorting to *colloquial speech, developed in the context of social experience, as the ultimate metalanguage. It provides the last instance for deciding on the paradoxes emerging from object- and metalanguages.* Neither the syntax nor the semantics of a system can be constituted within that particular system without resorting to the ultimate metalanguage.

The ambition to provide logic and mathematics with apriori validity is no longer tenable: an unambiguous linguistic fundament of science, one beyond further inquiry and supporting itself through direct evidence, cannot be secured. Language proves to be a perpetually open system with regard to its logical structures and cannot guarantee definiteness from within itself. This is the very conclusion that Eigen disputes with his language model. To briefly summarize this chapter:

- (a) There can be no formal system which is entirely reflectable in all its aspects while at the same time being its own metasystem.
- (b) Concrete acts and interactions are principally unlimited in their possibilities. There will always be lines of argumentation that lie outside of and have no connection with an existing system. Principally, every system can be transcended argumentatively. Newly emerging language games and rules may develop as novel structures which are foreign to previous systems and not merely a further step in a series in prevailing elements. These very discontinuities enable totally new language applications.
- (c) The ultimate metalanguage, colloquial language, provides indispensable evidence about the communication practice of subjects in the real environment; the operator of formalizations is himself an integral part of this. Reverting to this everyday type of communication reveals information about the subjects practising this usage. In this sense, pragmatism becomes the theoretical basis both for formal operating and for a non-reductionistic language theory.

Thus, Manfred Eigen (representing molecular biology and biochemistry) fails in his attempt to use the language and communication concept to explain observed biological phenomena and processes. Eigen is correct in recognizing that language and communication were and continue to be indispensable for the origin of life, the development of biological species diversity, as well as for the specifically human capacity for thought, speech, and action; at the same time, he is unable to provide an adequate foundation of these two terms. This casts doubt on the entire explanatory model for living nature as provided by the biological disciplines.

The inevitable question is: how can the use of the terms language and communication be expanded so that both concepts provide not only a sufficient explanation, but also an *understanding* of living nature?



## 7. Pragmatics of language (Sprachpragmatik) as a basis for a semiotically expanded language and communication concept in behavioral, socio-, and molecular biology

The insurmountable explanatory deficits in the depicting theory of language, as determined above in Manfred Eigen's usage of the terms „language“ and „communication“, require an expansion of the explanatory horizon he forwarded. The inability of cybernetic systems theory or information theory to establish and justify the application of either concept to explain central processes and structures of living nature is apparent; *further usage in the sense of Manfred Eigen would make this approach liable to criticism as an anthropomorphism* or would reduce it to mere metaphorical character. In my opinion, the expanded explanatory horizon for the application of „language“ and „communication“ to explain and understand

living nature could take on the following form:

### 7.1. Language as a medium of understanding (Verständigung). The apriori of the pragmatic situation of understanding (Verständigungssituation)

Organisms that communicate with each other by means of linguistic signs can correspond by coordinating their behavior. They represent real life-forms (Lebensformen) in a real, animate world. Language is necessary as an intercommunication medium for the overall organism, not only externally to develop optimal action criteria, but also internally to explore optimal reaction criteria.

The disruption of either external or internal communication can seriously endanger the survival of the organism as a whole, even if the pathways are completely different. The ability of organisms to adapt to changing environmental conditions is not the only result of successful internal and external communication. *The creativity, nonlinearity, and productive scope of new genetic texts, which serve as the construction and development plans for organisms, indicate the avenues that language and communication open up.* Indeed, their realization is difficult to explain without the assumption of sign-mediated communication processes.

Both, self-organization in autocatalytic processes and the creativity of human intellect require language and communication as the realization medium. From this perspective, language and communication serve as a *precondition for the possibility* of life (versus non-living matter), the evolution of biological species, and for the cultural evolution of human reason; Manfred Eigen is entirely correct in this respect.

Since users of linguistic signs can combine a finite number of characters with a finite number of rules to carry out an *infinite number* of sign-mediated communication processes, language and communication become the structural and organizational medium for biological species. Sign-mediated communication processes allow leaps in the evolution of biological species to be understood because such leaps are ultimately creations of

genetic text combinations; these have not developed from random, undirected changes in the genetic text, but rather were *initiated by protein individuals (enzymes) which are highly competent in the combination and recombination of genetic text sequences*. They are so highly competent that gene manipulators rely almost exclusively on this competence.

Reflection on the pragmatic intercommunication situation also helps us understand the *leaps in scientific knowledge*, whose critical phases are discontinuous and nonlinear (KUHN, 1970). While Manfred Eigen points out the similarities in such discontinuous and nonlinear processes, he is unable to explain this similarity on the basis of his language model.

Language enables constative and regulative linguistic action (Sprachhandlungen) -or linguistic behavior (Sprachverhalten) in nonhuman biological individuals- much more so than mere generative linguistic action (or -behavior). They help organize the everyday social environment in which organisms are immersed throughout their individual lifespans. Nonetheless, *linguistic-sign-utilizing individuals are equally capable of conducting generative linguistic action or -behavior*; here, new activities or new behavior, new rules, are constituted which themselves normatively orient further activities or behavior sequences.

Sign-using individuals are principally able to create entirely new activities, new behavior, completely new texts, completely new genetic texts in different realms (macro-level: domain involving phenomena of sensory perception; micro-level: domain of molecular interactions). These creations do not logically evolve from existing networks according to pre-existing rules; rather, they constitute something **new**, something foreign to that already in existence. This is precisely what Eigen's language model cannot explain, because Eigen neglects the constitutive capability of the pragmatic situation. *He thus eliminates the preconditions for his own theory development*.

## 7.2. No generative grammar without generative pragmatics

Generative grammar states that every sentence of a language (initially the underlying structure and then, with the help of transformation rules, the overlying structure) can be created. Accordingly, a linguistic-psychological theory of human language would be an empirical science whose object of study would be the preconditions for its existence. This would further raise the prospect for providing a linguistic foundation of logic - the question involving the difference between analytic and synthetic judgements would then lend itself to a linguistic solution. However, logic can hardly be founded by an explanatory, empirically testable theory (which itself presupposes logic).

The attempt to understand the subconscious adherence to grammatical rules when expressing and interpreting remarks as an extension of naturally governed behavior is *doomed to failure*: how linguistically competent individuals adhere to rules of grammar cannot be equated with how water crystallizes into ice or melts again to liquid form.

Following rules of grammar in speech (or writing) can itself become the topic of speech and can be intentionally altered, distorted, or even violated. This very creativity to change rules forms the much valued artistic quality of linguistic endeavor and enables poetic and speculative language usage along with novel types of rationality, thought patterns and life-forms. *The difference between rules of grammar and natural laws is unbridgeable.* Humankind cannot determine the degree of its adherence versus nonadherence to natural laws; we can, however, define this relationship with regard to grammatical rules at will. Even the rule-changing creativity in the realm of DNA indicates that **natural laws cannot explain** rule changes, i.e., innovation at the level of genetic text sequences. This pertains to those changes stemming from the activity of protein individuals competent in text modification, not to deformations of genetic text sequences arising randomly from external influences (for example radioactive radiation, chemically induced mutations, etc.).

Sign-mediated communication is a regulated interactive event between interactive individuals. The rules of sign usage are therefore a component of social norms, of normative activity or behavior, for which the interactive event is constitutive. This interactive event should not be reduced in a behavioristic manner, since the interpreter himself/herself is a member of the social community that intersubjectively made interpretation experiential. Interaction events are principally grasped subjectively before they can become the topic of objective description or explanation.

In humans particularly, the discussion about norm consciousness is not reducible to internalized or innate rule adherence. The constitution of this norm consciousness is the consequence of a social interactive event in a real environment. Equally, Eigen's postulate of an evaluation function that selects the universal grammar from all possible alternatives, shifts transformation grammar in the direction of a theory of (finitely deciding) automata and thereby relates to a possible algebra of linguistic computer programs. The aim of such a theory may well be the successful computer simulation of human language behavior, as was planned by A. Turing and J. v. Neumann and which an entire generation of researchers from numerous scientific disciplines has since set their *hopes* on. In this case one must systematically avoid *confusing* the simulation of human speech with speech itself. Even if machines could simulate how humans abide by rules, they themselves do not actually follow such rules, but „merely function in accordance with certain formal procedures“ (SEARLE. 1984). The machine simulates certain formal characteristics of mental processes.

*By loosely employing the term information (or: information processing) for such entirely divergent phenomena as the adherence of humans to rules on the one hand and the simulation of human rule adherence on the other, Eigen glosses over the confusion between human rule adherence and „as if“ human rule adherence by machines.*

The purely mechanical „as-if“ simulation could be transcended if a successful communication took place between computer and human subject, for example *in the form of a non-formalizable self-reflection*. This would, however, principally exclude Gödel's indecidability theorem.

### 7.3. From (privatistically conceived) generative grammar to the apriori of pragmatic speech situations

The Eigen language model interprets language as a monologic conveyance of information. According to Eigen, the fact that the speaker has a command of linguistic sign utilization (rules of language usage) is not due to co-constitution through a learning process involving social interaction in which socially integrated individuals master the meaning of linguistic signs in real-life communication situations. Rather, this is determined exclusively by its apriori identity with the logic behind the „system“ central nervous system or brain. Thus, the social interaction process would merely stimulates this innate capability; in reality this shared rule-understanding is an instinct-analogous process.

The theoretical perception of the information exchange process purely as message transmission *neglects* the constitutive contribution of those involved in the interaction process; communication is reduced to the genetically acquired language competence of the respective communication partner. Accordingly, each of these participants carries all the linguistic prerequisites apriori within him/herself, specifically within the language-forming organ. Both speaker and listener are viewed as entirely separate individuals. Although both are equipped with the same program, i.e., they abide by the same natural laws and can therefore establish a quasi-intersubjectivity about the validity of identical meanings, they remain entirely privatistic in their conception. Thus, the precondition for the constitution of meaning is not the apriori involving the understanding among individuals that share and communicate in a common life world (Lebenswelt).

Rather, the ultimate factor lies in the phonetic process between C and C' (Fig. 24), where information is conveyed between a speaker and a listener who use their individually given language competence and the apriori identical language to put their individual thoughts into words and to code them or, vice-versa, to decode and understand the contained information.

When members in the real environment communicate with each other about something (e.g., the coordination of behavior), Eigen argues that the meaning of this „something“ is ultimately constituted through syntactic rules. My aim here is to demonstrate how and why the meaning of this „something“ *is constituted in pragmatic speech situations*.

In a theory of language based on pragmatism, the sentences and texts of idealized speakers in syntactic/semantic theories are replaced by the remarks of speakers in idealized speech situations. The theory of speech competence must be supplemented by a pragmatism of the speech situations (theory of communicative competence); this can clarify the preconditions under which language is used to achieve understanding about something, i.e., under which conditions the contexts of actions or behavior constitute meanings of linguistic expressions.

Only the pragmatic, inherent structure of such communication situations can reveal, under scrutiny, *why a speaker shows what he/she means with what he/she says* (VOS-



SENKUHL, 1982). These meanings are in no way formalizable, and every operator of a formalization has presupposed and applied these pragmatic conditions long *before* actually knowing what formalization is. The underlying pragmatic structure provides a means of principally understanding even grammatically irregular sentences in speech situations; a purely grammatical analysis of such an anomaly may very well be confronted with insolvable paradoxes. The pragmatic level also provides hermeneutic access to an understanding of the rule-changing creativity process, which enables the sign user to design and express entirely new sentences, to conduct new actions, to develop new behavior - all in no way logically derivable from pre-existing states. Grammatical competence can never be fully separated from the communicative competence constituted in speech situations: assuming one without the other cannot adequately explain a sign-mediated communication (APEL (ed.), 1976 a; HABERMAS, 1989; SEARLE, 1976; ).

Eigen's reliance on Chomsky's generative grammar in no way eliminates the deficits of his language model.

#### 7.4. The constitution of meaning and understanding through real processes of understanding (Verständigungsprozesse)

Analysis of Eigen's language model shows that his language and communication concept is *insufficient* to comprehend and reconstruct human language usage and requires amendment through pragmatic points of view. Indeed, these pragmatic viewpoints of language usage largely determine our understanding of the adherence/non-adherence to grammatical and semantic rules. This is particularly evident in the attempt to analyse unconventional language usage (WUNDERLICH/MAAS, 1972; WUNDERLICH, 1976).

The pragmatic situation of understanding is characterized by a complementarity that is indispensable for the constitution of meaning or, in Eigen's words, for the evaluation scheme and the allocation of meaning to symbol combinations. Sign-mediated communication can only extract meaning from signs within a setting involving a reciprocal confirmation between language usage and daily life; for the sign-using subject, this transparent framework enables meaningful expression and permits successful intercommunication about a chosen topic. The pragmatic sign-usage situation is *ultimately constitutive* for the meaning of language application and speech behavior. Wittgenstein termed this situation „language game“ and K.O. Apel very aptly differentiated this term as „a 'life-form', a functioning unit of language usage, living expression, behavioral custom, and worldly openness“ (APEL, 1976 a, p. 321).

Meaning can only be grasped in the framework of (real or fictitious) participation in such language game. Language game even exists, or so we as humans can assume, in those cases where conspecific individuals exhibit species-specific behavior that takes on sign character whose particular meaning can be understood by the language game participants of that species. This remains valid even when we consider the differences between human and non-human, sign-mediated communication. An example is that specifically human quality in which the rules governing the sign-mediated communication are concurrently maintained as rules in the reflective consciousness and can often even be formulated as explicit rules.

The meaning constitutes itself through the specificity of the actual intercommunicative situation (whose purpose may be sociality or the coordination of activity or behavior); no one can seriously dispute such behavioral coordination in non-human biological individuals. *The pragmatic approach also explains how the same linguistic signs can take on different meaning in the various language games.* Shifts in *linguistic sign meaning* are an integral and important component in specific language game situations.

In the process of communicative interactions, norms - which serve to orient our activity and govern behavior - can be nullified or modified. The pragmatic language usage of individuals involved in species-specific, sign-mediated communication processes (language game, etc.) enables the change, expansion, and transformation of proven and conventional sign meanings. This gives rise to the possibility, even the *probability*, of an evolutive self-organization of organisms, one that involves a discontinuous differentiation of ever more complexly structured organisms, initially via intra-organismic communication processes.

This self-organization cannot in fact be explained or even understood (as Eigen postulates) as an algorithmic process; rather, it is a rule governed, sign-mediated (and consequently linguistic) communication process between a) the protein individuals of a biological organism, b) conspecific individuals, c) conspecifics and external environment.

*Evolutive self-organization is an evolutive possibility when intra-, inter-, and meta-organismic communication function in an equally complementary fashion and when they can claim linguistically-mediated, rule-changing creativity.*

An explanation of how to constitute irreversible processes - in particular with respect to a competent expansion or advantageous alteration of the genetic text through enzyme proteins - would hardly be possible: without assuming this complementarity, how could one understand the acquisition of a social interaction competence, much less the genetic fixation of specific, crucial experiences (WILSON. 1985)?

**Sign-mediated communication in non-human languages is also clearly oriented toward pragmatic conditions; it constitutes meaning and significance here as well. Examples include the bee language as well as inter- and intracellular communication (FRISCH, 1971, WITZANY, 1993 b).**

#### 7.4.1 The Apriori of understanding situations for constituting meaning in the bee language

As demonstrated in our treatment of two sign-mediated communication processes in the language of northern hemisphere honey bees, in certain situations the behavioral context determines the meaning of the linguistic signs used. The bees' ability to interact socially is no doubt genetically fixed. However, the constitution of the specific performance, i.e., of the actual communication process, is contingent on the actual situational demand:

a) In the sign-mediated communication process underlying the foundation of a new colony, only scouts participate in the search for a new home. They are the oldest bees in

the swarm and have already gathered food for the parent hive; they are fully experienced with the features of the local terrain. Why do only these experienced scouts swarm out, and not the inexperienced ones as well? Does the flight of the queen cause certain genetic text sequences in the scouts to be expressed, i.e., those that code for and initiate such a behavior? Or does the rule governing the participation of only experienced scouts underlie some other species-specific, intersubjective communication?

The criteria that a prospective hive must fulfil are so differentiated that one can reasonably assume a genetically determined inspection and evaluation behavior. On the other hand, these evaluation criteria clearly do not exist from the onset: they must have been constituted by experience, followed by subsequent genetic fixation. Pragmatic situations formed the evaluation pattern for the combination or creation of genetic sequences that then coded these experiences as text sequences. Naturally, there is no reason to doubt that enzyme proteins competent in text processing carried out this fixation, i.e., have structured and, above all, inserted the respective sequence at the appropriate site in the genome.

No haphazard change or deformation of genetic text sequences can shape the highly differentiated selection criteria for the winter hives of northern hemisphere honey bees: they are simply too rigorous. The failure of the hive selection process to closely match the required hive features can kill off the entire swarm in one winter. The argument that this involves the natural selection of many chance mutations would imply the extinction of all northern hemisphere bee populations before they ever had the opportunity to develop sufficiently differentiated selection criteria for suitable winter hives.

As demonstrated earlier, the process by which a potential winter home is scrutinized is itself incredibly complex and exact. The bees pace the entire length and breadth of the new site: no millimeter is left out. This explains why a single bee covers a distance of nearly 50 m in the course of this inspection, even though the cavity itself is relatively small.

This performance by the bee fulfils a reliable evaluatory function and is part of the overall sign-mediated communication process; in this case it represents an individual contribution. Such specific hive inspection behavior must have been constituted as experience and subsequently become genetically fixed. Enzyme proteins in the cell must have coded the specificity of this experience and inserted it into the correct site in the genome. Otherwise the tree hollow would be unable to trigger the expression of the particular genetic sequence that induces the individual bee - at the very time of its arrival there - to reproduce the genetically fixed experiences of past bee generations.

Even this transformation of the scouts' experience into the text-combining activities of enzyme proteins is insufficient to explain why such genetic text fixation provides the next bee generation with suitable hive-selection criteria. After all, the scouts have a different status than the queen, who gives birth to all bees. While she does move into the new hollow with the swarm, and a genetic fixation of how she experiences this hollow is conceivable, how can she genetically transmit the inspection procedure when she herself did not participate in the inspection? What plausible path exists between the experience of the

scouts and the genetic text of the queen? Can one assume a generative linguistic behavior in which experience is initially conveyed interindividually and only later - genetically combined - incorporated into the genetic make-up? One scenario: the scouts impart their experiences to the queen in the form of sign-mediated communication; she represents these internally as stimulation patterns, thereby providing the text-competent enzyme proteins with coding criteria that are inserted into the genome in correct relation to existing text sequences. And what might the criteria that govern the transformation into the genetic text be, i.e., which experiences are genetically fixed and which ones are not? Pragmatic interactions or communication situations which the overall organism experiences in real life apparently determine how the enzyme proteins of that organism constitute new or altered genetic text sequences.

The sign-mediated communication process underlying the founding of a new bee colony also points to numerous other pragmatic situations that must be or, if they are genetically fixed, must have been vital for the evaluatory function. The consultation between scouts about the potentially most suitable new home - in this case the tail waggle dance - raises the question: what induces bees that have identified a potential site as being less satisfactory to dance less vigorously, and bees that have identified a site as being highly suitable to dance more vigorously and to „symbolically code“ (TODT, 1986, p. 207) the direction and distance of their discovery? What induces the less lively dancers, those who are less convinced of their discovery, to take up the invitation of the more vigorously dancing bees to inspect the site they consider to be particularly suited, especially when this involves repeating the same complex and time-consuming inspection procedure? What subsequently enables these bees to decide in favor of the recommended, inspected, and perhaps more highly evaluated site and to themselves promote this site with an appropriately intense dance? Furthermore, this new decision may itself be temporary, and another, even better home may trigger a renewed inspection process, etc. At any rate, the final decision is a consensus decision by all scouts, all of whom have by then inspected the most highly advocated home. If no consensus can be reached, no decision is taken and the swarm freezes to death at the site of their deliberations during the first cold spell.

Provided that the decision-making process represents sign-mediated communication, then it cannot be of the algorithmic type; rather, it must be a truly communicative process between conspecifics in a commonly shared life world (Lebenswelt). They represent subjects for one another because they use the same linguistic signs in the same sign-mediated communication process to achieve understanding, form associations, and coordinate behavior. The fact that language is involved, i.e., language and not merely a formal procedure, opens the potential for generative and therefore entirely new linguistic behavior. Otherwise, northern hemisphere bees would never have been able to differentiate the necessary sign-mediated communication processes (processes outside the repertoire of southern hemisphere bees). Whereas southern hemisphere bees use behavior to constitute signs with direct indicatory or invitational character, northern hemisphere bees employ movements to constitute and utilize a symbolic sign character for these movements; understanding these signs permits more differentiated messages to be deciphered (messages that even humans can understand, provided that they can determine the rules underlying the use of these movement signs).

D. Todt, a sociobiologist whose research was instrumental in initiating an interdisciplinary dialog with semiotics in Germany, expressly underlines the use of symbols by bees of the northern hemisphere.

The specific sign-mediated communication process involved in searching for a home is terminated only when consensus has been reached. The process is completed when a new home (one selected exclusively by scouts) is inhabited and developed.

b) This marks the onset of the second sign-mediated communication process described above - food gathering. Again, the tail waggle dance is used to convey information. The rules underlying the movement sequences as well as the indication of direction and distance remain the same as in the preceding example. The sequence of signs is also the same. Their meaning, however, is different because they take on new meaning within the pragmatic context of a new communication process. The waggle dance may well be a rule-governed, genetically fixed behavior that is expressed as the need arises; nonetheless, the actual situation in which the signs are used within a population of communicating conspecifics lends meaning to the signs themselves and determines their sequence in a dance.

In addition, the target group addressed by these expressions is not the same as in the preceding case. All foragers, not just the scouts alone, are called upon to search for food sites. One situation-specific feature is responsible for the fact that foragers (and not just scouts) are being addressed, even though the mode of expression and the utilized linguistic signs are the same as in the previous example in which scouts were prompted to swarm out: only when the dancers carry flower pollen - which is not the case when the task involves searching for a new hive - is the call valid for foragers as well. In the absence of pollen, the foragers do not react to the messages or invitations. Understanding (*Verständigung*) between bees is not limited to dance movements alone. These movements are combined with (the very important) vibratory movements (KIRCHNER/TOWNE, 1994) of the wings and abdomen along with the rule governed use of olfactory signs. This marks the limits of our comprehension of the bee language. Human beings can never hope to progress much beyond a passable understanding of the rules governing the bees' use of linguistic signs: beyond a certain complexity of sign combinations, mastering the specific modes of use would require becoming involved in the bees' communication process as interactional subjects. This inherently transcends human capabilities and points to the limits in the compatibility of transspecific forms of communication, for example in metaorganismic communication.

c) One final pragmatic criterium for the signifying function of the utilized linguistic signs deserves mention: the occurrence of various bee dialects. The same sign (or the same sign sequence) can exhibit slightly different rules of usage in bee colonies that are geographically widely separated yet belong to the same species. In the case of the Austrian and Italian bees described earlier, the form in which the same symbolic (behavioral) sign is expressed can translate into site deviations of several hundred meters. The pragmatic context, in this case the bee colony's actual life-world (*Lebenswelt*), determines the semantic rules according to which this sign is interpreted.

#### 7.4.2. No intra- and intercellular sign-mediated communication process without real sign users. The importance of cellular communities of communication.

The genetic code which is fixed in DNA and read, copied, and translated in gene expression gains importance as a genetic text only if real sign-users are available to read, copy and translate it into the amino acid language. This gene expression, along with all of the related subprocesses is neither mechanistic nor mysterious and vitalistic. Rather, it is the result of complex, regulated interactions and highly specific behavior coordination between numerous types of enzyme proteins (WATSON, 1992).

These enzymes clear the text for reading, implement the copying into the three types of RNA, search the text for superfluous text passages, cut these out, to a certain extent repair damaged sections using rougher and finer techniques (excision- and postreplication repair), and complete the entire process of normal gene expression (HOWARD-FLANDERS, 1981). All enzymatic protein individuals are themselves coded as genetic sequences, yet enzyme proteins themselves always clear genes for reading and thus ensure the reproduction of all necessary enzyme proteins. This allows numerous generations of specific enzyme protein types to exist within the life-span of an organism, beginning at the onset of life.

The technique employed in the reproduction of the enzyme types is the same in all organisms in which genetic texts must be read, copied, and translated into the amino acid language. Every cell of the entire organism stores the complete genetic construction plan in the form of the genome, although only those text passages required for the function of the particular cell association are expressed. This also means that the specificity of the cell association is *decisive for evaluating* those passages (within the total genetic text) that are to be read, copied, and translated. Every organ, i.e., every specific cell association in which specifically associated cells must carry out a function for the complete organism (in a complex coordination with other organs), requires regulated interactions in order to fulfil the demands placed on it by the organism (e.g., raised pulse rate after physical exercise).

Today we appreciate how complex the execution of this sign-mediated communication is in specific communication situations and within specific requirement profiles (WITZANY, 1993 a). The communication between cells of a cell association (organ) is irrevocably limited to this context, i.e., the irreversibility is genetically fixed and virtually guarantees abundance by the rules that govern the reproduction of cell-association-specific progeny: we can be certain that liver cells reproduce only new liver cells.

At the same time, the specific position within a cell association determines the expression of those genes which code for the (punctual) reproduction of a cell in *precisely this specific position*. *The actual position of a cell in the real environment is the evaluation criterium for the gene-expressing enzyme* to express exactly that segment of the total genetic text which enables the reproduction of a cell in that and no other position (GEHRING, 1985).

Highly specific cell communication between cells of a cell association further enables the production of proteins required for the various functions (e.g., metabolism function) within the complete organism. The required proteins are not infrequently produced by very different cell associations via very cell-association-specific communication processes (WITZANY, 1993 b). The rules of these sign-mediated communication processes, both of the intra- and intercellular type, are followed, occasionally even newly constituted, by real users of linguistic signs. They (the rules) are not only structured by the syntax of the genetic text, but also by the real life-world (Lebenswelt) of the complete organism; this itself constitutes situational contexts and contexts of experience, or finds itself within such contexts, and is primarily responsible for imposing special tasks/demands on cell associations.

Specific task-accomplishing strategies can be (but need not be) genetically fixed as experiences. This indicates that text-generating enzyme proteins use specific stimulatory patterns of the organism, which are the result of situational contexts in a real life-world (Lebenswelt), as a basis for their text generating activity. Such stimulatory patterns may be neuronal or may function in combination with chemical messenger substances as text-generating stimulatory patterns. Interestingly, evidence for this was provided not by socio- or molecular biologists, but by biochemists (BONNER, 1983 a; WYLES/KUNKEL/WILSON, 1984; WILSON, 1985).

Protein synthesis probably takes place in all organisms in the same manner. Otherwise one would not be able to arbitrarily combine the mRNA, tRNA and ribosomes of completely different species of organisms in a cell-free environment. The nucleic acid language is governed by a common syntactic law, yet the real life-world (Lebenswelt) of protein individuals, of the cell components and cell associations, as well as of those organisms whose life is maintained by these cell associations, determine the use of this language; they initiate the generative, sign-mediated communication processes (i.e., not random mutations due to radiation or mutagenic agents) in which this language is changed, transcended in its meaning, newly combined, or its complexity increased or reduced. *Real life-world and the interacting, rule-abiding individuals that constitute them are indirect (via organismic body) co-constitutive for the sentence structure of the genetic texts* (WITZANY, 1993 b, 1997).

*Without a **molecular pragmatism**, neither the logic of the molecular syntax nor the molecular semantics that Eigen deduces from it could be understood; furthermore, their explanation would remain reductionistic.* Understanding the language of nature (nucleic acid language) requires a **molecular semiotics** (WITZANY, 1993 a) that analyses and interprets the molecular interaction processes as sign processes (semioses). This would reverse the omission of the actual sign users in the intra- and intercellular communication processes and would incorporate their co-constitutive role in the structure of the genetic text and its expression.

**This level of insight must be attained before one can legitimately refer to a language of nature: then we are no longer dealing with an explanatory model operating with**



**metaphorical terms, but have an approach that enables us to understand and substantiate the conditions that establish the possibility of living organisms.**

As long as molecular biology considers language to be an apriori for the evolution of organisms and, ultimately, also of human intellect, it has grasped language only syntactically/ semantically.

*From the standpoint of language philosophy, we can legitimately refer to a language of nature in the evolution of organisms and in the evolution of human reason only after incorporating the pragmatic dimension of sign utilization and thus including both the real life-world (Lebenswelt) of the sign user and an understanding of its life-form.*

A further example of how linguistic signs are constituted with meaning **through the pragmatic usage context** is provided by chemical messenger substances whose structure is the same but whose meaning differs in different communication processes. Thus, the same chemical messenger can assume an entirely different messenger function as a hormone than as a neurotransmitter in the communication between nerve cells.

The constitution of immunological memory is yet another example of how the interaction competence of the B-lymphocytes is co-constituted through pragmatic interaction:

After successfully warding off an infection, the B-lymphocytes which helped organize the defense remain present in the body as an immune memory. In the event of a renewed infection the immune response can proceed much more rapidly and more effectively. The immune response itself, however, is not genetically fixed, merely the structure of those proteins that organize the immune response. The immune response is the result of a complex identification and interaction process (TONEGAWA. 1985). On the other hand, the constitution of the immunoglobulins, in their incredible diversity, is the result of the variable combination of respective DNA sequences.

Here as well, sequence segments are not changed and combined automatically or randomly, but rather through *enzyme proteins* with *combinatory competence*. Using relatively few, variable sequence regions and following only a few rules, they produce a sheer endless number of *easily distinguished* identification proteins, which help organize a successful immune response. Highly complex interaction forms and mutually complementary communication types (intra-,inter-, and meta-organismic communication), not random sequence mutations, have led to the development of such an immune response competence. If the organization and structuring of such relatively simple biological processes is controlled by *highly complex enzyme sign processes*, then how much more plausible is the assumption that such sign processes are involved in actual evolutionary processes, in which much more complex symbol processes are required?

Enzyme proteins in particular, which combine and recombine genetic texts, provide evidence for an evolutionarily acquired competence in text processing. More specifically, recombination enzymes identify particular recognition sequences as such and use this ability to carry out combinatory operations on the genetic text; in this manner they cut out



semantically significant text sequences from the text assemblage and insert them somewhere else in the assemblage. The sequence combination itself is governed by syntactic rules; the exact nature of their combination is under the influence of pragmatic conditions. *The real life world (Lebenswelt) of the affected cells and molecular structures of a complete organism form the evaluation function which constitutes the actual text combination as a meaning function.*

The metaphor involving the „language of nature“, as applied by molecular biologists, should not be rejected out of hand. Nevertheless, to justify referring to a language of nature in the sense a philosophy of language ***requires an expansion of the reductionistic language concept of molecular biology.*** This would enable an understanding of living nature based not on metaphors but on a reconstruction of historical intercommunication situations and forms. The discussion about the language of nature opens new interpretation possibilities for observations in the realm of living nature - avenues that would principally be closed to reductionistic research methods.



# PART THREE



## 8. Types and forms of communication in living nature

The previous chapters served to round off the systematic part of this work and to examine potential areas of application opened by this approach.

The following **outlook**, which begins with evidence that living nature can be understood as a linguistically and communicatively structured and organized entity, bears programmatic features: the subsequent sections should be viewed as a blueprint and lay no claim to exhaustively treating the perspectives they introduce in a form and content.

At the same time, a *new philosophy of biology based on pragmatics of language* may well be emerging in the fields of research and education. It draws its justification from viewing living nature as being structured and organized in a linguistic and communicative manner; it founds its theses and methods on language philosophy and focuses its research on establishing a „**theory of communicative nature**“. I will outline the basic principles of such a theory in this chapter.

The preceding sections aimed at opening the door to understanding nature by demonstrating its linguistic, communicative structure and organization; such an approach would clearly allow traditional avenues of explaining nature to be newly oriented.

*On one hand*, this understanding of living nature is based on the language-like structure of the genetic code and on the sign-mediated communication processes leading from the genetic code to a living organism (whose form and function is in large part defined in that code).

*On the other hand*, understanding living nature means examining the different forms of rule-governed, sign-mediated interactions between discrete organisms. Depending on the biological species and the communication medium, the interactions involve various forms of sign-mediated communication, whereby the sign user constitutes and adapts them to its inherent physiological features.

Most rule-governed interactions between organisms involve behavioral traits that take on a symbolic character. To a lesser extent, symbolic linguistic signs may be used, i.e., a sign stands for a defined circumstance without in itself actually representing that circumstance.

Few fields of research attempt to understand living nature by deciphering all the grammatic, semantic, and pragmatic rules underlying linguistic sign use in a biological species. *Zoosemiotics* has tackled this problem with admirable success (FRISCH, 1965; GRIFFIN, 1985; HULTSCH & TODT, 1986; KROODSMA 1982; LINDAUER, 1981; MATTHES, 1978; PLOOG, 1974; SEBEOK, 1968, 1977; TEMBROCK, 1971; TODT, 1974, 1986). Based on the understanding of nature that this field achieves, semiotic research might well be expanded to include all other kingdoms of organisms, e.g., in the form of plant semiotics, fungal semiotics, prototist semiotics, and a prokaryont semi-

otics. This would cover the communication processes between discrete organisms. On the other hand, communication processes at the level of genetic text sequences fall within the realm of *molecular semiotics*, as discussed earlier. This branch of research will no doubt contribute significantly to deciphering protein structures and their relationship to protein function.

The rule-governed interactions between organisms, along with those in the intraorganismic realm (intra- and intercellular communication), have a series of common features above and beyond their distinct differences:

(a) the communication is sign mediated.

Several other formal-pragmatic features that I have attempted to formulate in this book can be found in all known forms of communication in every kingdom of organisms:

(b) species-specific communication also always serves to coordinate behavior in some manner.

(c) No association is possible without species-specific communication.

Many additional common features can no doubt be discovered and described: I restrict myself to these three characteristics because they represent key elements in the way mankind defines itself.

From an evolutionary standpoint, the commonality of such features in all forms of communication in living nature is understandable: all organisms stem from other organisms that are considered to be their ancestors. With the exception of the first life form, life was never again created from non-living material (*creatio toto ex nihilo*), i.e., each organism can look back on a species, family, and phylum history.

From the onset, biological sciences have devoted intensive effort to reconstructing such phylogenetic trees, and there is solid evidence for assuming that all living organisms are related to one another to some degree, be it direct or indirect.

Upon closer examination, evolutionary history is inextricably entwined with the phylogeny of phyla, families, and species. This history of biological organisms, along with the generations that reproduce them, is clearly characterized by an underlying, habitat-specific interactional logic and interactional dynamics; the designation as a social or associational history appears to be justified. The actual „histories“ clearly differ from one another, but share the fact that they involve organisms that communicate with one another.

The development and radiation of biological species would not have been possible without the nucleic acid language: it defined every step of this development and radiation in the form of genetic text sequences. It is the universal language underlying all life, and is virtually infinitely combinable in the extracellular environment. This universal language of life does more than merely fix newly acquired physiological and/or habitual developments, preserving them for the reproduction of future generations. Its role goes beyond merely sustaining the constitutive and regulatory functions within an organism. Ultimately, this language of living nature *enables the constitution of entirely new text sequences and text details, and thus the constitution of completely new biological species.*

This is the essence of the terms „biological self organization“ or „ongoing creation“ - the capacity and capability of an organism to adapt to changing environmental conditions by newly constituting genetic texts in the nucleic acid language, as well as the ability to ensure its intraorganismic communication and to irreversibly fix those genotypic and phenotypic changes that increase the reproductive potential of its lineage.

This, after all, characterizes every type of language use from the intracellular communication of the simplest unicells to human reflection:

*in language use, i.e., in sign-mediated communication, the rules governing sign use can principally be altered, expanded, and overstepped, thereby constituting new rules and new forms of communication; these need not be fully reconstructable or explainable based on predecessors and earlier forms, but exhibit truly novel qualities in key areas that are simply undetectable in predecessors, ancestors, or earlier representatives.*

As was demonstrated by numerous examples in the section on intraorganismic communication, this rule-changing creativity is *not* based on accidental changes in the genetic texts, but rather on the manipulation, specification, expansion, and alteration of genetic text sequences by enzyme proteins that are competent in text processing.

The full range of new perspectives revealed by the language-philosophical approach to living nature can help establish a „theory of communicative nature“. Such a theory, whose details remain to be formulated, is the research goal of a philosophy of biology based on linguistic pragmatics. Its task is to interpret the research of various biological subdisciplines in this light, without any concessions to traditional, reductionistic research methods. Its scientific purview would encompass all living organisms, including the interrelationships between these organisms. At present, the following key elements of this theory can be postulated:

1. *Language of nature*: language-philosophical aspects of the nucleic acid language, with special emphasis on *molecular-semiotic* aspects.
2. *Languages in nature*: language-philosophical aspects of sign-mediated communication processes between conspecifics in every kingdom.
3. *Types of communication in nature*: the study of all intra-, inter-, and metaorganismic communication types in every phylum.
4. *Forms of communication in nature*: Determination of all communication forms that are phylum specific with regard to their communication type; the various kingdoms as communication forms and their semicompatible relationship with one another.
5. *Evolutionary theory based on a philosophy of language*: reformulation of the classical maxims of evolutionary theory from the perspective of living nature as a linguistically and communicatively structured and organized living nature.

In the following section I plan to outline a new classification scheme in which all organisms can be interpreted precisely from the vantagepoint of living nature that is structured

and organized in a linguistic and communicative manner. At the same time, an effort will be made to point out unbridgeable differences: clearly, bees use language symbols differently than whales or, indeed, humans.

### 8.1. One language of nature - many forms of communication

As demonstrated earlier in this book, the nucleic acid language is vital for all forms of life. Even the most minute disturbances, the slightest reading, translating, or copying errors, can mean death or doom the organism to a suboptimal life. No organism in past or present times, not even the history of life itself, is possible or even conceivable without this universal language of nature.

The differentiation of this language was a prerequisite for the differentiation of every biological species known to have existed in the past or that still exists today. Moreover, this language largely governs the way organisms behave toward their environment: it can irreversibly fix the behavioral repertoire of preceding generations. Most importantly, it regulates the functions within the organism, i.e., on the intra- and intercellular level, as well as coordinates the behavior of the individual organs.

In vitro experiments have shown that the potential combinations of this language of nature - under adherence to its grammatic rules - are virtually limitless. Thus, the genetic text sequences of a mouse and a human being are compatible in the extracellular environment. If the text sequence for a growth hormone from the human genome is inserted into the proper site in the genome of a mouse (text-processing enzyme proteins are responsible for the correct insertion), then the mouse in fact does grow significantly larger than the original genetic makeup would have allowed.

This language of nature also enables organisms to store the experience they gain in the form of genetic text sequences (WILSON, 1985). This requires a coding process in which experiences - as the perception of sensory input - take on structural character; these characters, together with others (for example chemical messenger substances), can then be identified and coded as structural characters by enzyme proteins that are competent in processing texts. One central question involves the evaluation criteria used by such enzyme proteins, i.e., we are currently still unable to distinguish the *validity criteria* according to which one type of experience becomes genetically coded and fixed, while another is stored neuronally but not further processed. This successful coding capacity is, in turn, itself genetically fixed.

The language of nature defines the time and place of protein synthesis, i.e., of the enzyme protein production that phenotypically expresses this language. Although no genotypically fixed information could be expressed without enzyme proteins, the form and function of these enzyme proteins are themselves genetically fixed. The prerequisite for such a self-reflective, self-correcting, and self-expanding language of nature is the existence of protein associations whose individuals are capable of metabolic functions. We define an organism, in its most simple form, by its ability to take up, utilize, and break down exploited substances. The language of nature defines such organisms; the minimum requirement for



their full development, i.e., for the expression of all the information stored in this language, is a functioning metabolism of the new organism. Thus, the organism represents the medium in which these genetic text-processing functions can take operate in the real world.

*The language of nature and its capabilities are therefore inseparably linked with the communication forms of actual protein individuals. One is not viable without the other. When we refer to life, we must assume a complementarity between a single „language of nature“ and nature’s numerous communication forms; the latter can be viewed as the categorization of every conceivable phenotype in nature.*

The constitution of new genetic text sequences is only peripherally related to enlargements and changes in existing text sequences, i.e., to the coding of the formative experiences of living organisms in their environment. Rather, enzyme proteins competent in combining texts produce new text creations that function as blueprints for entirely new life forms - independent of such experiences. The ability to constitute new text sequences is an important factor for *optimizing living nature’s productivity*: each new organism arising in this manner constitutes - on the phenotypic level - a new form of species-specific communication. They enrich the diversity within the respective habitat and force existing populations to interact with the newly derived forms. This experience between old and new would never have taken place without the novel element. These new experiences, in turn, can initiate new codings (e.g., changes or expansions) in the genome of individuals of an existing population, codings that would never have been possible without the interaction with new life forms.

Thus, the appearance of new life forms (via text creations by text-processing enzyme proteins on the genotypic level) is a cofactor in the specification and accompanying expansion of the gene pool of existing populations. Such complementary effects no doubt contribute to creating new, organism-bound enzyme proteins that are more proficient in text processing than their predecessors, who themselves were sufficiently competent to organize the organism’s reactions to its erstwhile environment. (Consider, for example, the re-orientation of certain digestive processes through man’s introduction of dairy farming). The origin of new biological species or even kingdoms represents a novelty not only for the particular organisms involved, but also for all the other life forms that must interact directly or indirectly with the novel organisms.

The relationship between the single, universal language of nature and the kingdom-specific communication forms of the organisms themselves is manifold: their relationship, i.e., the relationship between the genotypic and phenotypic level, is a complementary one.

## 8.2. Semicompatible forms of communication in nature.

The classification of communication *types* and communication *forms*

Alongside this universal language of nature, which is instrumental in constituting all forms of life, there exist languages in nature: sign-mediated communication processes between individual organisms designed to coordinate behavior and promote the forma-

tion of associations. These types of communication can vary considerably from biological species to biological species; as demonstrated earlier in the case of bees, regional populations can develop habitat-specific communication types (dialects) even within one and the same species. The dialects within a regional population of a species provide leeway for an even greater differentiation. Every classification of communication types in nature must therefore focus on fundamental differences between biological kingdoms, differences that are reflected in the respective phylogenetic histories as well. Modern biological systematics, i.e., taxonomy, offers a useful approach: its differentiation of 5 kingdoms enables a principle distinction into kingdom-specific categories of communication forms. This will be treated at a later stage.

According to my thesis, every life form worthy of the definition (from single-celled organisms to human beings) is enmeshed throughout its life in three types of communication:

1. Each organism is subject to an *intraorganismic communication* that is indispensable for the internal organization of numerous vital functions, reactions, etc. Several such examples were presented in more detail in earlier chapters. This includes both intracellular and intercellular communication (the latter being especially well-developed in animals). Naturally, this also encompasses the expression of the genetic text, i.e., converting the genotype into the phenotype. Intraorganismic communication is ultimately responsible for the **external form** and function of the organism.
2. Every organism participates in *interorganismic communication*, i.e., communication between members of the same species; this also plays a role in coordinating behavior and forming associations, without which a biological species would be unable to survive. This category also encompasses all rule-governed interactions between conspecifics: their species-specific constitution endows them with an identical or at least similar repertoire of signs and rules, or enables the organisms to acquire this repertoire through learning processes. The most complex forms of interaction have developed in the communication between members of the same species, whereby this type of communication is once again most pronounced in the animal kingdom.
3. Every organism participates in *metaorganismic communication* processes in that it interacts with other species throughout its life. In most cases this type of communication is either *symbiotic* (vital to both interacting partners) or *parasitic* (beneficial to one species, detrimental to the other). Viewed superficially from a human perspective, the most conspicuous interaction processes are the violent ones between different species, i.e., those in which one organism serves as prey for another. Even in such cases, however, the „victims“ are not defenseless; rather, they have developed a range of species-specific defense strategies that are genetically fixed and thus hereditary. Countless examples of symbiotic and parasitic metaorganismic communication types exist. A select few biological species have developed *other* types of metaorganismic communication beyond symbiosis and/or parasitism (more highly evolved mammals and humans).

In this chapter I will interrelate these three types of communication with the various forms of communication; this yields a multi-level differentiation of sign-mediated com-

munication processes in living nature and reveals their relationship to the observed phenotypes. Such a summary is critical because kingdom-specific communication forms are manifested in the morphological structure and in the interactions of members of living environments. This is the reason why I refer to forms of communication in nature rather than to language levels.

#### 8.2.1. The arrangement of all known organisms into phylogenetically related groups

As mentioned earlier, nature's forms of communication differ from one another in the evolutionary sense as well, whereby each form discussed below need not differ from the preceding one in all features, but in characteristic ones. From the evolutionary standpoint, therefore, each new kingdom manifests itself as a fundamentally new communication form (of the language of nature) that can be distinguished from the preceding kingdom with regard to all three communication types.

The following presentation is based on modern biological systematics and avoids the old classification systems (zoology, botany, microbiology, etc.) along with their terminological inconsistencies; equal weight is given to all the important structural and organizational features distinguished by these fields of research. The most recent systematics is based on a model of R.H. Whittaker; it has since met with broad interdisciplinary acceptance and been published in updated forms by Lynn Margulis and Karlene V. Schwartz (MARGULIS & SCHWARTZ, 1988).

Accordingly, 5 kingdoms of organisms are currently distinguished on the basis of life cycles (phylogeny, reproduction, feeding, social interaction, etc.). The basic unit distinguished here is the species. Approximately 3 million species are thought to exist today, although the number may be as high as 20 million (the discrepancy is based on well-founded assumptions about unknown insect species). On the other hand, a far greater number of species has already become extinct during the course of geological history.

Closely related species are united into genera, with closely related genera being grouped into families, families into orders, orders into classes, classes into phyla, and phyla into kingdoms. In all cases, the arrangement into these categories is based on group features reflecting natural phylogenetic affinities. Thus, man belongs to the species *Homo sapiens*, to the genus *Homo*, the hominid family, the order of the primates, the class of the mammals, the phylum of the vertebrates, and the animal kingdom.

The five kingdoms can be clearly and definitively distinguished from one another: Single-celled organisms lacking a nucleus (**prokaryotes**) (I) differ much more from the next evolutionary step, i.e., unicells with true nucleus and their relatives (eukaryotes), than animals do from plants. Organisms with a true nucleus can be divided into eukaryotic microorganisms and their relatives (**protocists**) (II) as well as into the phenotypically larger eukaryotic organisms (**animals**) (III), **fungi** (IV), and **plants** (V). „These last three familiar kingdoms represent the three great ecological strategies for larger organisms: production (plants), absorption (fungi), and consumption (animals)“ (MARGULIS & SCHWARTZ, 1988, p. X).

From the perspective of the philosophy of language and the philosophy of nature, this traditional division (which is entirely useful in the framework of biological research) remains unsatisfactory when it comes to mankind's self-understanding (Selbstverständnis). Based on the communicative and linguistic competence of humans, it is most helpful to differentiate between the communication form of the animal kingdom and the communication form of humans. While we can relatively effortlessly trace our physiological descent from primate predecessors (compare also BUCHER, 1992), their cultural development shows that we have differentiated an evolutionary step lacking in any of the 5 kingdoms. The classification of communication forms therefore needs to be expanded to include the human element, so that in representing the communication forms of living nature I will refer to six such fundamental forms.

Clearly, each kingdom and its specific communication form developed at different times in Earth history from the evolutionary perspective, and a „before“ and „after“ can be distinguished; it therefore appears reasonable to begin with accepted divisions of time in order to be able to chronologically arrange the appearance of the respective kingdoms.

#### 8.2.2. Dating the origin of the 6 communication forms in nature

Geologists are continually improving the chronology of Earth's history. Rock layers are compared with one another, with the upper ones being considered to be younger than the underlying beds. The evaluation of decay processes of natural radioactive isotopes also enables relatively precise dating.

The age of the Earth has been estimated at 5 billion years. The oldest known fossils, bacterium-like structures, have been dated at approximately 3.5 billion years (ibid.). These earliest forms of life were prokaryotes. They ruled the planet for nearly 2.5 billion years, i.e., for more than half of Earth's history. This was followed about 1.2 billion years ago by the appearance of prototists, whose constitution introduced a fundamentally new dimension of biological possibilities: the evolutionary jump to cells with a true nucleus provided the basis for all future evolutionary steps.

The first typical animals appeared on the scene about 700 million years ago, followed 400 million years ago by the fungi. Plants represent the most recent evolutionary step, forming an independent kingdom ca. 380 million years ago. The sediments of the so-called Phanerozoic mark the point in time in which a detailed chronological differentiation is possible. This aeon began approx. 580 million years ago and is, in contrast to all earlier time periods, incomparably rich in fossils.

Since the communication form of humans differs distinctly from all others, dating its origin is justified in the present context. To the extent that one can interpret archeological finds as human fossils, the age of the genus *Homo* has been estimated at ca. 1.5 million years or more. Our species, *Homo sapiens*, is considered to be nearly 120 000 years old, with the definitive differentiation of the brain to its present state having occurred some 35 000 years ago (WASHBURN, 1978; BUCHER, 1992).

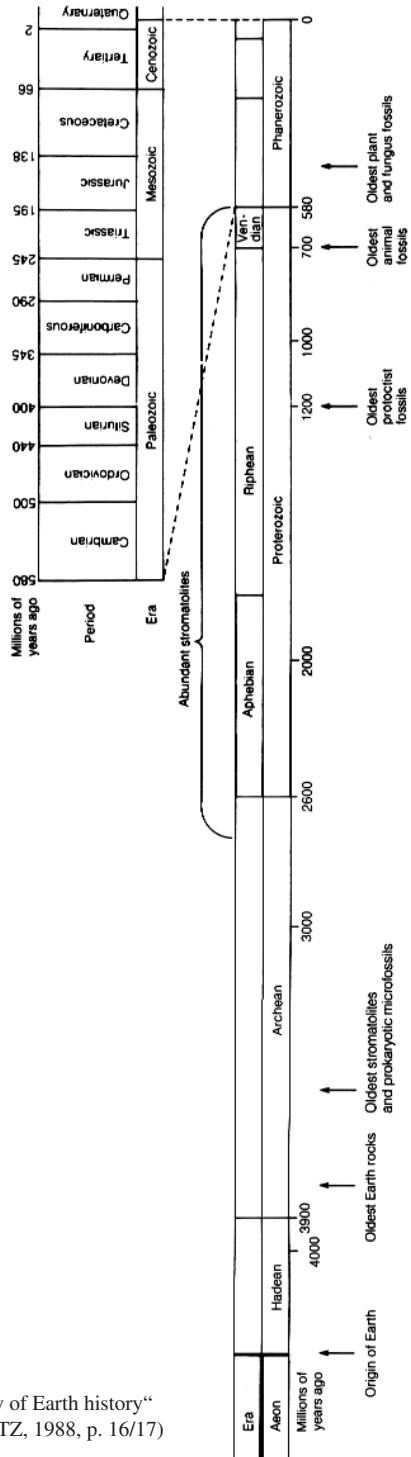


Fig. 26 „A geologic chronology of Earth history“  
(from: MARGULIS/SCHWARTZ, 1988, p. 16/17)

### 8.2.3. Expanding modern biological systematics in the dimension of a philosophy of language

Throughout its life cycle, every member of a particular kingdom is - from the language-philosophical perspective - the phenotypic **expression** of a genotype and its realization through enzyme proteins competent in text processing. Due to the closer natural phylogenetic affinities of organisms within a kingdom, the communication types within that kingdom will be more similar than between kingdoms. This is why I also refer to each kingdom as a communication *form*. The following descriptions of characteristic features therefore always encompass the underlying sign-mediated intraorganismic communication (coded in the nucleic acid language) that was necessary to shape such features.

Thus, the description of typical metabolic processes would always fall within the realm of intraorganismic communication, while the various forms of behavioral coordination with conspecifics would fall within the realm of interorganismic communication. Accordingly, forms of interaction between organisms belonging to different species would be classified as metaorganismic communication.

#### 8.2.3.1. The Prokaryotes

This kingdom consists entirely of microorganisms that are invisible to the naked eye, in particular the highly diverse group comprising the bacteria. All in all, more than 10 000 species are known. From the evolutionary standpoint, the prokaryotes represent the earliest forms of life. The fact that they escaped extinction at a time when all other forms of living nature were unfolding is no doubt due to the wide range of indispensable functional roles they play in the lives of other organisms (MARGULIS & SCHWARTZ, 1988, p. 33f.).

##### a) Intraorganismic communication

All vital functions within a prokaryote are organized by an enormous number of chemical transformations; these, in turn, are oriented and directed by intraorganismic communication. The specific implementation in a particular prokaryote is genetically defined. The DNA is contained within the so-called nucleoids, which *lack* a surrounding membrane. They also lack the chromosomes that characterize all eukaryotic organisms, having instead simple genophores („gene carriers“). The DNA is not surrounded by protein.

These simple organisms have apparently been unable to produce those enzyme proteins that can process the genetic text in a manner that would lead to the subsequent formation of a nucleus. The advantage of these life forms is their minute size, which opens up habitats that are inaccessible to larger organisms (ibid.).

The forms of metabolic function differentiated by bacteria *by far* exceed those developed by eukaryotic organisms. For example, bacteria produce or consume a range of gases; such metabolic processes contribute substantially to the formation of Earth's atmosphere.

Bacteria use a range of techniques to obtain their nourishment, among them photosynthesis and chemosynthesis. In both cases, food and metabolic energy is derived from inorganic sources (ibid.).

Bacteria are also capable of feeding on organic compounds from either living or non-living biomass. As opposed to plants, photosynthetically competent bacteria can utilize hydrogen sulfide instead of water.

Bacteria are among the hardiest organisms on the planet: by forming spores (which contain at least one copy of each bacterium gene) they can even survive spells of complete dessication. They reproduce chiefly by cell division (DNA replication), i.e., the division of a parent cell into two daughter cells (ibid.).

#### b) Interorganismic communication

Bacteria join together to form colonies. For many years, such bacteria colonies were mistaken for algae, which can take on a very similar appearance. This form of prokaryotic association is generally the product of increased cell division in the vicinity of a food source. Some such associations assume a specific structure, for example *Bacillus* colonies. They undergo coordinated movements and rotations as a unit. Little is known about how they coordinate such behavior, but there is no doubt that such a coordination takes place. Reproductive strategies in which the genetic material of two prokaryotes are combined - in unequal proportions - also exist, for example via a virus that can exchange genes between bacteria (ibid.).

(compare also KAISER/LOSICK, 1993, LOSICK/KAISER 1997)

#### c) Metaorganismic communication

As a rule, bacteria live in water or some other liquid medium. Their rule-governed interactions with other species have given rise to some highly differentiated forms which can be subsumed under one of two fundamental strategies. On the one hand they can be symbiotic, i.e., live in or with a host organism, with the latter being dependent on bacterial activity (for example for digestion). On the other hand they can be parasitic and cause disease in plants, animals, and humans. "Bacteria converse with one another and with plants and animals by emitting and reacting to chemical signals. The need to 'talk' may help explain why the microbes synthesize a vast array of compounds." (LOSICK/KAISER, 1997, p. 52) Sign-mediated, rule governed interaction leads to differentiation of species specific properties which enriches their communicative fitness. „Beyond conversing with their own kind, bacterial cells sometimes conduct elaborate chemical conversations with higher organisms.“(ibid., p. 55)

The so-called archaeobacteria (some scientists term it an own kingdom; WOESE, 1981) found optimal living conditions at the dawn of Earth's history, specifically in hot, concentrated sulfuric acid. These life forms die upon contact with oxygen. Since the advent of animals and plants, certain bacteria have specialized in releasing the remains of dead

organisms into the seawater in the form of nitrogen and phosphorus. These substances are, in turn, essential for the survival of other organisms (algae). *Without the organic compounds produced by bacteria, the food chains or food webs responsible for differentiating innumerable forms of life could not exist.* Bacteria are therefore integral parts of every community of living organisms.

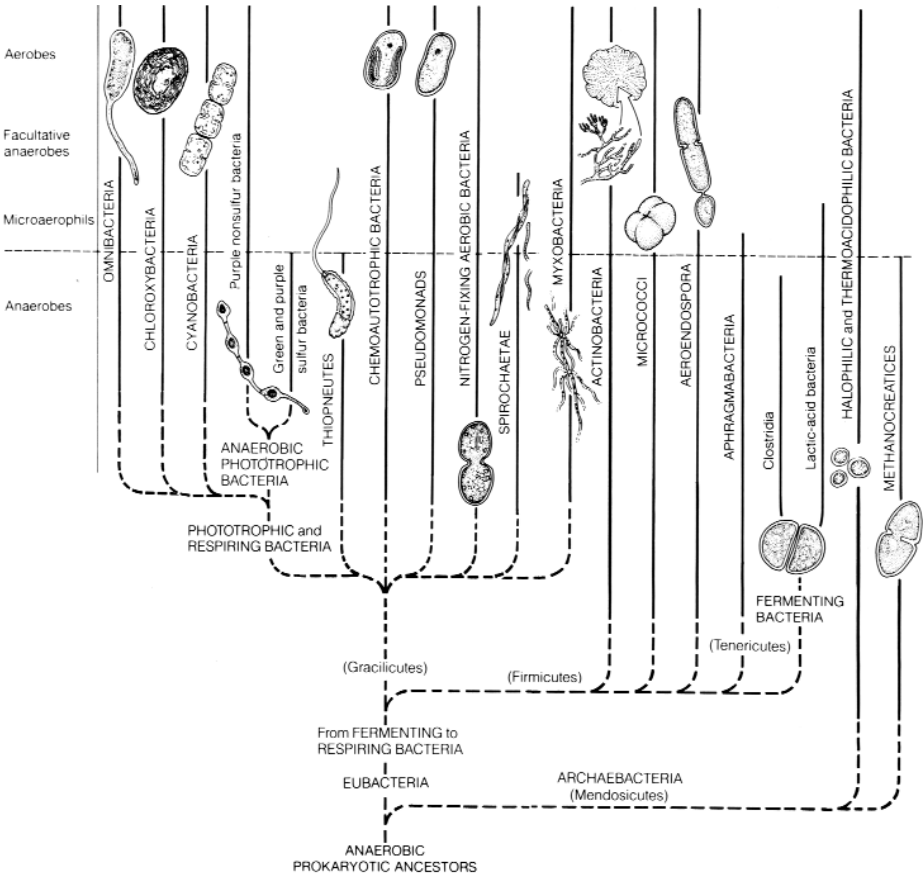


Fig. 27 Phylae of Prokaryotes (from: MARGULIS/SCHWARTZ, 1988, p. 24)

This kingdom, as a communication form in nature, comes closest to the universal language of nature from the perspective of its global distribution: bacteria can be encountered everywhere in nature. If bacteria were to become extinct as a kingdom, all remaining forms of life would be doomed. Most organisms would never be able to form proteins without the help of certain bacteria that can bind nitrogen - a prerequisite for photosynthesis.

The metaorganismic communication of bacteria in the earliest phases of Earth's history was, in fact, restricted to interactions between prokaryotes, as no other organisms were



present at the time. Only with the advent of protocists were prokaryotes able to communicate in a true metaorganismic manner.

### 8.2.3.2. The Protocists

The protocists represent a kingdom that has taken the **fundamental evolutionary hurdle** from cells without, to cells with true nucleus (MARGULIS & SCHWARTZ, 1988, p. 75f.). All subsequent kingdoms in the evolution of life consist of eukaryotic cells (i.e., have a true nucleus).

Protocists are neither prokaryotes nor animals, plants, or fungi. They encompass eukaryotic microorganisms and related forms. This includes all nucleated algae, flagellated water molds, slime molds (unrelated to fungi), and protozoans. Nearly 200 000 species of protocists are known today (ibid.).

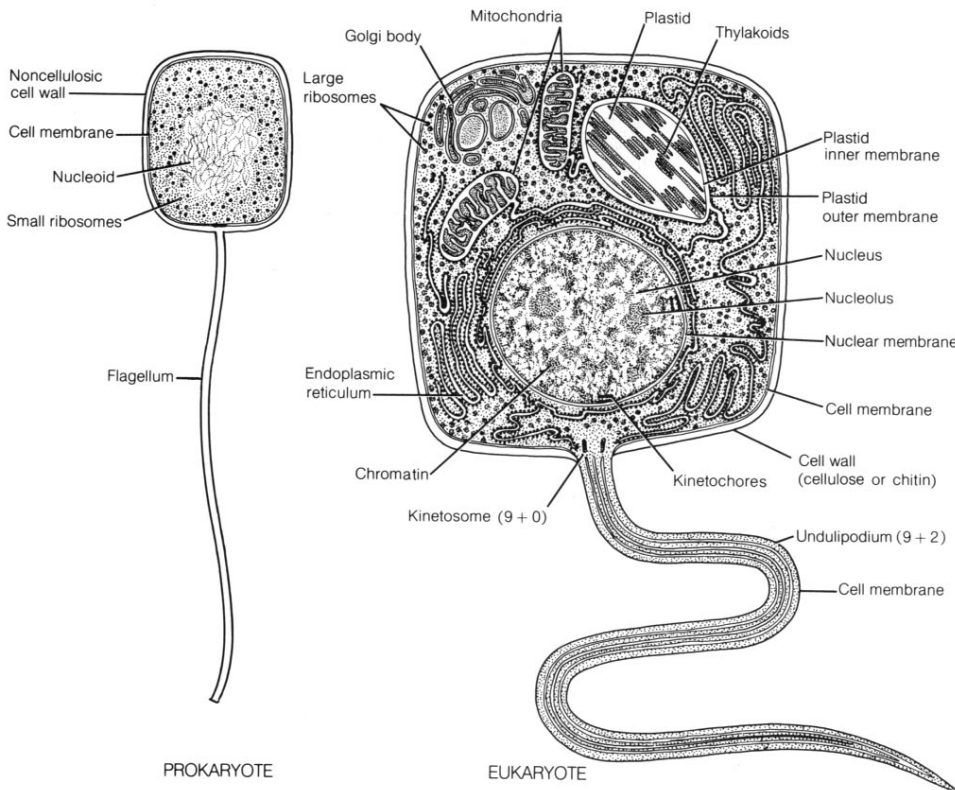


Fig. 28 Typical prokaryotic cell on the left; on the right a eucaryotic cell (from: MARGULIS/SCHWARTZ, 1988, p. 9)

a) Intraorganismic communication

The fundamental expansion of the genetic text that led to the constitution of nucleated cells ultimately gave rise to chromosomes consisting of DNA and proteins consisting of RNA. Cell division took place after prior nuclear division. Most protocists are capable of cell respiration, with eukaryotic cells principally requiring oxygen to survive. To the best of our knowledge, various forms of anucleate single-celled organisms attained a type of association around which - under a certain set of environmental conditions - a type of membrane developed; it was subsequently genetically fixed as an autogenous product of this „associational conglomerate“ of eukaryotic cells. Such an association hypothesis is plausible in the framework of a „theory of communicative nature“ (compare also DUVE, 1996 and MARGULIS, 1998).

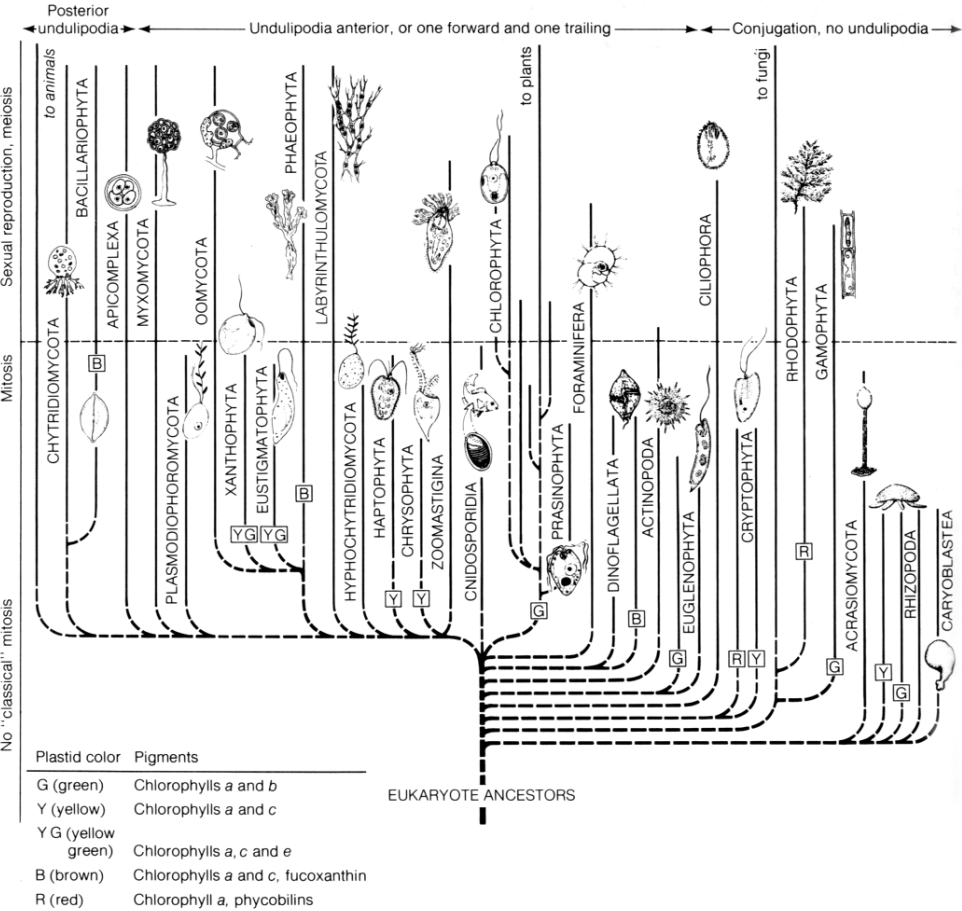


Fig. 29 The protocists are the first eukaryotic organisms. They are the starting point for the evolution of the latter organismic kingdoms animals, fungi, plants.  
(from: MARGULIS/SCHWARTZ, 1988, p. 76)

Cell respiration in protoctists takes place in organelles termed mitochondria. The cell organization and, more generally, the life cycles of protoctists are very variable. Nevertheless, this variability is far lower than in prokaryotes. On the other hand, the metabolic diversity within this kingdom exceeds that of animals, fungi, and plants. Some species release free oxygen, others ingest solid or dissolved organic substances, while still others release such material into their surroundings. Certain species of protoctists become photosynthetically active under light conditions, yet absorb particulate or dissolved organic substances in the dark. One of the few features common to all protoctists is their eukaryotic ancestry. One must always bear in mind that these many functions would not be possible without intraorganismic communication. However, while intraorganismic communication in prokaryotes was restricted to intracellular communication, in all other kingdoms it takes place on the intercellular level as well. The protoctists, however, are unicellular microorganisms in which the borders between intercellular communication (as a sector of intraorganismic communication) and interorganismic communication are sometimes blurred. I would like to briefly present one example of interorganismic communication in protoctists.

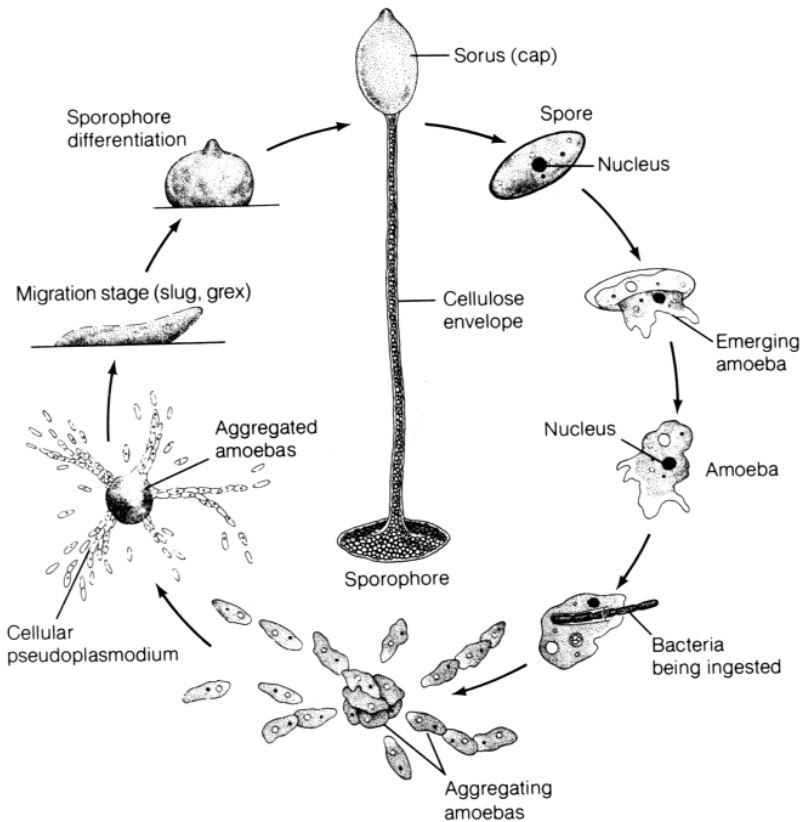


Fig. 30 Life cycle of the cellular slime mold, in which the amebas assemble themselves round a centre. Therefore the slime mold is termed by the scientists „the god of amebas“, because it is obviously a coordination of behavior, but nobody knows how it functions and which signaling processes are involved. (from: MARGULIS/SCHWARTZ, 1988, p. 133)

#### b) Interorganismic communication

Certain protocist phyla contain families encompassing both unicellular and colonial forms. They can develop complex forms of interaction.

For example, the life cycle of a plasmodial slime mold may involve differentiation into a stalk and a sporangium involving a large number of amoebas. The amoeba cells do not divide to form this slime mold structure. Rather, they coordinate their behavior such that some combine to form the stalk while others combine to form the sporangium. The plasmodial slime mold (*no relation to fungi*) therefore superficially resembles a uniform organism, while in reality it represents the structural aggregation of individual amoebas, i.e., rule-governed amoeba behavior.

#### c) Metaorganismic communication

In any event, protocists live exclusively in a liquid medium. Some inhabit the marine environment, others prefer freshwater, while still others are found in the bodily fluids of higher organisms.

Virtually all plants, animals, and fungi live in close association with protocists, either symbiotically or as parasites. Protocists may also feed on bacteria. The abundant supply of bacterial food in the early days of Earth's history enabled this kingdom to colonize the entire planet.

#### 8.2.3.3. The Animals

The first evolutionary differentiation of a new kingdom after the protocist innovation was that of the animal kingdom (MARGULIS & SCHWARTZ, p. 167 f.). It took nearly another 300 million years before the kingdom Fungi developed, and even longer for the first plants to appear.

The animal kingdom is so interesting because it contains the greatest structural diversity. The range of sizes and the many organizational types here are also quite impressive. A microscope is required to recognize the smallest animals, while the largest - the blue whales - belong to the same phylum and the same class (mammals) as humans and can reach a weight of ca. 130 tons as adults.

Most animal species are worm-like aquatic organisms, and the majority has already become extinct. Animals are the only organisms to have successfully invaded the skies. The creativity in constituting new genetic text sequences has given rise to numerous types of flying animals. The Arthropoda („joint-legged animals“) are the largest phyla of all, containing nearly 10 million species (insects). Perhaps the most well-known and familiar representatives of the animal kingdom are members of the chordate phylum, which includes all mammals, birds, reptiles, amphibians, and fishes. This phylum encompasses approx. 45 000 species, all of which stem from aquatic life forms. The presence of embryonic gill slits in all representatives (including humans) underscores this ancestry (ibid.).

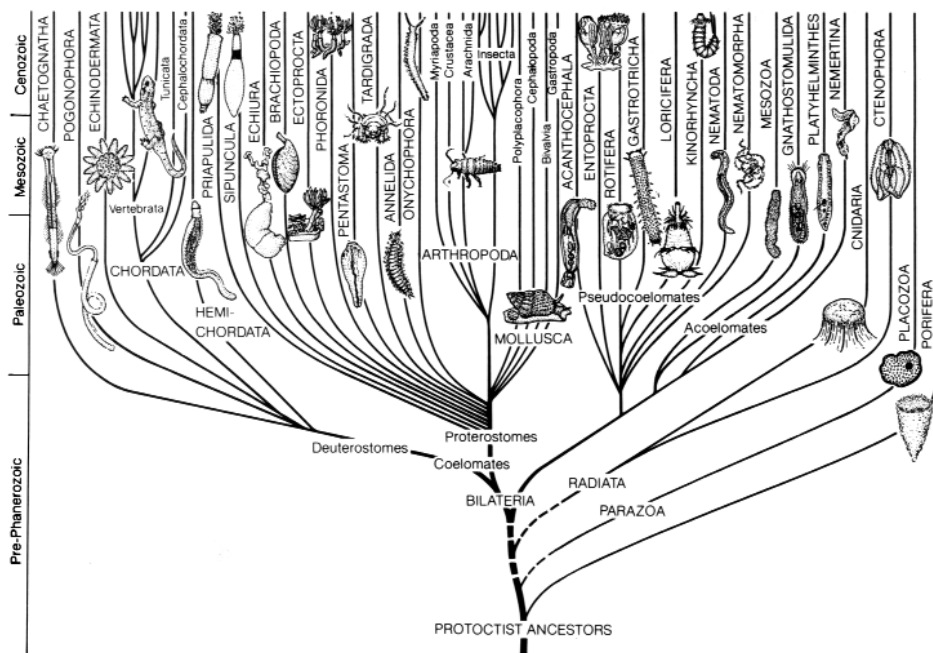


Fig. 31 The Animal kingdom (from: MARGULIS/SCHWARTZ, 1988, p. 168)

#### a) Intraorganismic communication

Intraorganismic communication in the animal kingdom has differentiated life forms that successfully developed many forms of interaction; at the same time, this type of communication is itself specialized for optimizing only a few fundamental reproductive strategies, metabolic pathways, etc. All animals are multicellular organisms that develop through fusion of an egg cell and a sperm cell. This fusion leads to a so-called zygote, which grows and differentiates via mitotic cell division.

The mitoses initially lead - in a manner defined by genetic text sequences that are similar in all animals - to a ball of cells and then to a hollow sphere; the latter character cannot be found in any other kingdom and is considered to be exclusive to animals. In the course of further differentiation, this hollow sphere gives rise to a hollow, tube-like digestive system.

#### b) Interorganismic communication

The animals we most commonly perceive are those belonging to the phylum Chordata, i.e., mammals, amphibians, reptiles, birds, and fishes. This phylum has also developed the most complex types of interorganismic communication. These range from sign-mediated communication in the tactile realm, to electrical, chemical (insects), and ultimately photonic and visual communication.

Signs can be used in two ways, either as a vehicle for mere signal transmission or, in many species, in the form of symbolic sign use. *The sign character of specific behaviors within behavioral sequences is particularly diverse.* This is the result of an intensive, rule-governed social structure which, thanks to the increased movement dynamics and responsiveness that the central nervous system or brain allows, can react very flexibly to the demands placed on it. Such an intensive interactivity is lacking in virtually all other kingdoms and has a corresponding, strong impact on the text-generating processes in the intraorganismic realm (WILSON, 1985); this complementary, dynamic interrelationship has no doubt given rise to a strong complement of text-generating enzyme proteins having text-generating competence (ibid.).

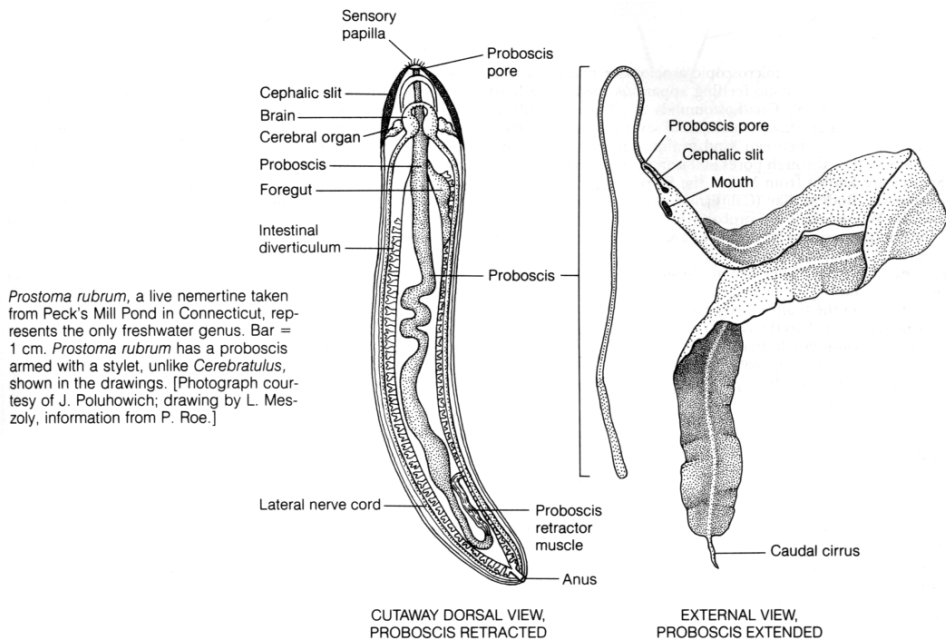


Fig. 32 *Prostoma rubrum*, a typical representative of the animal kingdom  
(from: MARGULIS/SCHWARTZ, 1988, p. 191)

Not only has interorganismic communication taken on its most complex form in the animal kingdom (although the more advanced animal groups first appeared after the evolutionary origins of fungi and plants), but it has also led to life forms whose communicatory competence and performance transcend that of the animal kingdom. This life form - mankind - has differentiated an independent, highly complex cultural evolution as the basis for its further development.

Interorganismic communication in higher animals may also manifest itself as assistance between conspecifics (mutual brood relief in bird species), primitive forms of ritual behavior (burial rites in elephants), or active support for ailing members (cetaceans, primates, elephants); a behavioristic interpretation is insufficient to fully explain these phenomena.



In such cases, pure biological evolution has clearly been transcended in the direction of cultural evolution. These can, *in part*, be genetically coded as behavior patterns and are thus inheritable, although the behavior patterns stem primarily from interorganismic communication and can, *in part*, also be reproduced through social interactions.

#### c) Metaorganismic communication

Animals may feed on other animals or plants as well as on dissolved or particulate organic matter. Highly developed parasitic forms of interaction can occur as well, for example between parasitic worms and more highly developed animals. Symbiotic interactions are particularly well developed here and play a decisive role in living nature (i.e., insect-plant interactions).

Due to its high complexity and dynamics, metaorganismic communication in the animal kingdom provides a dense sensory environment for all other kingdoms. Animals thus exert strong stimulatory potentials both for themselves and for members of other kingdoms. In this manner, they may prompt the evolutionary specialization of intra-, inter-, and metaorganismic communication in countless life forms.

#### 8.2.3.4. The Fungi

The fungi developed from protocists approximately 400 million years ago (MARGULIS & SCHWARTZ, 1988, p. 151f.). These eukaryotes form spores and lack flagella in any stage of their life cycle. The total number of species has been estimated at 100 000. Most are terrestrial, although some have been found in aquatic habitats as well. As inconspicuous as the Kingdom Fungi may seem at first glance, terrestrial plants probably could not have developed without them (ibid.).

##### a) Intraorganismic communication

Fungal spores germinate and grow to form so-called hyphae, which are subdivided by cross walls (septa). Genetic text-processing has given rise to structures unknown in either the animal and plant kingdoms. A larger mass of hyphae form a network termed a mycelium.

Fungi do not undergo embryological development. The spores develop directly into hyphae or, in certain cases, into single growing cells. Rather than ingesting particulate matter, fungi absorb dissolved substances. The fungal hyphae release enzymes into their surroundings: these break suitable food items down into their molecular components (ibid.).

##### b) Interorganismic communication

The dynamic repertoire of fungi is relatively restricted, so that interorganismic communication is limited to a few interactions in key phases of the life cycle. Fungi differ only little from their ancestors, the protocists, with regard to forms of association, colony formation, and other coordinated reproductive and dispersal strategies. On the other hand, the degree

of association and the underlying behavioral coordination is considerably more complex, with the mycelia capable of reaching a length of several meters. Fungi reproduce sexually by conjugation, whereby the hyphae of different mating types contact each other and subsequently fuse. This fusion initially only involves the cytoplasm, with the nuclei remaining separate. The two nuclei in the hypha, one from each parent, can remain separate over longer periods of time, but are present as a pair (*ibid.*). Fungi can also reproduce asexually: they produce spores that can be dispersed over great distances by the wind.

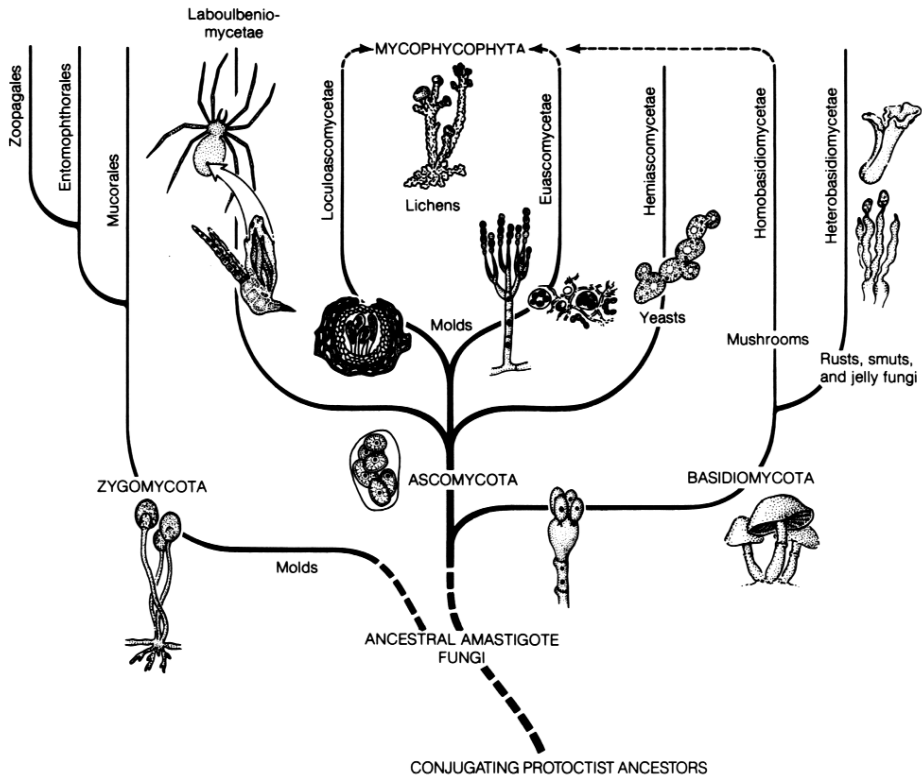


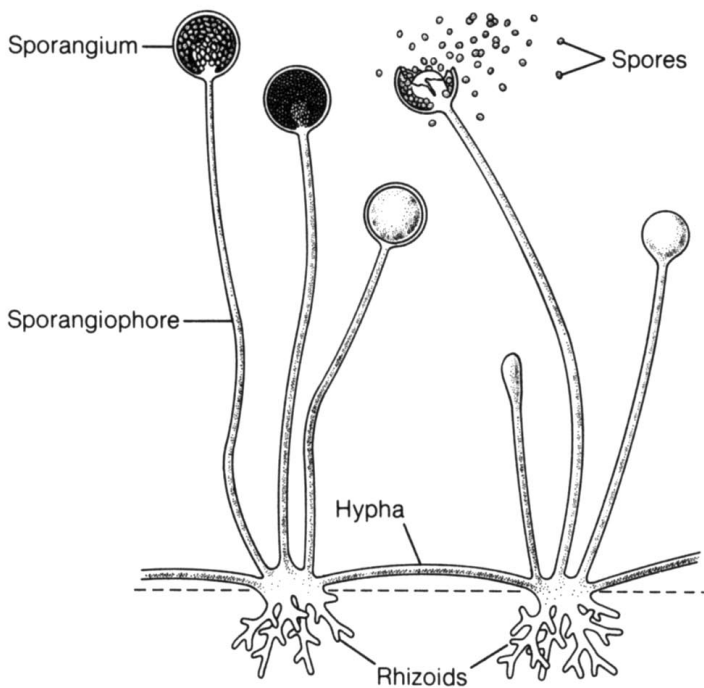
Fig. 33 The organismic kingdom of the Fungi  
(from: MARGULIS/SCHWARTZ, 1988, p. 152)

In the Kingdom Fungi, interorganismic communication between conspecifics is largely restricted to behavior coordination and association via chemical substances that serve as linguistic signs.

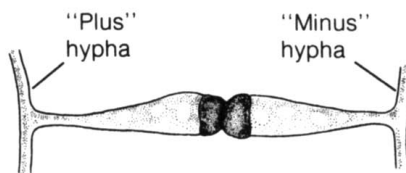
### c) Metaorganismic communication

The metaorganismic communication of fungi is restricted to parasitic or symbiotic interactions. Fungi produce a series of complex organic substances as a defense strategy; these can be very aggressive and even lethal to other organisms. Many fungi are also pathogens, especially in plants (*ibid.*).

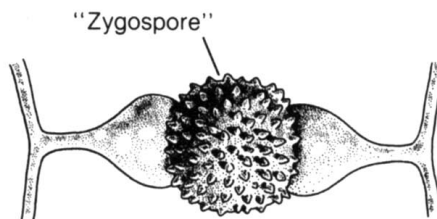




**D** *Rhizopus* sp. [Drawing by R. Golder.]



Conjugating hyphae



**E** Conjugation in *Rhizopus*. [Drawing by R. Golder.]

Fig. 34 The asexual reproduction of *Rhizopus* sp. (from: MARGULIS/SCHWARTZ, 1988, p. 157)

Symbiotic interactions within this kingdom are useful or even vital to a wide range of organisms. Many plants, for example, are known to cooperate symbiotically with fungi in their root systems, where the fungi help process the nutrients. **Forest trees that rely on dissolved nutrients would be unable to survive without fungi.**

Fungi serve mankind in a number of technical-industrial processes, i.e., in producing antibiotics and cheese, baking bread, and in brewing beer. Fossil finds showing fungi intimately associated with plant tissue support the hypothesis that a plant-fungus cooperation enabled aquatic plants to invade terrestrial habitats (ibid.).

8.2.3.5. The Plants

From an evolutionary standpoint, plants form the youngest kingdom within biological systematics (MARGULIS & SCHWARTZ, 1988, p. 257f.). They appear shortly after the fungi in the form of rootless, leafless organisms resembling seaweeds. Their ancestry is comparatively undisputed: they stem from green algae (same complement of photosynthetic pigments, same type of reproduction). As is the case in animals, plants always develop from embryos, i.e., multicellular structures enveloped by maternal tissue. All plants go through a sexual phase that is surprisingly similar and comparable in all phyla of the kingdom.

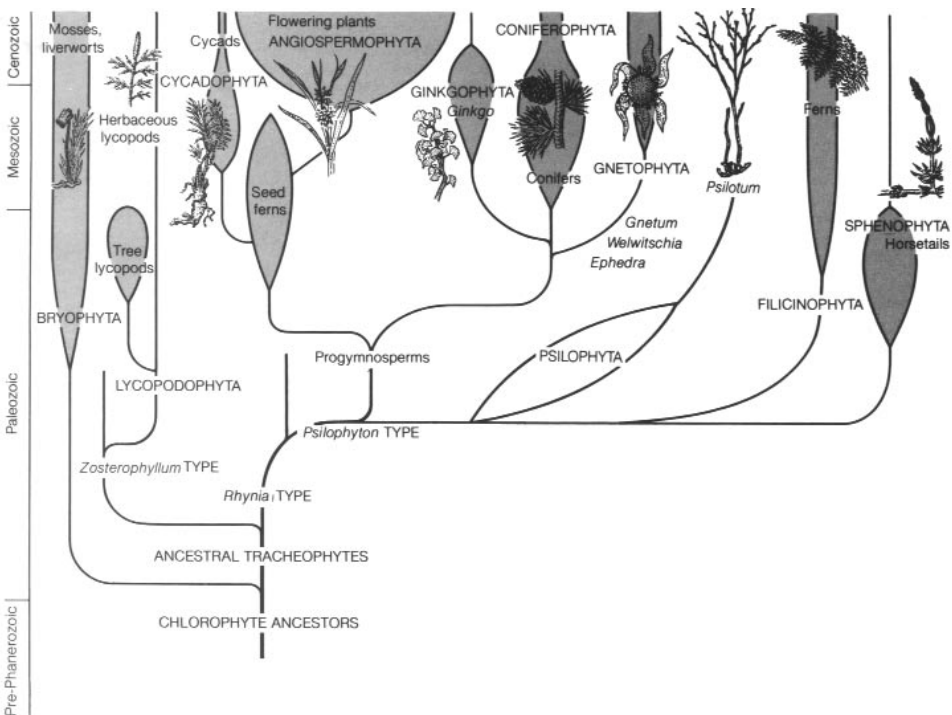


Fig. 35 The organismic kingdom of the plants (from: MARGULIS/SCHWARTZ, 1988, p. 258)

Plants considerably enrich the overall diversity of living nature; their physical presence constitutes an entirely new range of habitats (thus providing the foundation for higher animal life, for example). They encompass ca. 500 000 species, although some estimates are much higher (ibid.).

#### a) Intraorganismic communication

All plants are eukaryotic and possess so-called chloroplasts, i.e., photosynthetic structures that contain green pigments. Photosynthetically competent plants are the most important organisms involved in transforming solar energy and inorganic carbon into organic nutrients. Most plants belong to the so-called angiosperms or flowering plants, rather than to the gymnosperms (which produce naked seeds). Vascular plants and mosses have taken quite different routes in differentiating intracellular communication.

An innovative evolutionary step - the appearance of angiospermous flowering cells - gave rise to plants that bear fruit. This was the prerequisite for an environment that could support mammals.

#### b) Interorganismic communication

Plants form colonies and typically grow in aggregations that include different species, genera, etc. At first glance, or compared with the animal kingdom, their interorganismic communication appears to be quite undynamic and largely restricted to the exchange of chemical substances. This tends to obscure the diversity and complexity of the sign-mediated communication processes that take place here. Plant biotopes are characterized by a permanently coordinated production process in which the waste products themselves are fully recycled. On the interorganismic level, plants have a symbiotic and parasitic relationship with one another (ibid.).

#### c) Metaorganismic communication

As far as nutrient cycles are concerned, plants live in tight symbiosis with representatives of all other kingdoms, i.e., with bacteria, protocists, fungi, and animals (especially insects). This kingdom relies heavily on the diversity of such symbioses. Through its range of biotope-structuring, interorganismic associations, the plant kingdom provides an optimal environment for larger animals. Plants also produce an astounding variety of complex chemical compounds that are not directly required for feeding or reproduction, but that serve to defend the plant against animals, fungi, or even other plant competitors. By releasing such substances into the soil, plants prevent their competition from growing in the immediate vicinity (ibid.).

### 8.2.3.6. The Human beings

While human beings do not represent a kingdom of their own, they do have a unique form of communication. In our attempts to understand living nature, we approach our own species and non-human nature in a different manner. Any attempt to comprehend our-

selves as living beings is an expression of our own self-understanding (Selbstverständnis). *It is by understanding ourselves that we understand humanity.*

This understanding is based on and imparted by our expressions, actions, interactions, thoughts, etc.; in certain cases we are able to specify the laws underlying this understanding, that is we are in a position to comprehend this understanding as a *form of action* (transcendental-reflexively) and not merely as a form of behavior (empirically).

Mammals originated approximately 200 million years ago, and one of their orders encompasses the primates (100 million years ago). The primates themselves differentiated into two suborders, the prosimians and the true apes. The latter also gave rise to the anthropoids (hominoids). The hominoids, in turn, gave rise to the pongid and hominid families. According to current knowledge, the species *Homo sapiens* is ca. 120 000 years old and is the direct ancestor of modern humans, whose present brain size was differentiated about 35 000 - 40 000 years ago.

It is absolutely justified to place humans into the animal kingdom; after all, the DNA of chimpanzees and humans differs by a mere 1.2% (GHIGLIERI, 1985).

#### a) Intraorganismic communication

Our intraorganismic communication is closely related with that of primates. Nonetheless, the intraorganismic communication of humans split us off from the hominoid phylogenetic tree, and our brain differentiation enabled the organization of our many skills and abilities. This pertains to our linguistic development, our ability to communicate, and our use of reason in linguistic expressions, all of which so clearly differentiate us from the primates. Today, we understand ourselves to be very highly evolved living beings.

The genetic text processing involved in the respective intraorganismic communication is equally highly evolved:

„Quality control: No technical production system, regardless how perfect, even approaches the low error rate achieved in the DNA reproduction process in living organisms. This degree of precision is vital for humans as well: even a single mistake in the transmission of hereditary information can have lethal consequences, as for example in sickle cell anemia or cancer. In the course of developing from a fertilized egg to an adult human being, the three billion letter pairs of the human genome are reproduced nearly a quadrillion times. These orders of magnitude underscore the monumental scale of the task involved in correct transmission. An error rate as low as one in a million would still mean ca. 3000 mistakes per transmission: normal development would be impossible. Three enzymatically controlled processes are responsible for suppressing errors during the reproduction of the genetic text. Polymerases are responsible for selecting the correct letters, i.e., the nucleotide building blocks for the new DNA strands, while exonucleases are responsible for rejecting damaged letters. After these two steps, the error rate is reduced to one in ten million. The third and decisive step - correcting mistakes in the overall manuscript - is far more complex. Several proteins work hand in hand in this process. They recognize and excise sites in which the letters of one strand do not fit with those of the complementary

strand. The missing piece is completed by polymerases. After this final quality control step, the error rate is reduced to a mere one in ten billion“ (from: SPEKTRUM DER WISSENSCHAFT, 1988, vol. 9, p. 119).

This description of how the efficiency of intraorganismic communication is optimized in reproducing the genetic text clearly demonstrates that the text-processing competence of cooperating enzyme proteins has reached its evolutionary epitome in humans. („Hamilton draws our attention to the circumstance that the highest degree of cooperation does in fact take place in colonies of genetically identical cells such as those that form the human body“; SMITH, 1978)

## b) Interorganismic communication

Interorganismic communication between humans differs considerably from that between animals. Numerous independent scientific disciplines have shed more light on interorganismic communication than on all other types of human communication. Not only the philosophy of language, but also linguistics and (human) semiotics has provided comprehensive information about human language use and its rule-governed, sign-mediated interactions.

The specific human capacity for language and communication enabled mankind's development along a culturally derived pathway. „Despite many imaginative studies, the origin of man's language ability remains a mystery. Fossil remains also fail to provide any clues, although language was probably the decisive factor in accelerating human evolution“ (WASHBURN, 1978).

Brainpower enabled mankind to develop what we refer to as language (reason, consciousness, abstract thought) and to evolve a normative (moral) value system (which is no doubt in part also culturally determined) through coordinated action and associational activity. This value system is not inherited biologically, but rather reproduced or passed on from the older to the younger generation of a social and cultural community through spoken and written tradition as well as by role model.

In the case of eating habits, for example, this gave rise to culturally quite diverse customs. Some cultural communities are exclusively vegetarian, while others eat great quantities of meat; in short, what some consider to be a delicacy is strictly rejected by others (e.g., pork).

Approximately 5000 different languages are currently recognized. They represent evolved cultural traditions and tailored lifestyles that humans - as social creatures - have differentiated. Each of these cultural communities has a unique approach to maintain in its cultural traditions. Our social life pits religious, ritual, and mythological moral values and norms against the universalized, modern values of the techno-scientific, „enlightened“ society. What makes us unique is our level of interorganismic communication; precisely our ability to reflect upon this clearly reveals that language and communication serve not

only to perceive and regulate the structure and organization of social life, but especially also to change, expand, and transform it.

Interorganismic communication in humans encompasses everything we need in order to formulate mankind's understanding of itself.

#### c) Metaorganismic communication

When communicating with individuals of other species, humans operate within the framework of a culturally predetermined set of values. They use technical means to subjugate non-human nature, utilizing „natural resources“ to achieve predefined short-, medium-, and long-term objectives. We are the only creatures to direct our exploitative interest to members of virtually every kingdom of organisms (prokaryotes/bacteria: sewage treatment plants, pharmaceuticals, etc.; protoctists: medicaments; animals: meat production; fungi: antibiotic cultures, bread baking, cheese production, beer brewing; plants: plant cultures).

Since mankind's development is strongly oriented according to cultural values and norms, human reason should be applied to consider the consequences of our actions, for example on the future generations of all biological species. The rampant increase in potential technical threats endangers the very existence of living nature and calls for actively exercising our ability to reason. Massive and potentially irreversible impacts on the complementary interactions and functions *between* and *within* the various kingdoms endanger both the cultural and biological reproductive ability of the human species as a whole.

No other threat in Earth's history has ever endangered the overall biosphere as much as our technological and scientific activities. Mankind must therefore solve the crisis it has rigged by (a) altering its cultural values and norms and (b) altering those activities and agendas based on antiquated concepts. Should such a coordinated response lag too far behind the problem-solving imperative, then the adage that „humans are the crown jewel of evolution“ may well be reversed to read „humans are the bane of evolution“.

#### 8.2.4. The interrelationship of communication forms. The adaptation of Nicolai Hartmann's theory of levels in the philosophy of language sense

The formulation of 6 communication forms is an approach that allows all organisms to be arranged into natural phylogenetic groups - expanded by the human element - and allows these biological groups to be characterized with regard to the 3 types of communication inherent in all life forms.

The following *outline* presentation of biological systematics (as expanded in the language-philosophical sense) is per definition *programmatic* in character and does *not* purport to exhaustively categorize the actual, real communication processes in the respective phyla, orders, classes, families, genera, and species in the various kingdoms. Such a presentation should be entrusted to the individual scientific disciplines and their highly

specialized methodologies, for example biolinguistics and the biosemiotic disciplines envisioned above; these disciplines would then constructively integrate their contributions into a „theory of communicative nature“.

The representation of the six communication forms of nature, along with its reference to the evolutionary aspect, drew attention to the fact that, at the dawn of life, a relatively simple form of communication sufficed to give rise to a wealth of microscopic life forms; the differentiation of all subsequent organisms produced increasingly complex communication forms, all having a complementary relationship with one another.

From an evolutionary standpoint, the history of living nature is therefore a development from simple to complex forms of communication, from simple to complex organisms, yet without destroying or replacing those simpler forms. The evolution of new biological species is an extremely complex event not only for the new organisms themselves, but also for the extant species forced to adjust or adapt to the presence of the new forms, i.e., to develop and optimize rules of communication.

Ever since Aristotle's time, natural philosophy has striven to categorize observable differences. The result was a string of concepts that might be termed theories of levels. One of the latest versions is that forwarded by Nicolai Hartmann and brought up to the scientific standards of the late 1950s (HARTMANN, 1964).

He distinguishes 4 levels of being, the material, the vital, the psychic, and the mental, and determined the characteristic features of each of these levels. This concept is part of a philosophical ontology. I do not wish to go into this ontology and its associated problems in more detail here and will not structure my conception of the communication forms in nature around an ontological theorem. Nonetheless, Hartmann's blueprint characterized the interrelationships between his levels through so-called theory of levels („Schichtenlehre“). In my opinion, Hartmann's „laws“ offer - on a provisional basis - an absolutely *useful orientation* in determining the relationship of the communication forms to one another. I would like to begin by briefly summarizing Hartmann's Schichtengesetze and examine whether they are suitable - within the framework of a philosophy of *biology that is oriented according to linguistic pragmatics* - to determine the interrelationships of the communication forms:

1) Law of autonomy: According to Hartmann, each layer of being is autonomously structured and the genesis of this autonomy cannot be fully derived from the next lower level. The spiritual realm is therefore autonomous from the psychic realm, the psychic realm from the vital, and the vital from the inorganic realm. In Hartmann's opinion, this does not necessarily mean that the mental realm lacks psychic elements, the psychological realm vital elements, and the vital realm inorganic elements; rather, it emphasizes that each of these layers features inherent laws that can be found here and only here. Hartmann recognizes two subordinate laws in the framework of this law of autonomy:

1a) Law of novelty: In each higher layer, features appear which are lacking in the next lower layer. These features represent a novelty - something new compared with the lower



layer. Such new elements are neither a logical consequence in the development from the lower to higher layer nor can they be fully derived from the former.

1b) The law of modified, recurrent features: The laws of the lower layer reappear in the higher layer (never vice versa; semicompatibility), but in a modified manner. Specifically, the laws of the lower are structurally and functionally integrated into the higher. For example, the laws of the inorganic layer re-occur in the vital layer, but under the organizational principles of the vital layer, i.e., in a constellation unknown at the inorganic layer.

2. Law of dominance: The laws specific to a layer do not merely govern that layer. Within the overall organism, every higher layer acts on all layers below it, without dismantling or negating them. Humans, for example, possess a vegetative nervous system whose function is largely independent of mental activity. This mental activity, however, can influence the psychic state and, by destabilizing it, have an effect on the vegetative nervous system (similar to auto-suggestive techniques).

3. Law of dependence: Each higher layer is neither poised above, nor determined by the lower ones, although a certain dependence does exist. The mental layer functions on the basis of the psychic, this on the vital, and the vital in turn on inorganic substances. In the case of comatose patients, the vital layer and the vital organization of the inorganic matter comprising the body continues to function, but the psychic and mental is eliminated.

4. Law of distance: Due to the new, defining quality of a layer of being, Hartmann recognizes a „metaphysical discontinuity“ rather than actual transitions between the layers. While advocates of approaches based on the continuity theory have always postulated such transitions, no actual transitions have been found or convincingly reconstructed in the field of paleontology. According to Hartmann, nature progresses in discrete steps.

Independent of Hartmann's ontological theory of levels (Schichtenlehre), my thesis is that these laws of layers are applicable as structural features of the six forms of communication. *Here, they do not define ontological laws, but fundamental, formal-pragmatic rules governing the interrelationship of the communication forms*; these rules are constituted by communicating individuals that produce these communication forms using the 3 communication types. Using sign-mediated communication, nature evolves from simple to complex, complementary life forms; in doing so, it produces such fundamental formal-pragmatic rules. The linguistic and communicative structure and organization of nature are the very factors that enabled the differentiation of ever more complex kingdoms whose interrelationships reveal such underlying rules.

Hartmann's theory of layers (Schichtenlehre), in its adaptation to a philosophy of language, is not only useful in determining the interrelationships between the communication forms in nature. It can also serve to describe cultural evolution and human self-understanding - a point that I believe deserves mention here. Thus, clear analogies to progress in scientific knowledge, e.g., to „the structure of scientific revolutions“ can be discerned (KUHN, 1970).



At this point I wish to briefly outline the *semicompatible relationship between the communication forms* in nature. This draws attention to the fact that a linguistically and communicatively structured and organized living nature had to develop fundamental formal-pragmatic rules for its own differentiation; this is the only strategy capable of preventing more highly evolved features from being dismantled while at the same time enabling the abilities acquired in one kingdom to be effective in more highly developed kingdoms as well.

Ilya Prigogine adamantly pointed out how decisive this irreversibility in the differentiation of biological processes is (PRIGOGINE, 1980; PRIGOGINE & STENGERS, 1984). On the other hand, the insight that this irreversibility is the consequence of producing and adhering to such fundamental formal-pragmatic rules is an inherently language-philosophical hypothesis.

### 8.3. Delimiting the communication forms from one another

In the following, I categorize - in outline form - living nature from the perspective of the 6 fundamental forms of communication; the goal is to more closely define the interrelationships between these bauplan types, which modern taxonomy recognizes as the expression of genetically fixed units termed kingdoms.

Each individual of every biological species can be viewed as the expression of a genetically defined bauplan. As demonstrated in earlier chapters, this expression is the result of complex intra- and intercellular communication processes. Six *fundamental types* of such intraorganismic communication processes have evolved in the history of living nature; according to my thesis, their relationship with one another is semicompatible.

Even though all forms of life are more or less closely related to one another from the evolutionary standpoint, the individual kingdoms are differentiated by unmistakable features with no common denominator. Each kingdom has given rise to truly **new** forms (including humans as an independent communication form) that do not gradually build upon and *cannot* be defined exclusively by existing forms. Thus, the advent of prokaryotes, whose defining feature is the nucleic acid language, does not represent a gradual development of randomly strung together amino acids and protein components. Equally, the origin of eukaryotes was an original and **truly novel** event in living nature: it reflects a type of intra- and intercellular communication lying *beyond* the capabilities of prokaryotes. The development of the animal, fungal, plant kingdoms and, ultimately, of humans, also represents something **truly new** in living nature, something that other kingdoms lack in this shape and form.

At the same time, each newly developed kingdom contains organization forms and structures of the kingdom **(I) from which** it arose. Furthermore, all kingdoms are subject to determinants anchored in laws of nature governing the prebiotic level. In certain respects, all kingdoms are also **(II) dependent upon** interactions with others: thus, plants for example provide an optimal habitat for many other organisms, while at the same time being highly dependent upon prototists, bacteria, fungi, and animals (above all insects).

This „recycling“ of the organizational and structural features of „lower“ kingdoms is not what defines a particular kingdom. Rather, their novel element **(III) dominates** their form and function. The organizational and structural features of each less complex kingdom can be found in the more advanced kingdoms it gave rise to, **(IV) never vice versa**: the kingdom-specific structural and organizational features are precisely those that are not found in the lower one. This defines the semicompatibility of the communication forms: *each more highly developed or autonomous form of communication can incorporate features of the lower ones, but the lower never dominates features of the higher one.*

Ultimately, human beings are the only creatures capable of using *all* non-human communication forms in a technically compatible manner - a feat no member of any other kingdom can duplicate. The result, despite the great variety of communication forms, is an **unbridgeable (V) gap** between the various kingdoms and the human race. Transitional forms in the true sense are also missing.

All organisms can be clearly arranged into one kingdom or the other. Even in the step from our closest predecessors to modern humans, all conceivable transitional forms have become extinct, leaving no mixed or ancestral forms. The result: a human race which differs distinctly from animals. Ultimately, the most common denominator of all life forms is the nucleic acid language. The variations described below merely document the incredibly varied **forms of „expression“** that this language gave rise to. The differentiation itself, however, called for concrete *communication processes between real, interacting individuals.*

### 8.3.1. Precommunicative interaction level

Interactions between inorganic compounds are generally described by physical and chemical „natural laws“. These so-called laws govern the inherent properties of bonds and building blocks at the subatomic, atomic, and molecular level and define such properties in the form of conservation theorems of physics, for example the law of conservation of energy, of momentum, or of angular momentum.

This level of rules governing the interaction of inorganic matter (to name only the most important ones) includes the law of gravity, the second law of thermodynamics (entropy increases constantly), the general and special theory of relativity, electrodynamics, and optics. In a broader sense, this level encompasses every law that helps describe those physical-chemical processes whose rule-governed interactions **do not involve** the molecular genetic code (as the organizational form of biological self-reproduction).

***Natural laws are explanatory models*** with statistical character, i.e., with the character of probability. *They themselves are not what moves the world, but are merely rules that humans attempt to extract from their observation of events, specifically in an interpretational process.*

Even today, the quantum theory ranks as the most important natural law ever advanced by science. Interestingly, the physicist R. Ebert pointed out an analogy between the quantum

theory and language comprehension. This was summarized as follows by Hermann Krings: „The assumption of a complementarity in the properties of quanta, the non-objectification of elementary particles, the restriction of precise conclusions to probabilities (rather than determinability), and the meaning of information indicate that our understanding of elementary natural phenomena shows analogies to comprehension in the realm of language“ (In: KRINGS, 1982, p. 388).

The precommunicative interaction level was formed by a wealth of subatomic, atomic, and molecular structures and dynamic processes; these constituted specific molecular compounds that the earliest life forms were able to use to structure their own bodies as well as to develop their survival and reproductive strategies.

In my opinion, the border between the animate and inanimate, between the random arrangement of nucleic acids or amino acids and the functions of a self-reproducing protein individual, *lies in the difference between non-communicative and communicative organization*. The inorganic level produced macromolecules and all the nucleic acids, amino acids, and polypeptides necessary to constitute living organisms, but did not itself give rise to the first life forms.

***There is no seamless transition between the pre-grammatic (and thus fundamentally pre-semantic) laws governing the combination of molecular structures on the one hand, and pragmatically interacting, self-organizing protein individuals (much less living cells) on the other hand.***

While the self-organization of these protein individuals is, in fact, subject to such pre-grammatic and pre-semantic laws, the proteins transpose the laws into a grammatic and semantic dimension that would be principally inaccessible if protein individuals did not exist. Real organisms are a prerequisite for the language of nature to actually become language.

Scientists from various disciplines, for example evolutionary theory, biochemistry, and molecular biology, are busy probing the divide between the animate and inanimate; their approach involves a definitional convergence in the way we interpret what *still* belongs to the prebiotic and what *already* belongs to the biotic realm.

One such definitional approach was the proposal to already designate the formation of polypeptides or the molecular structures of amino acids and nucleic acids as life (EIGEN et al., 1981, p. 78 f.). In this case, the artificial polypeptides as well as amino acids and nucleic acids that have been produced in experiments would have served as proof that life can be created artificially. However, such „building blocks of life“ clearly lack the typical features of even the simplest life forms.

***As envisioned in my concept, the successful (i.e., reproducible) use of a simple form of nucleic acid language distinguishes life from non-living matter.***

This language is a prerequisite for sign-mediated communication processes in the molec-

ular realm - processes which are passed on (in the form of rule-governed interactions) when a cell divides into two and can enable the ongoing reproduction of the first individual in the descendants. The behavioral coordination and association between the simplest organisms - based on sign-mediated communication processes - only superficially resembles other interaction forms such as the inorganic differentiation of crystals („mineral associations“; SCHOPF, 1978); in fact, these two processes are fundamentally different.

### 8.3.2. Communicative levels of interaction

#### 8.3.2.1. The Prokaryotes (bacteria)

1. Law of autonomy: The simplest and oldest life forms from the evolutionary standpoint, the prokaryotes, have structural, organizational, and coordinational features that are missing in the precommunicative level.

1a) Law of novelty: Prokaryotes possess a genetic text in which the bauplan as well as the execution of the bauplan and the functions of the unicellular organism are anchored. The structure of the nucleic acid language alphabet underlies the same rules that also govern the constitution of all other organisms. Bacteria carry out metabolic activities and reproduce. The energy fueling this metabolism stems from their ability to carry out chemo- or photosynthesis. Further characters include a cell membrane, a cell wall, and a DNA nucleoid.

“A living cell has two decisive abilities: it can metabolize and it can reproduce. From the short-term perspective it survives by rearranging the atoms and substances it takes up, giving rise to molecules that it needs for its vital functions. In the long-term, it survives by reproducing itself and giving rise to descendants with biochemical capabilities identical to its own“ (DICKERSON, 1978).

All these features, packaged in this organizational form, are **missing** at the precommunicative interaction level. This organizational form was introduced into prokaryote communication by the nucleic acid language (which is nonexistent *as* a language at the precommunicative level).

1b) Law of modified, recurrent features: All rules of the inorganic level are also valid in the realm of prokaryotes. They are integrated into this level, with all prokaryote communication processes relying on the laws of the precommunicative level. The production of the various protein species is subject to the chemical and, above all, the physical laws governing molecular bonds. Every communication process follows the path of the least energy consumption and the least resistance („golden compromise“). Thus, the way in which various protein structures are produced in no way contradicts the electrical forces underlying the structure of molecules and their interrelationships.

2. Law of dominance: The communication types of prokaryotes do more than merely regulate biological processes. The use of sign-mediated communication processes funda-

mentally alters the structure of biological versus inorganic processes. The former are therefore newly combined (in accordance with the laws of the precommunicative interaction level) through the organizational form of the simplest unicells; they are integrated in an organizational process that would never have been possible without such laws.

3. Law of dependence: While the communication form of prokaryotes fundamentally transcends the bounds of the precommunicative interaction level (through the introduction of the nucleic acid language alone), the prokaryotes could not have arisen and developed without the precommunicative interaction level. The full range of molecular structures and the various types of bonds between them provide the basis for the origin and subsequent optimal growth of prokaryotes.

4. Law of distance: There is an **unbridgeable gap** between the precommunicative interaction level and the prokaryotic communication form, i.e., that between the animate and the inanimate. Viruses, which are generally not classified as living organisms (MARGULIS & SCHWARTZ, 1988, p. 14 f.) and which can even crystallize if their habitat dries out, reproduce exclusively in host organisms. They employ different strategies for their reproduction, all of which function on the basis of the nucleic acid language. Based on this fact, viruses are probably later differentiations of (very simple) predecessors of bacteria: if viruses need a host organism, how could they have reproduced themselves - as a transitional form from the non-living to the living - at a time when host organisms most certainly were not present?

#### 8.3.2.2. The Protoctists

1. Law of autonomy: In the field of biological research, the **evolutionary step** from the prokaryotes to the eukaryotes is considered to be the **most significant advance** in living nature. This transition from anucleate to nucleate cells does, in fact, represent a differentiation and development that provided the basis for the evolution of all more complex organisms.

1a) Law of novelty: The first eukaryotic forms, the protoctists, are characterized by cellular respiration and a more complex inter- and metaorganismic communication than the prokaryotes would ever have been capable of. While the metabolic diversity and thus the intraorganismic communication in prokaryotes is more varied, protoctist specializations go far beyond prokaryote capabilities. New protoctist features include the development of a true cell nucleus and the differentiation of microtubuli, which serve as the cell's energy-exploiting and storage structures.

1b) Law of modified, recurrent features: The first eukaryotes no doubt developed from the prokaryotes and possess numerous features that can also be found in the latter (nucleic acid language, cell membrane, behavioral coordination, formation of associations). On the other hand, eukaryotes possess true chromosomes, a true nucleus with its own membrane sheath, and more complex forms of behavioral coordination and association (see plasmodial slime mould example, MARGULIS/SCHWARTZ, 1988, p. 133)).

2. Law of dominance: The radiation of eukaryotic microorganisms and their relatives, the prototists, replaces neither the structural and organizational features adopted from the prokaryotes, nor the prokaryotes themselves. Within the eukaryotic level of organization, however, the typical eukaryotic interorganismic communication dominates, and the prokaryotic features are clearly overridden.

3. Law of dependence: The life histories of eukaryotic and prokaryotic microorganisms are not mutually exclusive, even though the differentiations of prototists far exceed those of the prokaryotes as far as the complexity of their abilities is concerned: the global success of prototists would not have been possible without the ubiquitous presence of prokaryotes. These served and continue to serve as food for prototists: the latter could never have survived without the former.

4. Law of distance: No transitions exist between prokaryotes and prototists. Unicellular organisms can be divided into those having and those lacking a true nucleus, those with or without cell respiration, and those with true chromosomes or with genophores, which differ distinctly from chromosomes. The communication form of prototists is a truly novel entity, an independent kingdom.

#### 8.3.2.3. The Animals

1. Law of autonomy: From an evolutionary standpoint, the animal kingdom most closely followed upon the prototists; it clearly arose from the prototists. This kingdom is characterized by a broad spectrum of organizational types and by a number of very large life forms. Both intra- and especially interorganismic communication have reached their most complex level of differentiation here.

1a) Law of novelty: All animals are multicellular organisms that have developed by the fusion of an egg and a sperm cell. Only animals possess a hollow, tubular digestive system. Intercellular communication in animals is by far the most complex in all kingdoms; it finds no equal elsewhere. This communication enabled the development of species-specific cell associations, i.e., organs. These, in turn, have differentiated an *interorgan communication* unique to this kingdom, one guaranteeing that even rather large individuals function optimally. A prerequisite for developing such specific animal organs was the creation of the three tissue layers typical for this kingdom. Another innovation in the animal kingdom involves ***nerve cells and brain tissue***: this initiated entirely new and much more rapid communication processes that were a precondition for highly efficient, coordinated movement in larger organisms.

The differentiation of highly complex behaviors in behavioral sequences, which can take on sign character within species-specific life-worlds (Lebenswelten), is the rule in the animal kingdom. The range spans from the use of simple signals to the constitution of signs with symbol function. Even the ability to transcend purely parasitic and symbiotic, metaorganismic communication - up to and including early forms of ritual behavior - is the norm in the realm of more highly evolved animal species.

None of these characters can be encountered in the preceding developmental levels. The animal kingdom is a discrete, new evolutionary stage.

1b) Law of modified, recurrent features: Animals also possess a nucleic acid language and a eukaryotic lineage; they also coordinate their behavior with conspecifics in a commonly shared environment and form associations.

2. Law of dominance: All prokaryotic and protocist communication processes, which are also present in animals, are subordinated to the communicative features that distinguish the animal kingdom from others, i.e., that characterize its novelty.

3. Law of dependence: The animal kingdom and its key communicative features would never have arisen without the prior developments at the prokaryote and protocist levels. Furthermore, the animal kingdom could not survive today without the existence of lower kingdoms of organisms. For example, the digestive process in animals cannot function without bacteria. Despite a communicatory ability that by far exceeds that of lower kingdoms, animals still depend on symbiotic, metaorganismic communication with prokaryotes and protocists.

4. Law of distance: No transition forms exist between protocists and the animal kingdom. A differentiation between the two is principally possible since animals possess communicative features missing from the protocists (e.g., brain lobes).

#### 8.3.2.4. The Fungi

1. Law of autonomy: Fungi appeared after animals and before plants. They are characterized by communicative features missing in all other kingdoms. Fungi absorb dissolved food.

1a) Law of novelty: Although fungi also stem from protocists, their communicative differentiations in the realm of feeding and reproduction differ fundamentally from those of all other kingdoms. The mycelial life form is truly a novel feature that protocists were never able to develop either geno- or phenotypically.

1b) Law of modified, recurrent features: Certain communicative features in the fungi are also present in the protocist kingdom, especially in the realm of food uptake.

2. Law of dominance: The feeding mechanisms that fungi share with the protocists are subject to the intraorganismic communication specific to fungi; this includes mycelium formation as an intraorganismically coordinated form of association and also includes the interorganismic fungal communication involved in reproduction via the fusion of hyphae.

3. Law of dependence: As was the case in animals, fungi could never have arisen without earlier protocist development. While fungi differ fundamentally from both protocists and animals, the prokaryotes and protocists provided the communicative cornerstone



upon which the fungi were able to develop by creating new genetic texts. As opposed to the animals and plants, symbioses between fungi and prokaryotes and protocists are less vital.

4. Law of distance: There are no true transitional forms between protocists and fungi. Certain candidates in the literature are merely the result of poorly differentiated descriptive processes by individual biologists. For example, a number of scientific disciplines continue to designate certain species of protocists as fungi, even though they completely lack a key character of the fungal kingdom, namely the multicellular, eukaryotic communication form.

#### 8.3.2.5. The Plants

Law of autonomy: The most recent kingdom is that of the plants. It stems from protocists, specifically from the green algae. It was the strong radiation of plants that provided the trophic basis for the differentiation of higher forms of animal life.

1a) Law of novelty: As opposed to all other kingdoms, plants possess chloroplasts with which they produce organic building blocks and food from sunlight and inorganic carbon. Their great diversity of forms characterizes Earth's landmasses and fundamentally distinguishes this kingdom from all others. Plants play a decisive role in structuring specific habitats. Plants also form unique and highly complex metaorganismic communication links with fungi and animals (especially insects).

1b) Law of modified, recurrent features: More than most other organisms, plants adhere strictly to precommunicative interaction rules in developing their diversity of shapes and forms („golden compromise“). Plants have cell walls and DNA as do prokaryotes, and nuclei as do protocists. Nevertheless, they differ fundamentally from these predecessors: they are multicellular and all of them pass through a developmental stage that involves an embryo.

2. Law of dominance: The communication processes and communication form inherent to plants build upon the communicative features of earlier kingdoms. Typical plant features (a cell wall consisting of cellulose) enable the differentiation of communication types that distinctively orient and restructure all the adopted ancestral forms to fit typical plant communication forms, expanding them by a dimension specific to plants.

3. Law of dependence: By their nature, plants provide an optimal habitat for other organisms; at the same time, they are highly dependent on the functional ability and functional diversity of lower kingdoms as well as of the fungi and animals (insects). This dependence is rooted above all in the realm of metaorganismic communication.

4. Law of distance: Although plants clearly arose from protocist green algae, the plant kingdom is fundamentally different from all remaining kingdoms. Close transitional stages no doubt existed between protocist algae and the first plants. Nonetheless, plants form embryos in the course of their development and are multicellular, features that are beyond the capabilities of protocists.



### 8.3.3. The human communication level

1. Law of autonomy: While humans have descended from the animal kingdom, we have grounds to believe that both our past and current development has taken us in a direction that clearly sets us apart from ancestral forms.

1a) Law of novelty: Humans have developed forms of interaction unknown in the animal kingdom. We use the probably most complex of all languages along with conceptual thought and foresighted actions even over lengthier time spans. In short, we are dealing with a **culturally determined genesis of norms** that biological considerations often fail to explain. Humans are set apart in the choice of means with which they pursue their goals, and they also reflect and confer on the process. For example, we can choose between actions designed to communicate and those that merely serve a strategic purpose. Humans can converse with one another and discuss that very conversation, i.e., they can *effortlessly switch back and forth between a formalized artificial language and their ultimate metalanguage, colloquial speech (Umgangssprache)*.

In their cultural differentiation of religions, humans have developed a broad spectrum of norms to govern their actions. Ultimately, humans can be described as beings that are anchored in their instincts but have the gift of reason. Art and craftsmanship are typical human abilities. As opposed to all other organisms, mankind makes every other form of non-human communication technically compatible. A range of communicative traits that cannot be derived from animal behavior appears in humans. The use of reason (a typically human trait), along with the different types of rationality that have been developed by the various cultural groups, cannot be found in any other kingdom and represent a true novelty.

1b) Law of modified, recurrent features : Humans continue to follow their (reduced) instincts, and those behavioral habits that have not been consciously planned and executed can relatively easily be traced to our close relatives in the animal kingdom. Psychological reactions such as aggression, fear, grief, pleasure, and numerous social behavior patterns can be found in slightly modified form in primates. Early forms of human social structures, such as those exhibited by hunter-gatherers, have been extensively documented in chimpanzees (GHIGLIERI, 1985; SMITH, 1978).

2. Law of dominance: Every type of behavior that we have inherited from primates has been integrated into behavioral contexts embedded in the cultural norms of culturally defined communities. Cultural norms are norms that have no biological/genetic basis. Rather, mankind imposes them on itself: it formulates them linguistically, generates them, and then adheres to them. The novel element in humans - their typical competence in language and communication - largely determines the structure of social interactions.

3. Law of dependence: Humans would never have developed without the development of primates. In unfolding our unique human quality, we are constantly confronted with relict primate instincts. Despite having developed the highest form of linguistic and communicative competence of all living beings, we rely much more heavily on the existence and complementary functions of other kingdoms than vice versa. Our survival without living,

non-human nature would be doubtful; conversely, the only effect that our extinction would have on nature is that 1000 species less would become extinct every year due to human activity.

4. Law of distance: There are no true transitional forms between primates and humans. Even the interpretation of archeological finds and their comparative analysis has failed to reveal a „missing link“. Definitional shifts have been introduced in order to circumvent this inconsistency in continuity theory, specifically regarding the timepoint at which a find can be interpreted as being typical for the genus Homo: again, this merely involves definition changes. In fact, there is an unbridgeable difference between the communication form of primates and that of humans.

8.4. Using the semicompatibility of nature's communication forms to systematically define kingdom-specific, sign-mediated communication processes

Arranging phylogenetically related groups of organisms into kingdoms represents a form of scientific systematization. Equally, systematizing the relationships among nature's communication forms also represents an orienting, **programmatic** endeavor, one that is necessary for detailed investigation of nature as a linguistically and communicatively structured entity .

The explication of the semicompatible communication forms of nature will serve to highlight the **most important steps taken in the evolution of life as far as the creation of genetic texts is concerned** (genotypic or molecular semiotics level); it will be equally in highlighting new kingdoms. In fact, each organism differs from all others through its characteristic individuality. Even organisms with the same genetic complement (so-called clones) are not identical to one another. For example, the layout of the finest vein networks in animals is determined by pragmatic, physiological rules rather than the genetic text.

Inasmuch as all organisms are members of a shared social environment and have an interlinked social history based on their phylogeny, reproduction, and species-specific interactions, they share rules pertaining to the three communication types. These rules define and govern behavior. This enviro-centric perspective and this focus on the life forms of biological species (especially as it pertains to members of one and the same biological species) leads to a systematization within the communication forms of nature.

***Communication forms represent systematizations of evolutionarily variously expressed genetic potentials, none of which can be reduced to any other form, each being characterized by key, new structural and organizational features that are absent in the other kingdoms.***

The repertoire of signs and the rules of sign usage are only *compatible* (with regard to the three communication types that accompany organisms throughout their lives) *insofar as the organisms belong to one and the same biological species*. The compatibility of com-

munication types of a biological species can even be used as a measure of phylogenetic affinity on the species level. Honeybees served as our example: Karl v. Frisch's comparative investigation into the rules governing sign use in Austrian and Italian honeybees revealed *habitat*-specific and *life-form*-specific deviations. In this case the rules could (abetted by breeding and acclimatization) be regarded as being compatible, while sign use in bees from the southern hemisphere (signs with analog, indicative character) versus the northern hemisphere (movements as signs with symbol character) appears to be much less compatible.

Comparing biological species that belong to different kingdoms (based on phylogenetic group, origins, evolutionary history, etc.), inevitably reveals the semicompatibility of the 6 communication forms of nature.

Thus, many biological species exhibit similar group-dynamic behavior types, for example closing ranks when threatened. Even if sign-mediated communication coordinates this specific behavior in all these species, the result (closing ranks) is often achieved with an entirely different repertoire of signs and a different set of rules governing sign use. Under certain circumstances, humans may also move closer together when threatened. This reaction in humans that are under attack (as a defensive strategy) may resemble the reaction of elephants, for example. On the other hand, criticism leveled at a cognitive approach may cause the research team that developed and applied the criticized method to form a tight argumentative front (argumentative defense strategy), which would certainly never occur in elephants.

Humans, applying their language and communication skills, are therefore in a position to observe and describe the communication forms of all biological species; in some cases we can even decipher the sign repertoires of a species and identify - as rules - the rules governing sign use.

In observing every facet of living nature, mankind can determine the ***fundamental, universal-pragmatic rules underlying all forms of communication***. We are able to apply these rules, modify them, and employ these modified versions. Furthermore, we are able to develop, construct, and apply artefacts that artificially achieve the desired effect or a result much in the same way as a natural communication form would.

Our ability to apply this observational talent in order to produce aesthetic reason merely adds another feature to our definition of typical human traits, traits that were nonexistent prior to the origin of mankind.

## FORMS OF COMMUNICATION

living nature: structured and organized in a language-like and communicative manner	PROKARYOTES (bacteria)	PROTOCTISTS (eucaryotic micro- organisms)	ANIMALS	FUNGI	PLANTS	(self-understanding of) HUMAN BEINGS
	protein synthesis; metabolism; feeding;	protein synthesis; metabolism; true nucleus; cell respiration; chromosomes;	protein synthesis; metabolism; digestive system; organs; nervous system; brain; consumption;	protein synthesis; metabolism; germinating spores; mycelia; absorption;	protein synthesis; metabolism; photosynthesis;	similar to primates; expanded brain structure
	intraorganismic					
	interorganismic	association; simple colony formation; coordinated behavior;	association; more complex colony formation; coordinated behavior;	complex forms of coordinated behavior; greatest diversity of sign use; signals and symbols; forms of social interaction; precursory ritual behavior	association; formation of large colonies; sexual reproduction; coordinated behavior;	association; colony formation; high diversity of chemical linguistic signs;
metaorganismic	parasitic; symbiotic	parasitic; symbiotic;	parasitic; symbiotic; social; phenotypic attack and defense strategies	parasitic; symbiotic; attack and defense strategies;	parasitic; symbiotic; attack and defense strategies	technical exploitation of all kingdoms of organisms; responsibility for the survival of life;

Fig. 36 Types and forms of communication in living nature

## **9. The origin of novel entities in living nature: Evolution as generative linguistic behavior**

The chapters on intraorganismic communication demonstrated that no organism could differentiate without intra- and intercellular communication, whether it be the differentiation from DNA (genotype) to the final form (phenotype), the temporal sequence of the individual developmental stages, or the physiological organization of all bodily functions and movements in the course of this differentiation.

The chapter on communication disturbances showed how sensitively intraorganismic communication reacts to even the slightest deviations from the rules; at the same time, this type of communication can correct communication disturbances or even prevent them from occurring (immune response).

The basis for this type of communication, which allows a wide range of phenotypes to be differentiated from a wide range of genotypes, is the language of nature, i.e., the nucleic acid language. It finds use in all organisms and involves a uniform repertoire of signs.

The communication types, i.e., intra-, inter-, and metaorganismic communication, are the same in every organism. No organism can extract itself entirely from these communication types over its full lifespan, although these communication types differ considerably from communication form to communication form.

The bee language example underlined that - beyond this universal language of nature (genotypic level) - numerous other languages exist in nature (phenotypic level). It also demonstrated that phenotypes communicate species-specifically, whereby the communicative aspect is more accessible to the human observer on the phenotypic level: Karl v. Frisch was awarded the Nobel prize in 1973 for detailing the bee language.

The fruitful interdisciplinary cooperation between sociobiology and semiotics (at the present time chiefly zoosemiotics) is evidence that the sign-mediated communication processes that individuals use to coordinate their behavior and to enter into associations are present in every biological species. We can also assume that humans are by no means unique in having a language and being able to communicate, even though our language and its application differs quite distinctly from the sign-mediated communication of our closest biological relatives.

In all these cases we are justified in using the terms language, languages, and communication, even though - species specifically - the languages and their usage differ dramatically from one another grammatically, semantically, and pragmatically. While Manfred Eigen no doubt suspected this, his explanatory model too narrowly defined the language and communication concept from the philosophy of language perspective.

Systematizing the key differences in the various kingdoms of organisms with regard to the 3 communication types defined 6 (fundamental) form-types of communication which

have a semicompatible relationship with one another. The briefly outlined, programmatic determination of the evolutionary novelty of each kingdom was designed to clearly differentiate these kingdoms into evolutionary levels in which the kingdom-specific novelty is missing and those in which it is present.

At best, we humans can hope to achieve a full „understanding“ of our own language (in the sense of absolute transparency of what is meant or not meant by a linguistic utterance). Even here, we must refer back to the cultural tradition that shapes the respective language and to a series of situative contexts. The species-specific interaction contexts of non-human organisms are principally inaccessible to us as humans, and the physical framework of these contexts is fundamental for the actual constitution of linguistic signs by real sign users. Therefore, our understanding of non-human languages will be *restricted to comparative analyses of sign-mediated communication processes, to the study of the rules governing sign use, and to the technical exploitation of individual non-human communication processes*. The chapter on the bee language was meant to show that we can in fact understand languages in nature, albeit only to a limited extent.

***On the other hand, it is becoming increasingly likely that we will eventually understand the universal language of nature.*** The rapid progress in the field of genetic engineering is the best evidence for this. Comparative analyses of genetic text sequences in quite different life forms are now standard procedure. Such sequence analyses were primarily designed to decode semantic/pragmatic rules. Nevertheless, it will take a number of years before the configuration of proteins and, above all, the rules underlying these configurations can be fully decoded.

### 9.1. Sign-mediated communication as an apriori for evolution

For some time, the many theories that explain the evolution of biological diversity within the 5 kingdoms of organisms, beginning from one or more primal cells, have relied on the terms mutation and selection. Specifically, changes in the genetic code due to environmental factors (radiation, chemical substances, etc.) and **chance** alter the genetic bauplan. This gives rise to new individuals that differ from their ancestors not only in a species character but, in extreme cases, even in their membership in one of the 5 kingdoms.

„Since the amino acid sequences in proteins ultimately determine an organism’s appearance and behavior, from the molecular standpoint its evolution is merely the substitution of one amino acid by another. Understanding the chemical nature of genes also allows us to explain the occurrence of mutations: A mutation is an error in the sequence of nucleotide bases in the DNA. Such an error is often limited to an incorrectly inserted nucleotide base in a codon (point mutation). This can cause one amino acid to be replaced by another („missense mutation“(…)). Those point mutations that transform an amino acid codon into a „stop“ codon are termed nonsense mutations. Still other mutations can lead to the insertion or elimination of a nucleotide from the DNA molecule. Under certain circumstances, such mutations may alter the entire framework in which the nucleotide base sequence is read; this effect is typically the result of several missense or nonsense

mutations. When such mutations occur in the DNA of germ cells, they are passed on to the next generation. The variation that gives rise to evolution may involve not only modified gene structure, but also changes in the number and organization of genes. DNA segments can replicate themselves or become lost. Gene replication is useful in evolution because the newly added DNA segment can take on new tasks without one of the old genes having to give up its function. Mutations occur at random, i.e., their potential usefulness has no influence on their frequency“ (AYALA, 1978).

The actual survival potential of a newly evolved organism determines whether its newly acquired abilities and skills are more (or less) advantageous than those of its immediate predecessors. Should the fitness of the organism that has newly evolved via mutation(s) be higher, then its probability of producing more viable future generations also increases. *Teleological* lines of argumentation can also be found in the theory of evolution:

„The evolution of birds, for example, which stem from reptiles, is marked by a stepwise transformation of the bones, muscles, and skin of the reptile forelimb, leading to a wing (...). The sternum increased in size and enabled the attachment of flight muscles. A general restructuring of the bones yielded a light yet strong skeleton. The development of feathers proved to be aerodynamically advantageous while providing a lightweight body cover. This, however, did not mark the end of the process.

After adaptation to an airborne mode of life, several birds reversed the process: penguins became adapted to life in the water by modifying their wings into paddles and providing their feathers with a water-repellent film“ (LEWONTIN, 1978).

The qualitative differences and innovative phenomena that evolution yields have been explained by the enormous quantity of random mutations over unimaginably long time periods. Selective pressure then sorts out the less useful individuals from the total number of viable mutations (alleles). „Scientists have been able to show that it is entirely possible to explain the origin of obvious discontinuities such as new species and new types, or of innovations like bird wings and lungs, via a step-wise evolution process“ (MAYR, 1978). Geological history is long enough to effect the selection of the more viable forms.

My thesis is based on the assumption that new life forms do not represent advantageous (albeit random) mutations in a field of innumerable disadvantageous ones, with the former asserting themselves in the fight for survival, but rather that ***new life forms are the result of advantageous versus less advantageous generative sign processes*** in the realm of the genetic text.

Clearly, text-processing enzyme proteins are unable to foresee the prospective level of fitness. Such an interpretation may be intimated by the occasionally anthropomorphic use of language in molecular biology („restriction enzymes that recognize interrupted palindromes“; WATSON, 1992). In fact, the expression „recognize“ is useful here only in the metaphoric sense. The enzyme proteins are, however, competent in the realm of efficient text processing: in producing an enormous amount of generative sign processes, they can also give rise to processes that are more advantageous than others in the fight for survival.



My assumption does not direct itself against the explanatory model of the „survival of the fittest“, but rather only against the assumption that *random mutations* are sufficient to explain the evolution of new organisms.

Environmentally induced or chance changes in the genetic text may plausibly explain evolution on the subspecies level. In the case of the evolution of a new species or even a new kingdom (for example the step from unicells without true nucleus to unicells with true nucleus), this explanatory model is no longer sufficient. Paleontological research indicates that new kingdoms arise discontinuously rather than continuously via innumerable small changes in existing members of an antecedent kingdom. At least this is the interpretation suggested by the paucity of transitional forms in the fossil material.

*Rather than yielding better or otherwise fitter specimens of a species, the overwhelming majority of all mutations observed to date are degenerative or lethal. Thus, the differentiation of new, functional kingdoms and their subgroups is highly improbable.*

My premise, therefore, is that viable representatives of a new kingdom or of its subgroups are the result of generative, sign-mediated text processing by competent enzyme proteins. These proteins are more likely to be successful in combining existing text sequences into completely new ones, in synthesizing new ones, and in inserting them into the existing text in such a manner that, as new characters, they can re-orient and restructure the existing old ones. I am by no means implying methodological activity by enzyme proteins, but merely their competence in the realm of genetic text processing and in the realm of both regulative and generative sign usage.

*According to my thesis, the evolution of entirely new species, or even more so of kingdoms, can be interpreted as the differentiation, transformation, change, or expansion of extant genetic texts by enzyme proteins competent in text processing.* In addition to spontaneous text generation, communication processes on the intra-, inter-, or metaorganismic communication level may fuel evolutive text processing: the experiences constituted here can be identified, in the form of stimulatory patterns (f.e. stress situations), as having text-processing relevance by enzyme proteins.

„More important was the recognition that behavioral changes are often, perhaps exclusively, the motor behind evolution. The selection of a new habitat or the exploitation of a new food item create selection pressures and can trigger important adaptational pulses. There can be little doubt that some of the most important events in the history of life have been set into motion by behavioral changes, among them conquering the land and the skys“ (MAYR, 1978).

Contrary to Manfred Eigen's assumption, the origin of new kingdoms and biological species, along with the origin of life itself, is a problem relevant to *molecular semiotics*, not merely to molecular semantics. Genetic texts do not arise through degenerative changes or defects in the grammar/semantics of the genetic code. Rather, they arise through text generation (insofar as they are highly coordinated, which is clearly the case



in novel life forms, e.g., the sudden appearance of an astounding species diversity in the Cambrian); such text generation also underlies pragmatic rules. This no doubt explains why natural evolution is so successful. Since three levels of evolution can be distinguished, confirmation for my thesis can be sought by investigating these three levels.

## 9.2. Molecular evolution

The evolution of all organisms in every kingdom represents a molecular evolution as well. New life forms originated by constituting new genetic text sequences or even entirely new genes. The guiding principle here is: no new biological species without new constitution and/or new combination of genetic text sequences. According to my thesis, this constitution or production of new genetic text sequences is carried out by enzyme proteins competent in text processing. Such enzyme proteins were found to be present whenever successful text processing occurred. In the molecular realm, they are the *actual sign-users of the nucleic acid language*.

„DNA polymerases have such effective methods of proof-reading and error elimination that they yield stable strand lengths consisting of millions of nucleotides“ (EIGEN et al., 1981).

They react to stimulatory patterns of a neuronal and/or hormonal nature that - on the intraorganismic level - represent specific experiences of the overall organism; under certain circumstances they can use their text-processing competence to code these patterns into the nucleic acid language (WILSON, 1985).

Two types of text processing can be distinguished. The great majority involve regulative and constative procedures, i.e., those responsible for normal reproductive processes and error-free reading of texts; they stabilize the normal intraorganismic functions of the overall organism. The second type involves text-processing procedures that are subject to a certain „**rule-changing creativity**“. In my opinion, this ability is a more plausible basis for evolution than explanations involving chance „mutations“; the latter are inextricably mired with preconceptions from continuity theory that are inadequate to explain discontinuous origins (for example the abrupt biodiversity of the Cambrium; compare also LEVINTON, 1992).

According to my thesis, genetic texts within a genome of an individual of a species in a particular kingdom are expanded and recombined such that the offspring of this individual represent a new species (i.e., they stem from the germ line of a member of an extant species). While the novel organism has biological ancestors, it represents a new biological species that differs from its immediate parental individuals and bears characters lacking in the old species.

The fact that such genetic, text-generative processes can also be triggered by inter- or metaorganismic phenomena changes nothing in our assumption that enzyme proteins carry out this text processing.

Since no transitional fossil forms exist between the various kingdoms, and the new communication forms appear abruptly, we can assume that enzyme proteins use the language of nature to expand and fundamentally transcend existing rules of language usage. ***My thesis therefore states that evolutionary history is basically the history of the acquisition of text-processing competence by enzyme proteins. The origin of the language of nature probably marked the onset of this history.*** Restriction enzymes probably represent the most competent lineage of enzyme proteins with text-processing competence.

### 9.2.1. The macromolecular basis of bioevolution

The mid-1980s were characterized by a controversy sparked by the poor fit between the research results of macromolecular chemistry and the chemical phenomena that neodarwinistically oriented evolutionary theorists used to support their arguments. Over the last few decades, macromolecular chemistry has devoted enormous energy to investigating the reactions in macromolecule genesis and synthesis. This field has a *very precise understanding* of the *conditions* and *laws* governing macromolecule formation (and DNA is a macromolecule) and therefore criticizes that the proponents of current evolutionary theories largely ignore these prerequisites in their explanatory attempts and models.

In turn, evolutionary theorists argue that the proponents of such a critical macromolecular chemistry cannot simply transpose the synthesis reactions in their laboratory findings (regardless of how well they are confirmed) to the biological realm of natural evolution. An impartial evaluation of this controversy yields insights whose importance should not be underestimated or neglected: from the vantage point of the present contribution, these insights address whether living nature is structured and organized in a linguistic and communicative manner.

Examining the evolution of life from primitive bacteria to humans without omitting any known intermediate stage reveals, in the macromolecular realm (particularly in the DNA), progressively longer DNA chains. In other words, the complexity of the genetic text sequences increases. The DNA of a modern bacterium is about 1 millimeter long. This corresponds to several thousand genes or several million nucleotides. The DNA of a modern mammal has a length of nearly a meter, corresponding to 2 million genes (VOLLMERT, 1985, p. 111) and (in the case of humans) to 3 billion base pairs.

In order to more clearly define the macromolecular basis of evolution, it is instructive to concentrate on this DNA chain growth. I expressly wish to *exclude the question of the origin of life* from these considerations. Bioevolution is the only relevant topic in the present framework, i.e., that phase of evolution that followed the first living cell. The focus of the present contribution is not the origin of life, but rather whether living nature is organized and structured in a linguistic and communicative manner.

It should be reiterated here that this *evolutive elongation* of DNA is a historical process that cannot be experimentally reproduced adlibitum by scientific methodology. Researchers in the field of macromolecular chemistry agree that mutations can never

account for the origin of species and, ultimately, of the 5 kingdoms of organisms or 6 communication forms of nature: mutations change *existing* sequences of the genetic text but cannot be called upon to explain DNA elongation or the addition of new genes (and their inclusion into the genome) (ibid. p. 113).

If one interprets the origin of species in Darwin's sense as a form of self-organization, then the origin of new genes or genetic text sequences involves, from the macromolecular point of view, a so-called *statistical polycondensation* (ibid.). This is considered to be one of the best-studied synthesis reactions. What, however, distinguishes mutation from polycondensation?

### 9.2.2. The difference between mutation and polycondensation

Chance and environmental factors (radiation, chemical substances, etc.) determine how mutations change parts of the genetic bauplan of an organism's genome. Gene replications are also not chain elongations in the strict sense because they do not lead to new features and in no way alter or otherwise influence the function of the original genome.

Polycondensation, however, refers to the process by which DNA elongates itself through attachment of new genes, whereby the sequence of the original genome initially remains unchanged. Although we know that such chain-elongating processes exist, we can only guess at how they work. For the present purpose, it is irrelevant whether this involves the addition of single nucleotide building blocks to the original chain, the insertion of entire genes, or some other mechanism. The decisive factor is that the development of truly novel organisms required the formation of many new genes with new genetic text sequences and thus new information.

Clearly, the development of new genes (in the case of mammal evolution, for example) does not itself represent an evolutive process in the development of a new species. After all, each gene is only effective in a particular context, in a particular evolutionary situation and in combination with specific enzymes. These very situations determine whether a particular new gene, protein or enzyme was already capable of cooperating with other genes in that situation. In other words, within a pragmatic evolutionary situation, in which the organism was involved, a gene happened to fit into the existing framework of the overall genetic text sequence. This was followed by the next gene, etc., all in a very specific sequence (ibid. 1985, p. 116 f).

Within an evolutive situation, new genes that became attached to the existing DNA chain and assumed a function had to cooperate with those that were already present. Otherwise, the development of a new species would not have led to a higher step in evolution. This merely highlights one problem area in the framework of the actual evolutionary process.

Another consideration is the fact that *one* new gene in a cell has virtually *no* effect. As a rule, at least 10 enzymes are necessary for the synthesis of a single, new, physiologically active substance. The production of such substances involves a number of intermediate stages, each of which - in the correct sequence - requires its own enzyme for the appropriate chemical reaction. In the genetic text, however, each enzyme corresponds to a sepa-

rate gene. The various synthesis stages form interconnected series and cycles, resulting in a spatial and temporal dependence of the reactions. A single reaction, or one cycle without the succession of the others, is inconsequential for the total cycle and useless for the cell.

*Consequently, in the development of a new cycle leading to a possible new enzyme (which itself is part of an entire series of enzymes which could constitute a new gene), the new cycle remains irrelevant and without effect until it is entirely functional, i.e., until it is constitutive for the structure of the genetic text of the genome.*

In addition, the numerous intermediate products in the biosynthesis of physiologically active substances are mere intermediate products and themselves have no significance in changing the feature: only *the end product* is part of a character- changing cycle. Such changes in features typically manifest themselves only after cycles of 30 to 50 enzymes are appended.

Mutations represent interventions on already established genetic texts. They often lead to conspicuous alterations of features which, in the sense of Darwin's survival of the fittest, inevitably lead to selection. Selection in the case of polycondensation, i.e., in the growth of DNA chains, however, is not possible because the addition of new genes remains without consequence for the organism until these new genes express new features. After all, the addition of new genes does not change the function of established genes or the life of the cell. Since those new genes, arising from or being attached by a polycondensation, find no expression, there is no test situation to determine whether that new gene happens to be adequate and whether it can enter a cooperative relationship with other, established genes. No selection can take place in polycondensation processes. The development of new organisms with new features is therefore not the product of a new gene: a single new gene cannot create a new substance, much less a new feature. New species require a great number of new genes. *This great number of new genes, however, cannot arise from mutations (changes) of already available genes.*

New genes first manifest themselves when their effect leads to the formation of many new substances which actually alter the phenotype. *Only at this time*, and no earlier, is the organism bearing the new features subject to selection. It requires the development of a harmonious sequence of genes to provide the cell with that protein sequence which, as enzymes, enable a cooperative, stepwise reaction sequence (including intermediate stages) leading to new characters.

These intermediate steps themselves are of little value in explaining the origin of new species, for example in considering the evolutionary pathway from reptiles to birds: all the intermediate levels have to be tested on land, whereas the complete bird can first be tested in the air. Intermediate steps that are „not quite yet“ a bird would have only little selective advantage on the ground (if not a disadvantage, because an animal that is „no longer a reptile“ can hardly escape selection pressure)(ibid. p. 126).

The entire sequence of substance modification in the evolutionary process from one species to the next (along with the corresponding DNA chain growth) had to take place

without selection. The development of new species had to be preceded by the development of new genes, in an orderly fashion and in a specific sequence of becoming operative. This required a large number of new substances, each of which necessitated a synthesis of five to twenty steps. This, in turn, required the repeated occurrence of a thoroughly improbable event (p. 128 f.)

Mutants, i.e., organisms having undergone changes on the established gene complement, are in fact subject to selection; this clearly leads to a stronger adaptation to the environment. This, in turn, inevitably leads to the *stabilization* of a species, not, however, to the complex process of DNA chain growth (with all its repercussions) that is responsible for the origin of new species. Under the perspective of macromolecular chemistry, the process called upon by evolutionary theorists to explain the *higher development* of species (***revolutionary-evolutive phase***) is actually not responsible for this advanced development, but rather for the *stabilization* of a species that has newly arisen (***normal-evolutive phase***).

Although I will not discuss the origin of new genes here, the process may well involve an „illegitimate crossing over“ such as that in meiotic cell division; in any case, enzyme proteins competent in text processing, such as polymerases or ligases, will play a role.

One factor is decisive in the framework of the present topic: from the perspective of macromolecular chemistry, the origin of new species, especially those that represent a new kingdom (i.e., something fundamentally novel) cannot proceed via mutation and selection as envisioned by Neo-Darwinism. These processes can function to stabilize a species, but not to generate a text.

For every new kingdom, Vollmert assumes an average increase of 10 000 genes in the length of the DNA.

„The probability that statistic (i.e., chance) chain growth is responsible for the transition from one of these evolutionary levels to the next higher one is on the average  $10^{-40\,000}$ . Even if one assumes 20 intermediate stages between such levels (of which not a single one has been found), then the probability per level would still be very low, namely (...)  $10^{-2000}$ “.

The fact that the whole universe consists of something on the order of only  $10^{80}$  atoms gives an impression of the improbability of such a chain of events“ (ibid. p. 130).

The assumption that most genes in a genome are redundant (or „silent“) is irrelevant for our considerations: no one knows precisely how many genes are actually redundant or that merely appear redundant based on the current status of research.

There are currently no satisfactory explanations for this problem. To date, all models based on the terms mutation and selection have been unable to provide a satisfactory answer to the likelihood and mechanism of macromolecular, coordinated DNA chain growth. Vollmert doubts whether this question can be solved at all using scientific methods (which rely on reproducible experiments). My intention therefore is to develop some-

thing along the lines of a hypothesis based on a language-pragmatically oriented philosophy of biology; this should provide a better understanding of the problem than traditional approaches.

### 9.2.3. DNA chain growth

#### 9.2.3.1. DNA chain growth through text-generative genes and enzymes?

From the vantage point of a language-pragmatic oriented philosophy of biology, the process of DNA chain growth is, in all its complexity, the result of enzyme proteins or enzyme groups exhibiting a text-editing type of competence; this complexity involves not only growth, but also the coordinated incorporation into the established genome. To date, such enzyme proteins have only been demonstrated in the areas of productive, regulative, and constative communication processes of the intra- and intercellular type. These communication processes correspond with the three known and differentiated code types: protein code, regulatory code, structure code.

In gene manipulation, certain enzymes are used for the text separation and insertion processes. They are known to be able to identify insertion sequences as such and are therefore competent in text splicing or, more broadly, text editing. Enzymes operating in this text-generating manner, i.e., which effect DNA chain growth along with the coordinated intermediate stages so as to give rise to a truly new form of life, have yet to be demonstrated.

This may perhaps be due to their being detectable only in a revolutionary-evolutive phase, during the development of a new species; thereafter they may disappear or remain behind as gene wrecks after mutations, something we would refer to as useless „junk DNA“. This would come as no surprise, since the development of a true new species is not a daily event but rather a historical process occurring during certain times in earth history and leading to the differentiation of five different organismic kingdoms (or six communication forms in living nature). Let us assume the presence of such text-generating enzyme proteins capable not only of extending available texts, but also of constituting new genes (I) and inserting them with numerous other enzymes (II) via numerous intermediate stages (III) at the right place (IV) and right time (V) in the proper sequence (VI). Then, we necessarily require genes that are capable of coding these enzyme proteins.

My hypothesis (Witzany 1993 b) is based on the assumption that specific **text-generating genes** must be or must have been present. Within the context of specific, pragmatic interactions which organisms experience, these genes are made available for reading and initiate the production process of such gene-constituting enzyme proteins competent in text editing.

Under this aspect it is irrelevant how many generations are required to realize this text generating process. The text-generating-process is largely independent of selective processes since no effect on the phenotype and the function of the established genome occurs up until the corresponding gene sequence is created and inserted into the genome.

The genetic text creation appears rather suddenly; the resulting organisms of a new species are (and must be) fully functional, since they are subject to immediate selective processes after their actual conception.

When a new species (or in extreme cases a new species representing a new organismic kingdom) enters evolutionary history, this text-generating, text-creative process ceases to function, and the reading of the text-generating genes is interrupted. This is probably due to a further special enzyme or enzyme group which stops the expression of the text-generating genes. Perhaps the production of special gene-constituting or text-generating enzyme proteins is interrupted when the new genes constituting the new organism are incorporated or successfully integrated into the genome. At this point a truly new organism has entered history.

Only at this juncture do mutation and selection again become important and lead to phenotype changes which themselves immediately underlie selective pressure. The stabilization phase of a new species can begin. At this point the *revolutionary-evolutive phase* is completed and the *normal-evolutive phase*, which merely serves to improve the prototype, is initiated. In this sense, successful evolutionary processes constitute themselves through the *complementarity* of revolutionary- and normal-evolutive phases.

This hypothesis renders several developments understandable: the process of DNA chain growth in the higher evolutionary development of species and the differentiation of various organismic kingdoms (I), the sudden appearance of new species (II), and the lack of numerous intermediate stages (III). It also affords an explanation for the absence of numerous „not-quite-yet“ life forms. In explanatory attempts based on continuity theory, such forms should be present in large numbers, but are de facto lacking.

This would also explain the fact that a variety of different prototypes appear whenever a new species arises, but that only a few are successful. Thus, few rather than many of the numerous prototypes survive up to the present. For example, we know today that all fossil predecessors of humans - from *Homo habilis* to Neandertals - in fact represent extinct prototypes of humans; the branch which gave rise to modern man developed rather abruptly and without discernible predecessors approximately 200 000 years ago in southwest Africa (BUCHER, 1992).

Notwithstanding the development of the first living cell with functional DNA, the first historically reconstructable revolutionary-evolutive phase is the jump from unicellular organisms without to those with a true nucleus. According to my hypothesis, one or more text-generating genes must have already been at work in this evolutionary hyper-event. The origin of such text-generating genes might be sought in the realm of associative processes of the anucleate unicells giving rise to the basic form of unicells with true nucleus.

Perhaps the so-called junk DNA, i.e., DNA segments to which no particular function or significance can be attributed, represent evolutionary relicts from a revolutionary-evolutive phase. They may have been destroyed by mutation or rendered inactive in the course



of the normal-evolutive phase; since the text-generative gene or genes were already switched off, they were also no longer repaired. After the new species was established, any repair here became superfluous.

Since the genetic text is complementary yet consists of quite different substructures (protein code, regulatory code, structure code), one can assume that a comparable **innovation code** (which could also be termed as **text-generating code**, **evolution code** or **creation code**) exists or once existed. No information is available on its substantive structure because to date no such code has even been postulated. Perhaps it deviates significantly from conventional, known codes or is subject to completely different rules of expression. Since its expression involves historically singular events and is not arbitrarily reproducible, it could have long since disappeared again (with the exception of remnants) from the established genome: most of the biological species that appeared during evolutionary history are already extinct. Today we are witnessing the tail end of biodiversity in Earth's history. Perhaps this innovation code lies concealed in those DNA structures that make no sense to us based on traditional assumptions?

These considerations are admittedly rather speculative. The hypothesis that text-generative genes and enzymes must exist is definitely worthy of being tested in the context of the present contribution and would certainly avoid overburdening the terms „mutation“ and „selection“. There is no reason why this hypothesis should not conform with the criteria of macromolecular chemistry.

Ultimately, the task of any hypothesis is to better explain those observations that traditional approaches have failed to explain satisfactorily, and at the same time to open up new, innovative arenas of research.

#### 9.2.3.2. Are structured biological languages potentially present in noncoding DNA sequences ?

The present study makes frequent mention of enzyme proteins that are competent in text processing, i.e. that precisely identify the splice sites in the genetic text, that cleave these sites, and that then join together the modified sections (WATSON, 1992, p. 153-171). Even though such enzyme proteins are the actual sign users in intraorganismic and, above all, in intracellular communication, one should always bear in mind that *genes code for all known enzyme proteins*. The assumption that enzymes are even able to determine the sequence of amino acids in polypeptide chains inevitably leads to a never ending succession of sequence- identifying enzymes and enzyme-identifying enzymes (anthropomorphically designated as „sequence-recognizing“ enzymes in molecular biology and genetics). J.D. Watson took a similar view:

„Although enzymes completely determine the specificity of the chemical reactions between small molecules, there is no way that they can be used to determine the order of amino acids in the thousands of different proteins that every cell possesses. An average-sized polypeptide chain contains several hundred amino acids arranged in a unique irregular sequence. If the ordering of the amino acids in such a chain were carried out by



enzymes, there would have to be an enormous number of these enzymes, each capable of recognizing a large number of contiguous amino acids. In turn, each of these hypothetical „amino-acid-sequence-recognizing enzymes“ would have to be put together by its own set of different „sequence-recognizing“ enzymes, and so forth. This type of scheme obviously cannot work, and we are led to the inescapable conclusion that cells must contain specific „information bearing“ molecules, analogous perhaps to the molds of the sculptor or to the master plates of the lithographer. Such molecules must encode the ordering information so that it can be used to select the correct amino acids in the course of polypeptide synthesis. These information-bearing molecules, moreover, must somehow also be able to synthesize new copies of themselves, so that when a growing cell splits into two daughter cells, each of the progeny cells possesses copies of the master molds (or templates).“ (WATSON, 1992, p. 6)

Watson himself believes that the chromosomes are these information-bearing molecules: „We shall in fact soon show that chromosomes contain the information that is used to determine the order of amino acids in cellular proteins.“ (ibid)

Is it thinkable that there are *other* components which could determine this order of amino acids?

How can this problem be solved? On the one hand we know that enzyme proteins are competent in processing genetic texts and that they are defined by genes. On the other hand, genes that order polypeptide chains would have had to be present since the origin of life. Which genes might these have been? Where and how have they been coded?

One solution may be to assume genetic codes that are not contained in conventional (protein-, structural-, and regulatory-) codes. Where might such codes be found? How might they be structured? And, above all, how can they become effective if not via the known pathways of gene expression? How might they have been read?

A team of researchers from Boston University and Harvard University subjected a series of coding and non-coding DNA sequences to linguistic tests (PENG et al. 1993; BULDYREV et al. 1993 a; BULDYREV et al. 1993 b; PENG et al. 1994; OSSADNIK et al. 1994; MANTEGNA et al. 1994; BULDYREV et al. 1995). The results showed that ordering principles *are present even in the non-coding DNA* and, furthermore, that these principles were not much different from those of the coding DNA. While coding DNA is predominantly *short-range correlated*, the order in non-coding DNA is largely determined by *long-range correlations*. The above tests revealed that non-coding DNA more closely resembles colloquial speech, while the structure of coding DNA (which codes for a particular protein) more closely resembles that of formalizable scientific languages. But this characterization is a metaphorical one. The unexpected résumé of this research is as follows:

„These results are consistent with the possible existence of one (or more than one) structured biological language(s) present in non-coding DNA sequences“ (MANTEGNA et al. 1994, p. 3172).

A more detailed investigation of which „structured biological language(s) are present in non-coding DNA sequences“, how they might be read, and whether they may harbor the postulated *innovation code* (or perhaps merely ordering principles that can assemble and activate an innovation code in the known code types, i.e. in the form of a „meta-code“) is an interesting task and would need to be treated in a separate contribution.

#### 9.2.3.3. The explanation of DNA chain growth through Serial Endosymbiosis Theory (SET)?

The Serial Endosymbiosis Theory (SET) of Lynn Margulis (MARGULIS, 1998) offers a very interesting possibility to explain DNA chain growth. This theory was rejected for a long time by molecular biologists and Neo-Darwinistic evolutionary theoreticians, but is nowadays discussed seriously; her arguments are fascinating because the SET can explain numerous of phenomena like the revolutionary evolutive phase from the unicellular organisms without a nucleus to those with a true nucleus as an *associating process* between some unicellular organisms.

This process must nonetheless have been characterized by very complex, dynamic, sign-mediated interactions that were successful in encoding their associating efforts. Some parts of this new DNA text must code for a membrane which establishes a metabolic world for an individual organism. Prior to this DNA chain growth and the establishment of a membrane, it is imaginable that the association processes between these unicellular organisms, i.e. kinds of bacteria, were historically developed ones within the whole world of individuals-interacting-in-populations. This means, a long-lasting developmental history of sign-mediated, rule-governed interactions between these kinds of bacteria and a long-lasting history of optimizing these interactional quasi-metabolistic processes.

The revolutionary evolutive phase arose when the associating processes had to change the rules: not further interacting between individuals-interacting-in-populations, but association within a new world of metabolism *within* a membrane with a true nucleus and the crucial development of encoding this newly developed interaction. This revolutionary evolutive step (and therefore one of the first processes of DNA growth) is thus the result of rule-changing creativity in the sign-mediated interactions between bacteria. And these bacteria had been different microorganisms with a different history and very different competences.

It is fair to say that revolutionary evolutive processes in the transition stage from unicellular organisms without to those with true nucleus are likely not the result of an innovation code, or creation code which leads to DNA sequences of a new species, but the real lifeworld (Lebenswelt) of individuals-interacting-in-populations which change their rules of interaction. And this change is encoded in DNA structure (e.g. through gene rearrangement or innovation/creation code expressed enzymes). The theory of an innovation code is more likely for encoding sign-mediated interactional processes.

The result was the very revolutionary evolutive process which has been the presupposition for the revolutionary evolutive phases to create the further organismic kingdoms

Animalia, Plantae and Fungi. I will not reconstruct the development of the SET theory here, but there are strong reasons to prefer this theory, which I tried to enrich here with the communication theory I developed in this book: To explain the evolution of unicellular organisms without to those with true nucleus through a theory of association is one aspect. To explain how this association has been developed as a historical process of individuals-interacting -in-population is the other aspect.

#### 9.2.4. Back to Lamarckism ?

or: forward to new concepts of development and evolution

##### 9.2.4.1. „Intelligent“ alteration of and retroaction on the genetic material?

For traditional molecular biologists these speculations on alteration and lengthening of DNA sequences or even coding enzymes which use stimulatory patterns or similar coding-relevant molecular features of the phenotype (e.g. stress situations) as a blueprint are no doubt unjustifiable and mere nonsense. Such speculations contradict the long-entrenched one-gene-one protein dogma (I) and the dogma that the transfer of genetic information is from nucleic acid to protein, never reverse (II).

Over the last decade, however, numerous investigations have yielded results which are not understandable by using the central dogmas of molecular biology. Especially in developmental genetics more and more experiences contradict the classical point of view of molecular biology.

No doubt, the text competence of enzymes plays a key role in explaining alterations and evolutionary lengthening of the genetic material. „Although there is a complicated machinery of enzymes and DNA-binding proteins capable of replicating, recombining and manipulating DNA, and despite considerable evidence for directed mutation, there is no hard evidence for an environmentally or somatically guided, „intelligent“ alteration of and retroaction on the genetic material.“ (RHEINBERGER, 1999, p. 14) Nevertheless, developmental genetics must not interpret their investigations in the light of classical molecular biology. „If we look for meaning in the organism, we must look, not at its genes, but at the multiple interfaces between the genome and the body“ (ibid., p. 15) Comment on Rheinberger's statement Michael Morange states „However, there are interesting, recent results (...) which show that organisms are able to adapt their mutation rates and to recognize their genomes in answer to the environmental conditions“ (with reference to KELLER, 1992 and SHAPIRO, 1995).

In his own statement, Morange describes the historically important contribution of F. Jacob and J. Monod, that the genome contains two different kinds of genes, „the structural genes coding for proteins and enzymes, and the regulatory genes coding for repressors, the only function of which was to control the activity of structural genes.“ (MORANGE, 1999, p. 27). The importance of the „developmental gene concept“ is to underline the pragmatic level of DNA information and the dependency on whose need they are used „(...) the same functionally equivalent genes control the development of very different

organisms which are built following different pathways and which have different plans of organization.“(ibid., p.31 with reference to KENYON, 1994). In these investigations Morange describes why regulatory genes formerly known as „master“genes play an important role in understanding development from genotype to phenotype. It is also important that some DNA sequences govern their own transcription. „Governors govern the governor. Regulators must be regulated by factors that are themselves both regulated and regulators“ (GILBERT, 1999, in his comment on Morange’s statement). At this point we should recall that some RNA molecules are able to double themselves and to rearrange the genetic material (so-called ribozymes).

#### 9.2.4.2. Molecular pragmatism: context determines meaning

Gilbert also recalls the context specificity: „So these developmental genes have to be both regulators and regulatees. The things they regulate and the things that regulate them are part of a pathway. In the end, it is not the conservation of the gene that is important, but the conservation of these developmental pathways that include them. The use of a gene can depend on its context. In one cell, enolase is a glycolytic enzyme, while in the lens cell, it’s a structural crystallin. The GSK-3b gene can play a role in the Wnt pathway for fly segmentation or frog neural axis formation, or it can help regulate glycolysis. Beta catenin can hold cells together as part of the desmosome or it can be a developmentally critical transcription factor (Piatigorsky and Wistow, 1991; He et al., 1995; Schneider et al., 1996). This is to be expected from our knowledge of evolution. As Jacob (1977) noted, nature should use what it has before inventing something new. Proteins have multiple sites. The fact that a gene can be used for different purposes within the body should not be troubling except by those people trying to name the gene.“ (GILBERT, 1999, p. 45).

This corroborates my contentions in chapters 4 to 7: The situational context, i.e. the pragmatic sign-using communication process in and between cells determines the meaning, i.e. the real processed enzyme protein and its function. Molecular pragmatism helps to understand why this enzyme is produced and no other.

The dogma of information flow from DNA to protein, never reverse, is reductionistic. Real life processes are more complex than a reductionistic point of view could explain adequately. Today developmental genetics acknowledge that cellular development depends not only on genetic information but also on cellular interactivities, „.... complex biochemical structures or networks constituted of proteins, RNA molecules, and metabolites which often, although certainly not always, executing their tasks in interaction with particular stretches of DNA. (Note: Executing a task means processing data provided both by the DNA and by the products of other programs - i.e. by information given in nucleotide sequences, chromosomal structure, gradients of proteins and RNA molecules, the structure of protein complexes etc.)“ (KELLER, 1999, p. 56). It is the dependency of genes on cellular context that I attempted to exemplify in chapters 4 to 7.

The working group on „Gene Concepts in Development and Evolution“ at the Max Planck Institute for the History of Science in 1999 discussed whether the Gene Concept is

still adequate today. Several years before, the results of developmental genetics - especially the „posttranslational modifications“ of proteins after synthesis - led to headlines like „Entering the Postgenome Era“ or „From Genome to Proteome: Looking at a Cell's Proteins“ (SCIENCE, Vol. 270, 1995, p. 368 f).

The above-mentioned working group treated special themes like the post-translational changes in structure and the subsequent secondary effects of cytoplasmic interactions with the polypeptide, the circumstance that eukaryotic cells can process the newly formed messenger RNA by cutting and removing internal sections known as *introns*, the *one locus- multiple product dilemma* and the special case of *overlapping genes* or *alternative splicing*. These show that a new kind of explanation and understanding of life is called for, and in my opinion interpretations anchored in pragmatics of language may be helpful.

If the locus is important for the meaning of the data, then the „grammar“ and the semantics deduced from it are less useful for evaluating the meaning. „If loci are contextually dependent for structural and functional evaluation, then it is unclear how a fully realized, or at least richly detailed, theoretical presentation would be possible using genes as an explanatory manipulative.

Coding information acts within a co-dependent cellular setting: localized sites of expression interacting among DNA domains and contingent upon genomic composition. Here, the term genome means more than a collective set of molecular genes of the organism; it refers to the rich tapestry of DNA domains that weave a pattern of expression.“ (FOGLE 1999, p. 84)

#### 9.2.4.3. The concept of „downward causation“

The results of developmental genetics are completed by new concepts of evolution. In his article „A unified view of the gene, or how to overcome reductionism“, P.J. Beurton (BEURTON, 1999, p. 97 f) also questions the sense of the traditional gene concept. Especially the „gene-in-pieces“ concept, introduced in the second half of the 1970s, made clear the need for a new concept because „a gene may consist of a mosaic of coding and noncoding sequences called ‘exons’ and ‘introns’“ and if the introns are highly repetitive sequences they „tend to be non-coding. They then hardly fulfil the criteria necessary for calling them genes.“ Genes-in-pieces are the rule not the exception in eukaryotes. „By the mid 1980s the first instance was recorded of the same exon occurring in different genes and thus coding for the same functional element in different proteins (Gilbert, 1985). Finally, it was found that exon shuffling is a process widely distributed among vertebrates. The important general insight was that gene shuffling through phylogeny could explosively increase the amount of protein diversity.“ (ibid., p. 104).

The so-called „pseudogenes“ are interesting as well. Do they play a role in the evolution of new genes? Perhaps during *revolutionary-evolutive phases* (chap. 9.2.2 this book) they take up their place in genomes, where later real coding sequences must be installed, or they mark potential insertion places. „Pseudogenes resemble active genes, but are rendered nonfunctional, for instance, by mutations that affect transcription or translation.

They arise, for instance, from unsuccessful gene duplication, either as a result of unequal crossing over or by retroposition, that is, reverse transcription of RNA intermediates into DNA.“ (ibid., p. 103).

No less interesting are the so-called „overlapping genes“. „Two reading frames may overlap so that in such area of overlap a single DNA sequence gives rise to parts of two proteins. Instead of comprising a single gene, such a DNA sequence suddenly turns out to stand in the services of two different genes!“ (ibid.)

Variations in the genetic material are crucial for evolutionary processes. And these variations are caused not only by DNA sequences, but also by interactions between DNA material and the complex interactional levels in the cytoplasm. These levels in the cytoplasm are no doubt influenced by the interaction between the environment and the whole organism, i.e. by how the intraorganismic communication reacts to environmental influences. These very complex demands need equivalences in protein differentiations, especially during developmental stages. One equivalence may be introduced by the discovery of „alternative splicing“. „Alternative splicing is the most dramatic discovery up to date in the context of genes-in-pieces. Not only do genes come in pieces, but during development alternative samples of exons from any one gene’s primary RNA transcript may be pieced together to form a mature mRNA. A single gene, then, may yield varying assemblages of exons or different protein isoforms to meet the demands of the developmental stage in question.“(ibid., p. 105).

Beurton explains the gene-generating processes in evolution in the following manner: Besides neutral mutations we have to propose new factors for disintegrating and varying genes, like the above-described ones (pseudogenes, overlapping genes, etc.). Environmental influences on the organism and the processual molecular representation (stimulatory patterns) are components of *materializing* into genes. Beurton is not alone with his risky speculations: „For instance, unsuccessful gene duplications by retroposition have been said to ‘keep the genome in flux ... they can be considered a shotgun approach of nature wherein the majority of these genetic elements are inactive and left to rot in the genomic soil. Nevertheless, some seeds will integrate near a fertile genomic environment giving rise ... to new genes or gene domains ...’(Brosius, 1991, p. 753). It follows from such and similar processes that ‘in principle, any string of nucleotides in a genome may be recruited as part of a novel coding region or regulatory element.’ (Brosius and Gould, 1992, p. 10708).“ (ibid, p. 109)

Beurton thus presumed correctly, that „natural selection is differential reproduction initiated by individuals“. Individuals of adaptation processes, which have selectional power. And these processes differ like the situational contexts of living beings specifically through their individual position while they interact within a population. Beurton there seems to find one crucial point of generating genes: „A difference in adaptive performance may then induce a hardening, or individuation, of both, the underlying genomic difference into a gene and of the adaptive difference into a trait.“(ibid., p. 110). In this sense it is correct to say „... the genome is, to some extent, a condensed history of what has been

going in populations“ (ibid. 111). The interactional history in populations (i.e. also the „sociology“ of populations) materializing into genes may happen. „Only in the context of selective spreading of genetic material in populations does the justification arise to talk of adaptive differences materializing into genes rather than the other way round. This horizontal dimension in populations is crucial for understanding downwards causation and how populations bring into being genes.“ (ibid., p. 112).

Beurton’s line of argumentation of becomes increasingly. „Downward causation“ is the model of explanation which could successfully explain what Lamarck wanted to express, and that for which he has been criticised until the present day. He was unable to foresee what developmental genetics would discover. „Downward causation“ is a hopeful trial for thinking beyond reductionism. It opens the possibility to also introduce the importance of sign-mediated, rule-governed interaction in intra-, inter- and metaorganismic communication into crucial evolutionary processes by reflecting on the history and dynamics of populations. „My claim that genes come into being only in the context of the horizontal dimension in populations is, in turn, equal to saying that no piece of DNA possesses in and of itself the capacity to form a gene. A piece of DNA, being inherently chemical, may take on the function of a gene and thus turn biological by imposition from above, that is, by coming to qualify as a unit of selection. This is no inborn characteristic of DNA, rather, it arises from downward causation.“(ibid., p. 113 f), and later coming to the point: „Not only are the selective values of genes emergent properties, but the genes themselves emerge from interactive processes in populations. Once it is possible to show that genes are products of populations, reductionism becomes evidently emptied of all content.“ (ibid., p. 114). This point of view perhaps has the power to turn around the perspective on evolutionary processes. „There are ‘last organic particles’ called genes; yet there is something behind them: the whole world of individuals-interacting-in-populations. Genes are not the product of human abstraction, but they become real in a process of material condensation taking place in populations of evolving organisms.“ (ibid. p. 116)

At this point we seem to have overcome both reductionism and the classical Lamarckism. The understanding of these interactional processes is not improved through experiments, but this new approach can orientate many coherent ways of constructing experiments which could improve the model. This point of view may open a new way of thinking about evolution which avoids the explanatory deficits of traditional evolution theory.

#### 9.2.4.4. The concept of „adaptive mutation“

The „adaptive mutation“ concept of J.A. Shapiro (SHAPIRO, 1995) is an additionally useful approach. Here, not the blind watchmaker but „natural genetic engineering“ is important for evolutionary change. Adaptive mutations are not directed mutations, but they play an important overall role for mutations. „Because biochemical complexes that act on the genome are subject to physiological regulation like all cellular functions, it is logical that they display much more activity under certain conditions. For example, plasmid transfer and RecA function are regulated by cellular control circuits responding to oxidative metabolism, DNA damage, and carbohydrate starvation.“(ibid. p. 374). Shapiro



further concludes „That genetic change in bacteria is often multicellular. DNA rearrangements can occur in one cell and be transferred to another before a clone of ‘mutant’ bacteria proliferates on selective medium.“ Such „altruistic mutational events“ are found not only on the level of bacteria, but also in cells of higher organisms „and the cells of most organisms can take up and integrate foreign DNA under certain circumstances. In stress situations, likely to prevail at critical episodes of evolution, intercellular genetic exchange may well be more common than we have believed.“ (ibid.).

The reductionistic point of view is increasingly becoming irrelevant for explaining evolutionary processes. „The discovery that cells use biochemical systems to change their DNA in response to physiological inputs moves mutation beyond the realm of ‘blind’ stochastic events and provides a mechanistic basis for understanding how biological requirements can feed back onto genome structure.“ (ibid.).

#### 9.2.4.5. Homeotic genes and evolution

The discovery of the homeotic genes was crucial for understanding the dominant role of the regulatory code for evolutionary processes. Especially the explanation of arthropod and chordate evolution in the light of homeotic genes was very helpful and shows again: the context determines the meaning, i.e. the morphological evolution of animals strongly depends on homeotic gene expression. „Clusters of homeotic genes sculpt the morphology of animal body plans and body parts. Different body patterns may evolve through changes in homeotic gene number, regulation or function. Recent evidence suggests that homeotic gene clusters were duplicated early in vertebrate evolution, but the generation of arthropod and tetrapod diversity has largely involved regulatory changes in the expression of conserved arrays of homeotic genes and the evolution of interactions between homeotic proteins and the genes they regulate.“(CARROLL, 1995, p. 479).

*Hox* genes are important constituents in the genomes of all animals. „Three remarkable conserved features unite the *Hox* genes of higher animals: (1) their organization in gene complexes, (2) their expression in discrete regions in the same relative order along the main (A-P) body axis; and (3) their possession of a sequence of 180 base pairs (the homeobox) encoding a DNA-binding motif (the homeodomain).“ (ibid.) Most animals have the same array of *Hox* genes, and they are expressed in a relative order along the main body axis. It was therefore clear that *Hox* genes „act only to demarcate relative positions in animals rather than to specify any particular structure.“(ibid.).

The same DNA sequence has different meanings in different contexts. „Between species, the same *Hox* gene can regulate the homologous segment or body region in different ways. The key to understanding how *Hox* genes control morphology and diversity is based on their action as regulatory proteins and the wide range of target genes regulated by different *Hox* genes in one animal, and by the same *Hox* gene in different animals.“ (ibid.). The *Hox* genes are no instructional code type, but they are important in explaining large-scale morphological evolution because they determine, through the upstream regulators, whether changes in axial morphology as well as in limb patterns occur. „The earli-



est tetrapod-like fossils suggest that the vertebrate hindlimb evolved first from the pelvic fin of fish, with the forelimb evolving subsequently from the pectoral fin.“ (ibid., p. 483).

It has been postulated that there must also be changes in the „response of *Hox* genes to these regulators“. It becomes increasingly clear that there is primacy of regulatory evolution and the strong relationship to developmental genes. „The phylogeny of *Hox* genes and the many examples cited above of large-scale morphological changes associated with diversity in *Hox* gene regulation and target regulation suggest that the primary genetic mechanism enabling morphological diversity among arthropods and vertebrates is regulatory evolution.

The anatomical complexity of vertebrates, reflected by a larger relative number of different cell types, may be a consequence of a greater number of developmental genes.“ (ibid., p. 484).

So we have strong reasons for believing that the *Hox* genes determine the large-scale morphological evolution in animals and that there is a creative change of rules of the interacting *Hox* gene expression and a response of the *Hox* gene expression to the regulators which induce the expression. „How can regulatory evolution be sufficient to explain the differences between trilobites and butterflies, or dinosaurs and sparrows? The creative potential of regulatory evolution lies in the hierarchical and combinatorial nature of the regulatory networks that guide the organization of body plans and the morphogenesis of body parts. We now know that *Hox* genes are regulated by many upstream factors, and that *Hox* proteins act as sculptors that modify the basic arthropod or chordate metamere by modulating the expression of potentially dozens of interacting genes, the products of which determine the cellular events of morphogenesis.“ (ibid.).

The interacting processes are undoubtedly sign-mediated, rule-governed interaction processes which have grammatical, semantic and (context dependency) pragmatic levels. Especially the pragmatic level decides which function should arise, i.e. which „meaning“ a product of gene expression should fulfil. The evolution of *Hox* genes plays a key role in the revolutionary evolutive phases of the diversity of the animal kingdom.

#### 9.2.4.6. The importance of gene rearrangement in evolution

For more than 30 years, A.C. Wilson has worked on concepts of evolution stressing strong interactional moments between chromosomal evolution and anatomical evolution. What I have outlined in chapter 9 - the paradigmatic change in explaining and understanding evolutionary processes - Wilson anticipated several decades ago. Wilson's team compared „the relative rates of protein evolution and chromosomal evolution in frogs and mammals. The average rate of change in chromosome number has been about 20 times faster in mammals than in frogs. Whereas it takes only 3.5 million years, on the average, for a pair of mammal species to develop a difference in chromosome number, the corresponding period for frogs is 70 million years. In contrast, the rate of protein evolution in mammals has been roughly equal to that in frogs. The rapid rate of gene rearrangement in mammals parallels both their rapid anatomical evolution and their rapid evolutionary loss

of the potential for interspecific hybridization. This, gene rearrangement may be more important than point mutations as sources for evolutionary changes in anatomy and way of life.“ (WILSON et al., 1974, p. 3028).

What might be the reason for such relatively rapid evolutionary changes in the chromosome number of mammals versus frogs? The protein evolution in mammals has not been accelerated, but the „rapid chromosomal evolution in mammals parallels their rapid anatomical evolution.“(ibid, p. 3029). „A contrast between protein evolution and chromosomal evolution is also evident from studies conducted by population geneticists. Although it is rare to find cases of intraspecific variation in chromosome number, it is now well established that populations often exhibit other types of karyotic variation, for example inversion or translocation of small chromosomal segments.“ (ibid.).

In the early 1970s Wilson discovered the important role of gene rearrangement for regulatory evolution, „thus, mammals appear to have undergone both rapid regulatory evolution and rapid rearrangement of genes. This correlation may indicate that gene rearrangement provides an important means of achieving new patterns of regulation.“ (ibid, p. 3030). He postulates that rearrangements of genes are more important than point mutations. „It may be useful, then, to regard adaptive evolution as resulting primarily from changes in the expression of genes relative to one another rather than from amino-acid substitutions in the products of those genes. Adaptation is probably a complex process requiring new interactions among many genes.“ (ibid.).

#### 9.2.4.7. Informational transfer from protein to DNA

Evelyn Fox Keller (KELLER, 1992) investigated the question of directed mutations. She initially studied a paper by Salvador Luria and Max Delbruck of 1943, who „examined the origin of mutations rendering *E.coli* resistant to infection by the bacterial virus that is now called T1 and concluded that the presence of the selective agent (in this case the virus itself) had no influence on the emergence of these particular bacterial mutants.“ (ibid, p. 293). Keller reported that this work was „taken as conclusive demonstration that even bacteria (which Luria himself described as ‘the last stronghold of Lamarckism’) were organized by genes subject to spontaneous mutation and hence to the conventional process of natural selection.“(ibid.). Cairns et al. published a critical review on the Luria/Delbruck experiment in *Nature* (1988) and described their own experiments which suggest „that bacteria may in fact be able to ‘choose which mutations they should produce’“(ibid.). The experiments by Cairns et al. opened the horizon for a less dogmatic view on genetic information flow. Keller cites them „‘Now almost anything seems possible. In certain systems, information freely flows back from RNA to DNA; genomic instability can be switched on under conditions of stress, and switched off when the stress is over; and instances exist where cells are able to generate extreme variability in localized regions of their genome’“. (ibid.).

This article produced turbulences among the community of molecular biologists. Keller described that the article was sharply criticized, but the interesting thing was that the Luria/Delbruck experiment was good enough to show that the Darwinian paradigm did

not allow one to detect „the existence of a non-random, possibly product-oriented form of mutation“ (p. 294)

Keller clarified the different point of views on these experiments by distinguishing between „(a) the observations, (b) the phenomenon inferred from the observations, and (c) the mechanisms hypothesized to account for such a phenomenon as each of these appears in the original paper by Cairns et al“ (p.295). Interesting for the present investigation is Keller's note on how Cairns et al. interpreted their experiments, i.e. speculating, that „the cell could produce a highly variable set of mRNA molecules and then reverse-transcribe the one that made the best protein.´, or, more simply, ´that made it able to grow´. For this, the cell would need ´some element that somehow monitors the protein product and determines whether the mRNA should go on being translated or should be transcribed into DNA ... in effect´, they conclude, ´provid(ing) a mechanism for the inheritance of acquired characteristics“ (p. 296).

In the responses, Keller describes that of Franklin Stahl, who proposes a „trial-and-error“ mechanism. In his opinion the production of nonspecific mutants is the result of a disturbed correction system of the normal mechanisms of mismatch repair. The mechanism is performed by „post-replicative mismatch-correction enzymes“ and Keller notes correctly „The underlying question is whether one can encompass mutations that are preferentially induced or stabilized in a Darwinian framework, relying solely on the language of chance and selection, or whether it is necessary to have recourse to a Lamarckian language of purpose and choice.“ (p. 297)

In the further discussion the terms „selective transcription“ and „preferential mutations“ were raised by other authors, but, from the view of the present theory of communicative nature the arguments of Keller and Cairns et al. strengthen the argument that evolutionary processes are processed by text generative enzymes. Cairns concludes: „We now know that, in the processing of biological information, almost anything is possible. Sequences are spliced, rearranged, cast aside, resurrected, and to a limited extent may even be invented when the need arises, and so it should not be difficult for an organism to devise a way of testing phenotype before adopting the new genotype. It therefore seems almost perverse to maintain, as a matter of principle, that such a mechanism has never evolved.“ (p. 298).

Keller's historical reconstruction of this discussion shows that on the level of bacterial evolution there are phenomena that can be explained if one supposes a flexible information flow not only from DNA to protein, but also vice versa. Ultimately we must accept that the dogmatism of Neo-Darwinism has failed; A reformulation of Neo-Lamarckian positions, however, must keep in mind that the circumstances of reverse transformation flow remain to be identified in their full complexity. We may assume that specific stimulatory patterns (e.g. stress) are part of such circumstances.

#### 9.2.4.8. Back to Lamarckism?

We have shown that there are many efforts to explain how influences on the individuals-interacting-in-populations are encoded in the genomes of such individuals and that this

encoding processes led to higher rates of evolutionary processes. We need not return to traditional Lamarckism, but traditional Neo Darwinistic concepts are clearly no longer useful for explaining and understanding evolutionary processes, especially *revolutionary evolutive phases*.

That these processes are structured and organized in a language-like and communicative manner is evident, and the discovery and investigation of sign- mediated interaction processes in and between cells has grown enormously in the last decade. Interaction in and between cells and organisms-in-populations cannot be described sufficiently without semiotic terms and without language-pragmatic philosophy of biology. If we wish to understand rule-changing creativity in sign- mediated interactions, especially in evolutionary processes, this interdisciplinary concept of life and its communicative structure is indispensable.

### 9.3. Organismic evolution

The interaction of organisms via inter- and metaorganismic sign-mediated communication processes also leads to the differentiation of specific behavior patterns; in the form of neuronal stimulatory patterns (e.g. stress situations), these can be identified through cellular control circuits as being relevant and be genetically coded by enzyme proteins competent in text processing (or an ensemble of enzymes, each competent in splicing, rearranging or similar abilities). Thus, the evolutionary dynamics of certain members of a kingdom are strongly oriented according to the brain's capacity for intraorganismic communication (WILSON, 1985).

Since neuronal stimulatory patterns in the brain can be particularly relevant for generative genetic text-processing, the phenotypic diversity in the animal kingdom is most conspicuous in cases where brain size is relatively large compared with body size. *Specifically, research has shown that the average speed of anatomical evolution in mammals and songbirds increases with relative brain size* (BONNER, 1983 b; WYLES, KUNKEL & WILSON, 1984; WILSON, 1985).

Modified behavior patterns (in response to the demands of a stimulus-rich environment) as well as imitative behavior can give rise to new organismic stimulatory patterns that induce enzyme proteins to code them. For example, the ability of human adults to metabolize lactose is 90% genetically fixed in peoples with a long history of dairy farming, while it is almost entirely lacking in peoples who rarely if ever drink milk. The generative cultural communication processes that the brain has enabled can promote organismic evolution processes (WILSON, 1985).

### 9.4. Cultural evolution

Organisms with a capacity for highly complex neuronal and therefore complex interorganismic communication processes can initiate cultural developments that can be passed

on to their descendents by species-specific forms of socialization. Rather than being genetically coded, such cultural achievements are reproduced from generation to generation in the form of culture-specific rules of behavior (which can be changed and expanded as needed, or occasionally even dropped).

One of the best known and most thoroughly studied examples in non-human organisms involves blue-tit populations in England. Some of these birds discovered that they could gain access to the cream in milk bottles (delivered to the doorsteps of households) by piercing the foil cap with their beaks. Within no time at all, millions of blue-tits imitated this discovery, and in the course of a few decades this behavior successfully spread throughout England, necessitating putting the bottles into containers (WILSON, 1985).

Cultural evolution can also be found in other members of the animal kingdom, e.g., in the *social* behavior of cetaceans or elephants. These achievements go beyond metaorganismic strategies such as symbiosis, parasitism, or the virtually ubiquitous attack and defense strategies and that are passed on to descendants via specific forms of socialization. In the case of cetaceans we know that brain capacity is on par with that of humans, even though their external habitus has differentiated along a dramatically different path.

We humans perceive ourselves to be the epitome of cultural evolution. We explain this by our rationality and our specifically human linguistic competence and performance, all of which enable us to determine our own development in a free and deliberate manner that strives to conform with the respective culturally evolved rationality types. The attempt to systematically promote cultural evolution (for example in the non-violent solution of conflicts in the political arena) is designed to orient the ongoing development of advantageous values and norms. Human cultural evolution also occasionally requires a change, expansion, or transformation of existing values and norms (see, for example, the dynamics of theories in science). Research in the field of science history has proven beyond a doubt that the most important steps in this evolution are discontinuous and do not arise as induction or deduction from previously existing research material (KUHN, 1970).

***As the argumentation outlined above hopes to show, the decisive evolutionary steps on these three levels proceed via generative sign use or sign processes (semioses); using a finite number of signs and finite number of grammatic, semantic, and pragmatic rules, existing rules of sign use can be indefinitely expanded, altered and/or newly combined to yield new genetic texts, new kingdoms of organisms, new forms of behavior, and new norms of actions (in humans).***

Whenever such novel blueprints help optimize the „overall fitness“ of sign processes in intra-, inter-, and metaorganismic communication types, then the living representatives bearing these new blueprints will have a greater reproductive success.

Cultural evolution in humans has taken on a life of its own; it has increasingly decoupled itself from molecular and organismic evolution to the point that mankind must develop

culturally in order to survive. Thus, the mounting irreversible damage to the very foundations of our existence calls for action: there is widespread recognition that a „business as usual“ approach to contaminants will make life for future generations impossible (POSNER, 1990 a).

Evolution, as briefly outlined above, is not the result of mutation and selection as has been assumed by the biological sciences. Rather, it is the product of *sign-mediated communication and the selection of the produced communication forms*.

## 10. Nature as a norm subject

„We term ‘nature as productivity’ ‘nature as subject’“. Schelling’s statement takes on a new perspective in the framework of the present contribution. If we focus on the realm of living nature, then „productivity“ in our sense would mean: *communication processes carried out by communication-competent individuals in a variety of communication media, each reflecting its own real life-world* (Lebenswelt). This encompasses the realm of intra-, inter-, and metaorganismic communication (3 types of communication) and is set in the framework of a broad phenotypic diversity which can be systematized into six basic, semicompatible forms of communication (Chapter 8).

Just as this semicompatibility indicates successive phylogenetic origins, it equally provides evidence for the evolution of organisms that, compared with existing forms, represent a novum. The origin of the novel entity has been explained by evolutionary theory in the form of an exhaustively discussed explanatory model based on continuity theory. Its central concepts are „mutation“ and „selection“.

*The inevitable problems associated with the continuity theory vanish in the framework of a „theory of communicative nature“:* A characteristic feature of any language use in communication processes is that a finite number of signs governed by a finite number of rules principally enables existing rules and sign sequences to be expanded and/or changed. The abrupt appearance of new biological species, even the semicompatibility of the six fundamental communication forms in nature, can be plausibly explained and understood if one assumes that living nature is structured and organized in a communicative manner. Thirty years of research in the field of language and communications theory has enabled us, as humans, to ever more clearly recognize these abilities of linguistic communication in both human and animal (compare the comprehensive research on zoosemiotics) communities.

(A similar phenomenon is evident in the field of science. In analysing epistemological progress, the discussions of the 1970s and 1980s on science theory showed that explanatory attempts based on the theory of continuity have been superseded by the recognition that *revolutionary scientific phases* and knowledge are abrupt, discontinuous phenomena).

When communication processes in living nature go awry, a wide range of organisms will suffer negative repercussions. Virtually every species will be affected because the „living nature as a global community of communication“ is subdivided into an almost impenetrable maze of communication links and relationships involving even the smallest specific communicating populations, each of which is anchored in the three communication types. (The systems-theoretical metaphor „network“ may have a certain illustrative value; on the other hand, as was demonstrated in Chapter 6 where Manfred Eigen’s language and communication concepts were critically analyzed, systems theoretical and information theoretical tools are fundamentally insufficient to fully back up these two terms and justify their application to the realm of living nature.)

As far as the three communication types are concerned, humans are also entwined in this communicative web. **Above all, the human element has introduced a new quality into the productivity of nature: In the form of human self-consciousness, nature is in a position to be aware of itself.** This logically occurs against the interpretational backdrop of evolved cultural traditions, each with its own genesis of unique cultural norms. Scientific research, on the other hand, involves abstracting from this specific, culturally determined interpretational horizon and operating according to the respective state of objectivating knowledge.

At the same time, such scientific criteria also represent a relative evaluatory scheme that can be changed, expanded, or even become superfluous. The pathway to scientific understanding of nature can serve as an example: it ranges from the metaphysical study of nature by Greek philosophy to the crypto-metaphysical science theories of logical empiricism and to the hermeneutic-pragmatic reflection on language as a precondition for the possibility of intellectual reflection.

Human self-consciousness, which continues to develop linguistically and communicatively, has not yet attained a stage in which cultural norm genesis has institutionalized a special consensus of norms: This point must be reached before the communicative relationship between human culture to non-human nature reaches fruition, i.e., before the human species not only finds successful solutions to the ecological crisis, but finds these solutions **in time** and can fully implement them.

The **cultural evolution** this will require of humans still lies ahead. Mankind's own fate rests on this future achievement: if we are unable to solve the ecological crisis in time, then we will destroy the cornerstone of our own existence. A detailed blueprint setting the course for a sound cultural evolution goes beyond the scope of this book. Nonetheless, we can postulate three procedural steps that offer hope for a cultural evolution of the required scale:

- a) rational definition of living nature as a norm subject
- b) genesis of norms in shaping generally acceptable political ideas
- c) institutionalizing the results of this norm genesis in the form of internationally binding, enforceable legal norms.

It cannot be the task of the present contribution to elaborate these (potential) procedural steps, nor is it within the scope of the book to provide a rational foundation of living nature as a norm subject. This is the task of **ecological ethics**.

However, the results of this book enable us to evaluate the communicative relationship between humans and (living) non-human nature. Specifically, in which cases and under which conditions do we humans behave toward non-human organisms in a **communicatively appropriate or in a communicatively pathological** manner? This recognition could provide the basis for dialog within ecological ethics and contribute to a rational definition of living nature as a norm subject.



## 10.1. The communicative relationship between man and nature

### 10.1.1. Intraorganismic communication in humans is almost exclusively a natural phenomenon

As is the case in all organisms, humans are also anchored in the three communication types of living nature. Our own evolution no doubt owes much to evolution in the realm of our three communication types. Human intraorganismic communication, which is far more a natural than a culturally derived phenomenon (perhaps with the exception of the human brain), differs only minimally from that of our closest primate relatives (the DNA in chimpanzees and humans differs by a mere 1.2%; GHIGLIERI, 1985). This is the type of communication in which we most closely resemble our closest relatives in the animal kingdom.

On the other hand, the complexity of the brain also represents a distinct difference biologically and probably contributed considerably to the independent development of the human race. Thus, the text-processing competence of cooperating enzyme proteins has no doubt reached an evolutionary peak in humans („Hamilton draws our attention to the fact that the highest degree of cooperation can, in fact, be found in colonies of genetically identical cells such as those that shape the human body“; SMITH, 1985, p. 164).

### 10.1.2. Interorganismic communication in humans is largely a cultural phenomenon

The realm of interorganismic communication differs quite distinctly from the aforementioned case. In humans, this realm has also been the subject of the most intense scientific inquiry. The unique capacity of humans for language and communication has enabled us to undergo a culturally derived, linguistically mediated development. Of course, we are still in the dark about the origins of human language (GAMKRELIDSE, 1990; ROSS, 1991; CAVALLI-SFORZA, 1991). „Despite a wealth of imaginative studies, mystery still surrounds the origin of the human capacity for language. Fossil remains also fail to provide any clues. Yet, language was probably the decisive factor in the accelerated development of mankind“ (WASHBURN, 1978)

Our brain enabled us to develop what we term human language, reason, consciousness, and the capacity for abstract thought. It also gave rise to a normative awareness of values in coordinating our actions and forming associations. Rather than being biologically inheritable, these moral values are a cultural variant, i.e., they are passed down from the older to the younger generation of a social and cultural community in the form of linguistic-cultural tradition and a mixture of demonstrative role models and emulation.

Approximately 5000 different human languages are currently known. They represent evolved cultural traditions and culture-specific lifestyles that the „social animal“ man has differentiated. Each of these cultural communities fosters its cultural traditions in its own manner. Religious, ritual, and mythological moral concepts and norms shape social and

individual life, as does the confrontation with the universalized, modern moral concepts associated with the techno-scientifically oriented, enlightened society.

Interorganismic communication in humans (to which we as humans have privileged access) is uniquely suited to highlight the power of language and communication: using a finite number of signs and finite number of rules, they not only shape and regulate the structure and organization of individual and social life, but, above all, alter, expand, transform, and even revise them.

*Our interorganismic communication enables us to formulate our empirical (I) and transcendental-reflective (II) self-understanding (Selbstverständnis).*

It is precisely in the organization of social and cultural life that humans differ so distinctly from analogous organizational structures in their closest biological relatives. At the same time, this communication level has a broad cultural variability. While in earlier times and even today there are human cultural traditions that are cosmocentric rather than anthropocentric, others are explicitly anthropocentric, i.e., cultures in which „humans are the measure of all things“. Even in the latter norm tradition one can differentiate (in the framework of political ideology, for example) an individual-based anthropocentrism and a collective anthropocentrism.

This range of cultural norm traditions in the realm of interorganismic communication (the type of communication with which humans discuss their social organization in a species-specific manner using the same or compatible repertoire of signs and rules) helps determine the norms according to which humans interact with non-human nature. These norms belong in the realm of metaorganismic communication.

#### 10.1.3. Cultural tradition plays an important role in orienting metaorganismic communication

Humans differ distinctly from their closest biological relatives on this level as well: they are in a position to technically decipher and strategically utilize every communication form found in living nature. Humans generally interact with other species in the framework of culturally determined moral concepts.

Thus, the diet of certain cultures consists exclusively of vegetable foodstuffs, while others eat meat as well. What some consider to be a delicacy, others strictly reject (e.g., pork, turtle meat). In some peoples, cultural norms justify only absolute essential interventions into the natural environment; others produce food surpluses that go to waste.

When felling a tree or killing an animal, for example, animistic or spiritistically oriented cultural communities often apologize or make a sacrificial offering to the „spirit“ that „resides“ in the particular organism. In enlightened, techno-scientific society, trees and animals are defined as commercially calculable and exploitable objects, and there is little understanding for the normative behavioral codex of animistic or spiritistic cultural traditions. This can lead to a considerable clash of moral concepts (cutting down rain forests or mining uranium in environments occupied by indigenous peoples).

The above represents little more than an arbitrary slice in the spectrum of culturally determined value systems. I base my discussion of the communicative relationship between humans and non-human nature on the norms and underlying values of contemporary, scientific-technically oriented civilization. There can be no doubt that this civilization bears the prime responsibility for the current ecological crisis, a crisis that will necessitate rapid cultural evolution in our relationship with living nature.

#### 10.2. Remedying the human (metaorganismic) communication pathology towards living nature as a necessary step in cultural evolution

Mankind uses technical means to subjugate non-human nature for its purposes and takes advantage of „natural resources“ to realize its directed short-, medium-, and long-term goals. We are *the only* life form to extend our sphere of interest to representatives of *all* kingdoms (prokaryotes/bacteria: sewage plants, pharmaceuticals, etc.; protoctists: medical preparations; animals: meat production; fungi: antibiotic cultures, bread baking, cheese making, beer brewing; plants: plant cultures).

Providing food for the 10 to 15 billion people inhabiting our planet requires clearing gigantic areas of cultivable land. This cannot but reduce overall biological diversity and reduce the global communication community of living nature by tens of thousands of **member** species. The natural balance of mutually stabilizing communicative relationships is disturbed and would have to be stabilized by strategic-technical interventions. Failure would jeopardize the survival of the global community of communication as a whole. Can our human community, with its system of values, assume responsibility for such a development? Who will actually bear the responsibility if such strategies fail? These are the types of questions raised by an ecologically oriented ethics.

On the other hand, a „theory of communicative nature“, whose systematic details remain to be elaborated, could help us determine the communicative relationship between humans and non-human nature, provided that true communication is involved rather than *distorted* communication in the form of a monological relationship based on cultural values and norms; *deformed* communication such as that appearing in the psychosomatic realm; terminated communication, for example due to special scientific methodologies; or - and this is probably the crux of the urgent cultural evolution needed to solve the ecological crisis in time - forms of **communication pathology**. Such forms of pathology must be assumed to exist in cases where the habitats of biological species are destroyed, casting doubt on the future of nature as a global community of communication.

The culturally variable system of moral concepts and norms which determines the relationship between humans and non-human nature is being replaced by the universalized values and norms of techno-scientific society, foremost by economic reason. This transmits an anthropocentric relationship to nature, in which living nature is merely an exploitable resource subject to cost-benefit analyses, to all other cultures. This colonial cultural view must therefore be revised in the course of remedying our pathological communication behavior toward non-human nature. The vehicle for this is the indispensable cultural evolution of universally valid values and norms. Otherwise, we run the risk that

uncoordinated, culturally varied values and norms will not only fail to rectify this pathological communication, but *may even exacerbate* our anthropocentric relationship with non-human nature.

To be more precise, the cultural evolution necessitated by the ecological crisis and called upon to newly define the relationship with living (non-human) nature begins with the internalization of systems of values and norms, systems that are capable of counteracting - **in a timely manner** - the consequences of techno-scientific anthropocentrism and its inherent communication pathology. Recognizing living (non-human) nature as a norm subject is a way forward: as long as the various cultural traditions are willing to accept the global environmental crisis as fact, they should be open to a plausible explanation of our communication pathology toward living nature from the perspective of living nature as a global community of communication“.

Under the assumption that nature is a global community of communication, non-human nature becomes definable as a norm subject in the interplay of nature's semicompatible communication forms. Therefore we **cannot** assume that non-human nature will treat us as a subject of equal rank, nor can we attribute non-human nature with an consciousness of norms (this would give rise to the absurd situation that norm violations by organisms would be punishable in the framework of the human legal system).

Humans, by applying their powers of reason, are in a position to recognize how significant the complementarity of the communicative interrelationships is for ecological stability. They can also correct this relationship with non-human nature, because they can recognize how dependent communication within non-human nature is on this prevailing complementarity (which mankind is in the process of destroying).

Since human development is largely oriented according to cultural values and norms, we (or our reason) are called upon to consider the consequences of our actions, for example as they pertain to future generations *of all biological species*. The potential overkill of technical threats endangers the very survival of living nature and makes the use of reason the perhaps single **most important action that must be set in our recent evolutionary history**.

Massive and potentially irreversible damage to the complementary interactions and functions between and within kingdoms of organisms endangers the cultural and even the biological reproductive ability of the entire human species. At *no other time* in history has the entire biosphere been threatened to such a degree. Our techno-scientific civilization must solve the problems it has triggered by (a) changing its system of cultural values and norms and (b) changing the programs and activities stemming from these concepts. Should the requisite coordinated action lag behind the level of threat, then the cliché (or our image of ourselves) as the „crown jewel of evolution“ might flip to the opposite extreme (mankind as the „curse of evolution“).

The moral concepts and norms of modern techno-scientific civilization are spreading unabated across the globe and colonizing traditional cultural societies to their core. In

many respects, this enlightened consciousness toward nature has supported our struggle against the forces of nature. Modern medicine is only one of the factors that have increased our life expectancy considerably: we are no longer at the mercy of diseases against which there was little chance of survival in earlier times. On the other hand, our achievements have led to a series of threats unknown in the past, such as overpopulation of the planet. The relationship between humans and non-human nature is developing along new lines due to the immense scale of the human factor.

Ultimately, we can interpret our ability to apply reason as an expression of the type of nature's productivity (in the sense of Schelling) that has led nature to differentiate - albeit by other mechanisms - all other biological species: none of this would have been possible without the formative potential of the nucleic acid language. Should we be unable to master the ecological crisis and should our activities be the prime force behind the collapse of the global biosphere, then mankind could no longer define itself as an integral part of nature's productivity. Why? Because the fundamental feature of this productivity is that communication interlinks are stabilized by being multiplied. The communication pathology towards living (non-human) nature would disqualify nature *that has attained consciousness* (humans) vis-à-vis nature *that has not attained such consciousness*. Mankind would lose its status of „nature as subject“ (in the sense of Schelling) to non-human nature.

Our opportunity to continue to view ourselves as „nature as subject“ lies in cultural evolution. This evolution would dismantle the current communication pathology toward living nature in favor of conduct that fosters communication, would master the ecological crisis, and would be the expression of an adequate, productive form of nature that enhances overall survival.



# Bibliography

- Adler, B.K./ Hajduk, St.L., „Mechanism and origins of RNA editing“,  
In: Current Opinion in Genetics and Development, 4, 1994, p. 316.
- Apel, K.O. (Ed.) „Sprachpragmatik und Philosophie“, Suhrkamp, Frankfurt, 1976 (a).
- Apel, K.O. „Transformation der Philosophie“ (2 volumes), Suhrkamp,  
Frankfurt, 1976 (b).
- Ascher, Ph., Stevens, Ch.F., (eds.) „Signalling mechanisms“,  
In: Current Opinion in Neurobiology, Vol. 6, No. 3, 6/1996, p. 191.
- Austin, J.L. „How to Do Things with Words“, Oxford University Press, 1962.
- Ayala, F.J., „The Mechanisms of Evolution“, Scientific American, 9/1978, p. 48.
- Beardsley, T., „Intelligente Gene“, Spektrum der Wissenschaft, 10/91, p. 64.
- Beauchamp, G.K., Yamazaki, K., Boyse, E.A., „The Chemosensory Recognition  
of Genetic Individuality“, Scientific American, 7/1985, p. 166.
- Bekoff, M., Wells, M.C., „The Social Ecology of Coyotes“,  
Scientific American, 4/1980, p. 112.
- Berg, P., „Dealing with Genes“, University Science Books, 1992.
- Berridge, M.J., Irvine, R.F., „Inositol Triphosphate, a Novel Second Messenger  
in Cellular Signal Transduction“, In: Nature, Bd. 312, Heft 5992., 1984.
- Berridge, M.J., „The Molecular Basis of Communication within the Cell“,  
Scientific American, 10/1985, p. 124.
- Beurton, P.J., „A unified view of the gene, or how to overcome reductionism“,  
In: Max Planck Institute for the History of Science, Preprint 123,  
Gene Concepts in Development and Evolution, Berlin 1999, p. 97.
- Bishop, J.M., „Oncogenes“, Scientific American, 3/1982, p. 68.
- Boehmer, H.v.(u.a.), „How the Immune System Learns about Self“,  
Scientific American, 10/1991, p. 72.
- Bonner, J.T., „Chemical Signals of Social Amoebae“,  
Scientific American, 4/1983 (a), p. 106.
- Bonner, J.T., „Kulturevolution bei Tieren“, Parey, 1983 (b).
- Bossinger, O., Schierenberg, E., „Cell-cell communication in nematode embryos:  
differences between *Cephalobus spec.* and *Caenorhabditis elegans*“,  
In: Development Genes and Evolution, Vol. 206, Nr. 1, 6/1996, p. 25.
- Brosius, J., „Retroposons - seeds of evolution“, In: Science, 251, 1991, p. 753.
- Brosius, J., Gould, S.J., „On ‘genomenclature’: A comprehensive (and respectful)  
taxonomy for pseudogenes and other ‘junk DNA’“,  
In: Proceedings of the National Academy of Science, 89, 1992, p. 10706.
- Bucher, Z., „Die Abstammung des Menschen als naturphilosophisches Problem“,  
Königshausen + Neumann, Würzburg, 1992.
- Buldyrev, S.V., Goldberger, A.L., Havlin, Sh., Peng, Ch.-K., Simons, M., Stanley, E.E.,  
„Generalized Lévy-walk model for DNA nucleotide sequences“,  
In: Physical Review E, Vol. 47, No. 6, June 1993 (a), p. 4514.

- Buldyrev, S.V., Goldberger, A.L., Havlin, S., Peng, C-K., Stanley, H.E., Stanley, M.H.R., Simons, M., „Fractal Landscapes and Molecular Evolution: Modeling the Myosin Heavy Chain Gene Family“,  
In: Biophysical Journal, Vol. 65, December 1993 (b), p. 2673.
- Buldyrev, S.V., Goldberger, A.L., Havlin, S., Mantegna, R.N., Matsa, M.E., Peng, C.-K., Simons, M., Stanley, H.E., „Long-range correlation properties of coding and noncoding DNA sequences: GenBank analysis“,  
In: Physical Review E, Vol. 51, No. 5, May 1995, p. 5084.
- Buske-Kirschbaum, A., et.al. „Die klassische Konditionierung von Immunreaktionen“,  
In: Kirschbaum, C., Hellhammer, D., (eds) Enzyklopädie der Psychologie: Biologische Psychologie; Psychoendokrinologie und Psychoimmunologie. Hogrefe, Göttingen, Bern, Toronto, Seattle, 1999.
- Bystrina, I., „Kodes und Kodewandel“,  
In: Zeitschrift für Semiotik, Band 5, Heft 1/2, Stauffenburg, Wiesbaden, 1983.
- Carafoli, E./Penniston, J.T., „The Calcium Signal“,  
Scientific American, 11/1985, p. 50.
- Carroll, S.B., „Homeotic genes and the evolution of arthropods and chordates“,  
In: Nature, Vol. 376, August 1995, p. 479.
- Cavalli-Sforza, L.L., „Genes, Peoples and Languages“,  
Scientific American, 11/1991, p. 72.
- Chairns, J., „The Cancer Problem“, Scientific American, 11/1975.
- Chairns, J., „The Treatment of Diseases and the War Against Cancer“,  
Scientific American, 11/1985, p. 31.
- Changeux, J.P., „Chemical Signaling in the Brain“,  
Scientific American, 11/1993, p. 30.
- Cheung, W.Y., „Calmodulin“, Scientific American, 6/1982, p. 48.
- Chomsky, N., „The Logical Basis of Linguistic Theory“,  
In: Proceedings of the 9th International Congress of Linguistics, Cambridge, Mass. 1962. The Hague, 1964.
- Chomsky, N., „Current Issues in Linguistic Theory“, The Hague, 1964.
- Cohen, I.R., „The Self, the World and Autoimmunity“,  
Scientific American, 4/1988, p.34.
- Collier, R.J./Kaplan, D.A., „Immunotoxins“, Scientific American, 7/1984, p. 44.
- Croce, C.M./Klein, G., „Chromosome Translocations and Human Cancer“,  
Scientific American, 3/1985, p. 44.
- Darnell, J.E.jr., „RNA“, Scientific American, 10/1985, p. 54.
- Delbrück, M., „Der kartesische Schnitt“, In: Küppers, B.O. (Ed.),  
Leben = Physik + Chemie, Piper, München, 1987.
- Devoret, R., „Bacterial Tests for Potential Carcinogenes“,  
Scientific American, 8/1979, p.28.
- Dickerson, R.E., „Chemical Evolution and the Origin of Life“,  
Scientific American, 9/1978, p.62.
- Doolittle, R.F., „Proteines“, Scientific American, 10/1985, p. 74.
- Duve, Ch, de., „Die Herkunft der komplexen Zellen“,  
Spektrum der Wissenschaft, 6/1996, p 60.



- Eigen, M., Winkler, R., „Das Spiel - Naturgesetze steuern den Zufall“, Piper, München, 1975.
- Eigen/M./Gardiner, W./Schuster,P./Winkler-Oswartitsch, R., „The Origin of Genetic Information“, Scientific American, 4/1981, p. 78.
- Eigen, M., „Virus-Quasispezies oder die Büchse der Pandora“, In: Spektrum der Wissenschaft, 12/1992, Heidelberg, 1992.
- Felsenfeld, G., „DNA“, Scientific American, 10/1985, p. 44.
- Fogle, Th., „The dissolution of protein coding genes in molecular biology“, In: Max Planck Institute for the History of Science, Preprint 123, Gene Concepts in Development and Evolution, Berlin 1999, p. 69.
- Folkman, J. (1976), „The Vascularisation of Tumors“, Scientific American, 5/1976.
- Frisch, K.v., „Die wechselseitigen Beziehungen und die Harmonie im Bienenstaat“, In: Colloques d.Centre Nat. de la Recherche Scient. XXXIV, Paris, 1952.
- Frisch, K.v., „‘Sprache’ oder ‘Kommunikation’ der Bienen?“, In: Psychologische Rundschau, Band 4, Jg. 1953, Amsterdam 1953.
- Frisch, K.v., „Sprechende Tänze im Bienenvolk“, München 1955.
- Frisch, K.v., „Tanzsprache und Orientierung der Bienen“, Berlin, Heidelberg, New York, 1965.
- Frisch, K.v., „Ausgewählte Vorträge 1911 - 1969“, München, Basel, Wien, 1970.
- Frisch, K.v., „Bees: Their Vision, Chemical Senses and Language“, revised ed. Cornell University Press, Ithaca, 1971.
- Gamkrelidse, Th.W. (u.a.), „The Early History of Indo-European Languages“, Scientific American, 3/1990, p. 82.
- Gehring, W.J., „Genetische Architektur: Ein Lebewesen nimmt Gestalt an“, In: Bild der Wissenschaft, Heft 11/1984, Stuttgart, 1984.
- Gehring, W.J., „The Molecular Basis of Development“, Scientific American, 10/1985, p. 136.
- Ghiglieri, M.P., „The Social Ecology of Chimpanzees“, Scientific American, 6/1985, p. 102.
- Gilbert, S.F. „Comments“ to M. Morange, In: Max Planck Institute for the History of Science, Preprint 123, Gene Concepts in Development and Evolution, Berlin 1999, p. 43.
- Gödel, K., „Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme“, In: Monatshefte für Mathematik und Physik, 38, 1931, p. 173.
- Griffin, D.R., „The Cognitive Dimensions of Animal Communication“, In: Hölldobler, B., Lindauer, M. Experimental Behavioral Ecology and Sociobiology, Stuttgart, New York, 1985.
- Groves, D.I./Dunlop, J.S.R./Buick, R., „The Early Habitat of Life“, Scientific American, 10/1981, p. 56.
- Grunstein, M., „Histones as Regulators of Genes“, Scientific American, 10/1992, p. 40.
- Habermas, J., „What Is Universal Pragmatics“, In: „Communication and Evolution of Society“, Beacon Press, Boston, 1979.

- Habermas, J., „Vorstudien und Ergänzungen zur Theorie des kommunikativen Handelns“, Suhrkamp, Frankfurt, 1984.
- Habermas, J., „Theory of Communicative Action“, Vol. 1, Heinemann London, 1985, Vol. 2, Blackwell, 1989.
- Habermas, J., „Actions, speech acts, linguistically mediated interactions and the lifeworld“, In: Floistad, G. (ed.), *Philosophical problems today*, Vol. 1, Kluwer Academic Publishers, 1994, p. 45.
- Hartmann, N., „Der Aufbau der realen Welt“, Berlin, 1964.
- Heckmann, R. (ed.) „Natur und Subjektivität“, Fromann-Holzboog, Stuttgart/Bad Cannstatt, 1985.
- Heinrich, B., „The Regulation of Temperature in the Honeybee Swarm“, *Scientific American*, 6/1981, p. 120.
- Hellhammer, D.H., „Psychoendocrinology: The Brain, Hormones and Behavior“, In: Ehlers, A. et.al. (eds) *Perspectives and promises of clinical psychology*, Plenum Press, New York, 1992, p. 61.
- Hoffmeyer, J., Emmeche, C., „Code-duality and the semiotics of nature“, In: *On Semiotic Modeling*. Myrdene Anderson, Floyd Merrel (eds.) Mouton de Gruyter, Berlin/New York, 1991, p. 117.
- Hoffmeyer, J., „Some Semiotic Aspects of the Psycho-Physical Relation: The Endo-Exosemiotic Boundary“, In: Sebeok, Th.A., Umiker-Sebeok, J. (eds.) *From Biosemiotics: The Semiotic Web 1991*, Mouton de Gruyter, Berlin, 1992.
- Horner, J.R., „The Nesting Behavior of Dinosaurs“, *Scientific American*, 4/1984, p. 62.
- Howard Flanders, P., „Inducible Repair of DNA“, *Scientific American*, 11/1981, p. 56.
- Höfer, M., „Transport durch biologische Membranen“, Weinheim, New York, 1977.
- Huber, F./Thorson, J., „Cricket Auditory Communication“, *Scientific American*, 12/1985, p. 46.
- Hultsch, H., Todt, D., „Signal matching: Zeichenbildung durch mustergleiche Antworten“, In: *Zeitschrift für Semiotik*, Bd.8, Heft 3/86, Stauffenburg, Tübingen, 1986.
- Hunter, T., „The Proteins of Oncogenes“, *Scientific American*, 8/1984, p. 60.
- Iversen, L.L., „The Chemistry of the Brain“, *Scientific American*, 9/1979, p. 118.
- Jacob, F., „The Logic of Life“, Vanguard, New York, 1976.
- Jablonka, E./Lamb, M.J., „Epigenetic Inheritance and Evolution: The Lamarckian Dimension“, Oxford University Press, Oxford, 1995.
- Kahn, P., „From Genome to Proteome: Looking at a Cell's Proteins“, In: *Science, Genome Issue*, Vol. 270, 10/1995, p.369.
- Kahn, P., „Entering the Postgenome Era“, In: *Science, Genome Issue*, Vol. 270, 10/1995, p.368.
- Kaiser, D., Losick, R., „How and Why Bacteria Talk to Each Other“, *Cell*, Vol. 73, No. 5, June 4, 1993, p. 873.
- Karplus, M. /McCammon, J.A., „The Dynamics of Proteins“, *Scientific American*, 4/1986, p. 30.
- Keller, E.F., „Between language and science: the question of directed mutation in molecular genetics“, In: *Perspectives of Biology and Medicine*, 35, 1992, p. 293.

- Keller, E.F., „Decoding the genetic program“,  
In: Max Planck Institute for the History of Science, Preprint 123,  
Gene Concepts in Development and Evolution, Berlin 1999, p. 49
- Kenyon, C., „If birds can fly, why can't we? Homeotic genes and evolution“,  
In: cell, 78, 1994, p. 78.
- Kimura, M., „The Neutral Theory of Molecular Evolution“,  
Scientific American, 11/1979, p. 94.
- Kirchner, W.H., Towne, W.F., „Die Tanzsprache der Bienen: eine akustische  
Kommunikation“, Spektrum der Wissenschaft, 8/1994, p.68.
- Kirschbaum, C., Hellhammer, D.H., „Hypothalamus-Hypophysen-Nebennieren-  
rindenachse“, In: Hellhammer, D.H., Kirschbaum, C. (eds)  
Enzyklopädie der Psychologie. Psychoendokrinologie und Psychoimmunologie,  
Biologische Psychologie, Vol. 3, Hogrefe, Göttingen, 1999, p. 79
- Kremer, B.P., „Mikroalgen als Zellgäste“, Spektrum der Wissenschaft, 2/1994.
- Krings, H., „Kann man die Natur verstehen?“, In: Kuhlmann, W., Böhler, D. (eds.)  
Kommunikation und Reflexion, Suhrkamp, Frankfurt, 1982.
- Krings, H., „Natur als Subjekt. Ein Grundzug der spekulativen Physik Schellings“,  
In: Heckmann, R. (ed.) Natur und Subjektivität, Stuttgart, 1985.
- Kroodsma, D., Miller, E., „Acoustic Communication in Birds“, New York, 1982.
- Kuhn, Th.S., „The Structure of Scientific Revolutions“,  
University of Chicago Press, Chicago, 1970.
- Levinton, J.S., „The Big Bang of Animal Evolution“,  
Scientific American, 11/1992, p. 52.
- Lewontin, R.C., „Adaptation“, Scientific American, 9/1978, p. 156.
- Ligon, J.D./Ligon, S.H., „The Cooperative Breeding Behavior of the  
Green Woodhoopoe“, Scientific American, 7/1982, p. 106.
- Llinás, R.R., „Calcium in Synaptic Transmission“, Scientific American, 10/1982, p.38.
- Lindauer, M., „Verständigung im Bienenstaat“, Stuttgart, 1975.
- Lindauer, M., „Kommunikation im Bienenstaat - Arbeitsteilung, Nahrungssuche,  
Wohnungssuche“,  
In: Scharf, J.H., Kämmerer, W. (eds.) Nova Acta Leopoldina, Leipzig, 1981.
- Lloyd, J.E., „Mimicry in the Sexual Signals of Fireflies“,  
Scientific American, 6/1981, p. 110.
- Losick, R., Kaiser, D., „Why and How Bacteria Communicate“,  
Scientific American, 2/1997, p.52.
- Mantegna, R.N., Buldyrev, S.V., Goldberger, A.L., Havlin, S., Peng, C.-K., Simons, M.,  
Stanley, H.E., „Linguistic Features of Noncoding DNA Sequences“,  
In: Physical Review Letters, Vol. 73, No. 23, December 1994. p. 3169.
- Margulis, L., „Symbiotic planet“, Basic Books, New York, 1998.
- Margulis, L./Schwartz, K.V., „Five Kingdoms“,  
Freemann and Company, 2nd Ed., New York, 1988.
- Matthes, D., „Tiersymbiosen und ähnliche Formen der Vergesellschaftung“,  
Stuttgart, New York, 1978.
- May, R.M., „The Evolution of Ecological Systems“,  
Scientific American, 9/1978, p. 118.

- Mayr, E., „Evolution“, Scientific American, 9/1978, p. 39.
- McKnight, St.L., „Molekulare Reißverschlüsse bei der Genregulation“, Spektrum der Wissenschaft, 6/1991, p. 58.
- Morange, M., „The developmental gene concept: history and limits“, In: Max Planck Institute for the History of Science, Preprint 123, Gene Concepts in Development and Evolution, Berlin 1999, p. 25.
- Morange, M., „Comments“ to H.J. Rheinberger, In: Max Planck Institute for the History of Science, Preprint 123, Gene Concepts in Development and Evolution, Berlin 1999, p. 20.
- Moses, P.B./Nam Hai Chua, „Light Switches for Plant Genes“, Scientific American, 4/1988, p. 64.
- Nicolson, G.L. (1979), „Cancer Metastasis“, Scientific American, 3/1979, p. 50.
- Old, L.J. , „Cancer Immunology“, Scientific American, 5/1977.
- Ossadnik, S.M., Buldyrev, S.V., Goldberger, A.L., Havlin, S., Mantegna, R.N., Peng, C.-K., Simons, M., Stanley, H.E., „Correlation approach to Identify Coding regions in DNA Sequences“, In: Biophysical Journal, Vol. 67, July 1994, p. 64.
- Palm, G., „Assoziatives Gedächtnis und Gehirntheorie“, Spektrum der Wissenschaft, 6/1988, p.54.
- Patridge, B.L., „The Structure and Function of Fish Schools“, Scientific American, 6/1982, p. 90.
- Peng, C.-K., Buldyrev, S.V., Goldberger, A.L., Havlin, S., Simons, M., Stanley, H.E., „Finite-size effects on long-range correlations: implications for analyzing DNA sequences“, In: Physical Review E, Vol. 47, No. 5, May 1993, p. 3730.
- Peng, C.-K., Buldyrev, S.V., Havlin, S., Simons, M., Stanley, H.E., Goldberger, A.L., „Mosaic organization of DNA nucleotids“, In: „Physical Review E, Vol. 49, No.2, 1994, p. 1685.
- Peukert, H., „Wissenschaftstheorie, Handlungstheorie, Fundamentale Theologie“, Suhrkamp, Frankfurt, 1978.
- Ploog, D., „Die Sprache der Affen und ihre Bedeutung für die Verständigungsweisen des Menschen“, München 1974.
- Philippe, H.,Chenuil, A., Adoutte, A., „Can the Cambrian explosion be inferred through molecular phylogeny?“, In: Development Supplement, 1994, p. 15.
- Popp, F.A., „So könnte Krebs entstehen“, In: Bild der Wissenschaft, Heft 1/1976, Stuttgart, 1976.
- Popp, F.A., „Biologie des Lichts. Grundlagen der ultraschwachen Zellstrahlung“, Parey, Berlin, Hamburg, 1984.
- Posner, R., (ed.), Warnungen an die ferne Zukunft“, Raben, München, 1990 (a).
- Posner, R., „Pragmatics“, unreleased script, Berlin, 1990 (b).
- Posner, R., et.al.(eds.), „Semiotics. A Handbook on the Sign-Theoretic Foundations of Nature and Culture“, Berlin, New York, 1990 (c).
- Prestwich, G.D., „The Chemical Defenses of Termites“, Scientific American, 8/1983, p. 68.
- Prigogine,I., „From Being to Becoming“, Freeman, San Francisco, 1980.
- Prigogine, I., Stengers, I., „Order out of Chaos. Man's new Dialogue with Nature“, Heinemann, London, 1984.

- Rheinberger, H.J., „Gene concepts: fragments from the perspective of molecular biology“,  
In: Max Planck Institute for the History of Science, Preprint 123,  
Gene Concepts in Development and Evolution, Berlin 1999, p. 3.
- Révész, G., „Der Kampf um die sogenannte Tiersprache“,  
In: Psychologische Rundschau, Bd.4, Jg. 1953, Amsterdam, 1953.
- Richards, F.M., „Die Faltung von Proteinmolekülen“,  
Spektrum der Wissenschaft, 3/1991, p. 72
- Ross, Ph.E., „Hard Words“, Scientific American, 4/1991, p. 70.
- Rothmann, J.E., „The Compartmental Organization of the Golgi Apparatus“,  
Scientific American, 9/1985, p. 84.
- Rubenstein, E., „Diseases Caused by Impaired Communication Among Cells“,  
Scientific American, 3/1980, p. 78.
- Ryker, L.C., „Acoustic and Chemical Signals in the Life Cycle of a Beetle“,  
Scientific American, 6/1984, p. 86.
- Sachs, L., „Growth, Differentiation and the Reversal of Malignancy“,  
Scientific American, 1/1986, p.30.
- Sapienza, C., „Parental Imprinting of Genes“, Scientific American, 10/1990, p. 26.
- Schopf, J.W., „The Evolution of the Earliest Cells“, Scientific American, 9/1978, p. 84.
- Searle, J.R., „Speech Acts. An essay in the Philosophy of Language“,  
Cambridge University Press, Cambridge, 1976.
- Searle, J.R., „Minds, Brains and Science“, Harvard University Press, Cambridge, 1984.
- Searle, J.R., „The Rediscovery of Mind“,  
Massachusetts Institute of Technology, Massachusetts, 1992.
- Sebeok, Th.A., „Animal Communication“, Bloomington, Indiana, 1968.
- Sebeok, Th.A., „Zoosemiotic Components of Human Communication“,  
In: Sebeok, Th.A. (ed.), How Animals Communicate, Bloomington/Indiana, 1977.
- Sebeok, Th.A., „The Sign & Its Masters“, University of Texas Press, Austin, 1979.
- Sebeok, Th.A., „The semiotic self“,  
In: Semiotics, Self and Society, Lee, B., Urban, G., (eds.), Mouton de Gruyter, Berlin, 1989.
- Seeley, Th.D., „How Honeybees Find a Home“, Scientific American, 10/1982, p. 144.
- Sharon, N., Lis, H., „Lectins as Cell Recognition Molecules“,  
In: Science 246, oct. 1989, p. 227.
- Shapiro, J.A., „Adaptive mutation: Who's really in the garden?“  
In: Science, 268, 1995, p. 373.
- Shapiro, R., „The Human Blueprint“, New York, 1991.
- Sippl, M.J., „Knowledge-based potentials for proteins“,  
In: Current Opinion in Structural Biology 5, 1995, p. 229,
- Sippl, M.J., „Proteinfaltung, Gene und Konzerne“ (unreleased paper),  
Center for Applied Molecular Engineering, Salzburg 1996 (a).
- Sippl, M.J., „Helmholtz Free Energy of Peptide Hydrogen Bonds in Proteins“,  
In: Journal of Molecular Biology - MS1353 Cust.Ref.No. CAM 076/96, 1996 (b).
- Smith, J.M., „The Evolution of Behavior“, Scientific American, 9/1978, p. 136.
- Smith, K.A., „Interleukin-2“, Scientific American, 3/1990, p. 26.
- Snyder, D.H., „The Molecular Basis of Communication Between Cells“,  
Scientific American, 10/1985, p. 114.

- Sonenberg, N., „mRNA translation: Influence of the 5´and 3´untranslated regions“,  
In: Current Opinions in Genetics and Development, 4, 1994, p. 310.
- Spitzer, M., (et.al.), „Functional MR imaging of semantic information processing and learning-related effects using psychometrically controlled stimulation paradigms“,  
In: Cognitive brain research, 4/1996, p. 149.
- „SPRACHE“, in: Funk Kolleg Sprache. Eine Einführung in die moderne Linguistik,  
Fischer, Frankfurt 1977.
- Tembrock, G., „Biokommunikation“ (Vol.1/2), Berlin, 1971.
- Todt, D., „Zur Bedeutung der ‘richtigen’ Syntax auditiver Muster für deren vokale Beantwortung durch Amseln“, in: Zeitschrift für Naturforschung, Nr. 29 c, 1974.
- Todt, D., „Hinweis-Charakter und Mittler-Funktion von Verhalten“,  
In: Zeitschrift für Semiotik, Bd. 8, Heft 3/1986, Stauffenburg, Tübingen, 1986.
- Tonegawa, S., „The Molecules of the Immune Systeme.“  
Scientific American, 10/1985, p.104.
- Tycowski, K.T., Mei-Di, s., Steltz, J.A., „A mammalian gene with introns instead of exons generating stable RNA products“,  
In: Nature, 379, 1996, p. 464.
- Uexküll, Th.v. (ed.), „Jakob von Uexküll. Kompositionslehre der Natur“,  
Ullstein, Frankfurt a.M./Berlin/Wien, 1980
- Uexküll, Th.v., „Semiotics and medicine“,  
In: Semiotica 38 - 3/4, Mouton Publishers, Amsterdam, 1982, p. 205.
- Uexküll, Th.v., „Semiotics and the problem of the observer“,  
In: Semiotica 48 - 3/4, Mouton Publishers, Amsterdam, 1984, p. 187.
- Uexküll, Th.v., „Medicine and semiotics“,  
In: Semiotica 61 - 3/4, Mouton de Gruyter, Amsterdam, 1986, p. 201.
- Uexküll, Th.v., „Naturwissenschaft als Zeichenlehre“,  
In: Merkur, 3/1989, München, 1989.
- Uexküll, Th.v., Geigges, W, Herrmann, J.M., „Endosemiosis“,  
In: Semiotica 96 - 1/2, Walter de Gruyter, Berlin, 1993, p. 5.
- Unwin, N./Henderson,R., „The Structure of Proteins in Biological Membranes“,  
Scientific American, 2/1984, p.56.
- Valentine, J.W., „The Evolution of Multicellular Plants and Animals“,  
Scientific American, 9/1978, p. 104.
- Verkhatsky, A., Kettenmann, H., „Calcium Signaling in Glial Cells“,  
Trends in Neurosciences, 8/1996, Vol. 19, Nr. 8, p. 346.
- Vollmert, B., „Das Molekül und das Leben“, Rowohlt, Reinbek, 1985.
- Vossenkühl, W., „Anatomie des Sprachgebrauchs: Über die Regeln, Intentionen und Konventionen menschlicher Verständigung“, Klett-Cotta, Stuttgart, 1982.
- Vossenkühl, W., (ed.), „Von Wittgenstein lernen“, Akademie Verlag, Berlin, 1992.
- Vossenkühl, W., „Ludwig Wittgenstein“, C.H. Beck, München, 1995.
- Walker, A./Leakey, R.E.F., „The Hominids of East Turkana“,  
Scientific American, 8/1978, p. 44.
- Washburn, S.L., „The Evolution of Man“, Scientific American, 9/1978, p. 146.
- Watson, J.D., Tooze, J., Kurtz, D.T., „Recombinant DNA“, Scientific American Books, 1983.

- Watson, J.D., Gilman, M., Witkowski, J., Zoller, M., „Recombinant DNA“, 2nd Ed., Scientific American Books, 1992.
- Weber, K., Osborn, M., „The Molecules of the Cell Matrix“, Scientific American, 10/1985, p. 92.
- Weinberg, R.A., „A Molecular Basis of Cancer“, Scientific American, 11/1983, p. 102.
- Weinberg, R.A., „The Molecules of Life“, Scientific American, 10/1985, p. 34.
- Weinberg, R.A., „Finding the Anti Oncogene“, Scientific American, 9/1988, p. 34.
- Wilson, A.C., Sarich, V.M., Maxson, L.R., „The importance of gene rearrangement in evolution: evidence from studies on rates of chromosomal, protein, and anatomical evolution“, In: Proceedings of the National Academy of Science, USA 71, 1974, p. 3028
- Wilson, A.C., „The Molecular Basis of Evolution“, Scientific American, 10/1985, p. 148.
- Witzany, G., „Zeichenprozesse als Bedingungen der Möglichkeit von Leben und Evolution: Zur Notwendigkeit einer Molekularpragmatik“, In: Zeitschrift für Semiotik, Bd. 15, Heft 1-2, Stauffenburg, Tübingen, 1993 (a), p. 107,
- Witzany, G., „Natur der Sprache - Sprache der Natur. Sprachpragmatische Philosophie der Biologie“, Königshausen & Neumann, Würzburg, 1993(b).
- Witzany, G., „From the 'logic of the molecular Syntax' to molecular pragmatism“, In: Evolution and Cognition, Vienna University Press, Vol.1, No.2, Vienna, 1995, p. 148.
- Witzany, G., „Semiosis and Evolution“, In: Irmengard Rauch (Ed.) Semiotics Around the World: Synthesis in Diversity, Mouton de Gruyter, Berlin, 1997, p. 977.
- Witzany, G., „Explaining and understanding LIFE“, In: Semiotica 120 - 3/4, Mouton de Gruyter, Berlin/New York, 1998, p. 421.
- Witzany, G., „Reduction of biological phenomena? Deficits of systems theory and the alternatives“, In: Walther Schmitz (Ed.) Sign Processes in Complex Systems. Mouton de Gruyter, Berlin /New York, 2000.
- Woese, C.R., „Archaeobacteria“, Scientific American, 6/1981, p. 94.
- Wright, G.H.v., „Erklären und Verstehen“, Suhrkamp, Frankfurt 1974.
- Wunderlich, D., Maas, U., „Pragmatik und sprachliches Handeln“, Suhrkamp, Frankfurt, 1972.
- Wunderlich, D., „Sprechakttheorie und Diskursanalyse“, In: Apel, K.O.(ed.) Sprachpragmatik und Philosophie, Suhrkamp, Frankfurt, 1976.
- Würsig, B., „The Behavior of Baleen Whales“, Scientific American, 4/1988, p. 75.
- Wyles, J.S., Kunkel, J.G., Wilson, A.C., „Birds, Behavior and Anatomical Evolution“, In: Proceedings of the National Academy of Sciences USA, Vol. 80, 14/84, p. 4394.

