The Epigenetic Research Program (EPR): a transdisciplinary approach for the dynamics of knowledge, society - and beyond

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Abstract

With the "epigenetic approach", an entire research program has been set up which is devoted to the study of "knowledge-based processes" in human societies - and beyond. More concretely, an epigenetic approach has been built up in which two different areas are addressed and dealt with *simultaneously*, namely *theoretical* foundations for the analysis of "knowledge based processes" and a comparatively large number of empirical applications, ranging from the study of organizations to the level of "National Innovation Systems". Moreover, the emphasis on "knowledge and information societies" is not motivated by current reconfigurations *via* communication and information technologies or the expansion of "knowledge generating capacities" beyond the confines of traditional universities or research institutes. Likewise, "knowledge and information societies" are *not* conceptualized as a stage beyond socio-economic inequality, contrasting it, for example, to traditional "class societies", but, once again, as a theoretical approach which offers new insights into the basic structure of current societal disparities.

Zusammenfassung

Mit dem "epigenetischen Zugang" wurde ein einheitliches Forschungsprogramm aufgebaut, das zur Analyse von "wissensbasierten Prozessen" in einer Unzahl von Bereichen dient. Konkret wurde mit dem epigenetischen Programm bislang auf der einen Seite ein anspruchsvolles "transdisziplinäres Forschungsprogramm" konstruiert und auf der anderen Seite eine Reihe von Anwendungen im Bereich von Organisationsanalysen oder auch "Nationalen Innovationssystemen" durchgeführt. Darüberhinaus erlaubt das epigenetische Programm, sich jenseits der gegenwärtig diskutierten Merkmale von "Wissensgesellschaften" wie der Diffusion von Informations- und Kommunikationstechnologien oder der Ausweitung in den traditionellen Stätten der Wissensproduktion - Universitäten und Forschungsinstitute - zu bewegen. Zu guter Letzt sei der Hinweis angebracht, daß gerade die neue Architektur von Wissens- und Informationsgesellschaften innovative Schlaglichter auf Fragen der gesellschaftlichen Ungleichheit wirft und gegenwärtige Problemfelder in diesem Bereich scharf zu akzentuieren vermag.

Keywords
Evolution, Network Theory, Knowledge, Information, Complexity

Schlagworte
Evolution, Netzwerktheorie, Wissen, Information, Komplexität

Contents

Introduction: A Short Preface for Two Long Articles

Concepts like "knowledge societies", "information societies", "post industrial societies", "knowledge and information societies", "knowledge based economies", "new production of knowledge" or "National Innovation Systems" (see, among *very* many others, only BELL 1979a,b, DRUCKER 1993, GIBBONS *et al.* 1994, KREIBICH 1986, LUNDVALL 1992, NELSON 1993, 1996, THUROW 1996) have become widely used for the description and the analysis of contemporary societies in which, summarized into two words, "knowledge matters". What the present set of two articles tries to achieve lies, in contrast to *most* of the existing literature on the topic of "knowledge and information societies", in three essential points.

> *First*, an entire "research program" has been set up which is devoted to the study of "knowledge and information societies", past, present and future. More concretely, an epigenetic approach[1] has been built up in which two different areas are addressed and dealt with *simultaneously*, namely *theoretical* foundations for the analysis of "knowledge based processes" and a comparatively large number of empirical applications, ranging from the study of organizations to the level of "National Innovation Systems".
>
> *Second*, the emphasis on "knowledge and information societies" is not motivated by current reconfigurations *via* communication and information technologies (CIT) or the expansion of "knowledge generating capacities" beyond the confines of traditional universities or research institutes. Rather, the basic architectures which will be laid out in the course of the next two articles can be applied to *any* type of societal formation, including pre-capitalist ones as well as to any type of "knowledge based processes" around individuals, households, organizations and the like. Likewise, "knowledge and information societies" are *not* conceptualized as a stage beyond socio-economic inequality, contrasting it, for example, to traditional "class societies", but, once again, as a theoretical approach which offers new insights into the basic structure of current societal disparities.
>
> *Third*, the new epigenetic approach has been constructed, again in an uncommon move, as an *applied basic* framework, which does *not* remain, as the German "morbus philosophicus" strongly suggests, a possible future oriented theory project *in statu abscondito, i.e.,* as a general methodological and

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[1] For the core concept of epigenesis, the subsequent definition will serve as a useful guideline:
Epigenesis: Development in which an initially unspecialized entity gradually develops specialized characters. (WEBSTER 1993:337)
Thus, from a *very* general transdisciplinary perspective, the term "epigenesis" refers to the gradual or the rapid emergence of new *and* more *complex* phenomena ...

epistemological device way above a *closed* carpet of empirical clouds and *beyond* the reach of everyday social science research like in the case of HABERMAS 1981 or LUHMANN 1984, 1997. Rather, the current epigenetic approach has been built up deliberately as a *complete* "package for analysis" which contains all relevant ingredients of being imitated, adapted and modified to the empirical study of any type of "knowledge-based processes". Moreover, the realm of "intended applications" of the epigenetic program is unusually diversified, extending over areas like -

individual behavior and interactions
households
organizations
sub-national regions
nation-states
international domains
the global realm

Thus, it has become the apparently highly ambitious goal from the very beginning to present, in the course of the subsequent articles, a short overview of the theoretical foundation of the epigenetic program - and some of its potentially rewarding and innovative insights on the basic architectures of contemporary knowledge and information societies.[2]

[2] These two articles are a condensed version of a very comprehensive IHS-research effort towards establishing a new type of evolutionary socio-economic framework. Over the last months, an intense discussion has helped me to clarify the essential building blocks of this epigenetic program (ERP). Special thanks go to Jonathan Turner and Alexandra Marijanski (University of California, Riverside) for the possibility of presenting some of these ideas at a departmental colloquium in Riverside and, above all, for a phantastic reading and discussion week in Idyllwild, CA. In a similar vein, Stuart A. Umpleby (George Washington University, Washington D.C.) has organized an extremely interesting sequence of discussion events, one of them being a luncheon speech at WESS (Washington Evolutionary Systems Society). Last, but not least, Richard Hull and Stan Metcalfe at CRIC (Centre for Research on Innovation and Competition, Manchester) have offered me with the opportunity of presenting an intensive two day seminar on the epigenetic perspective where, as an ever-lasting consequence, the basic terminology of the ERP-program underwent a final revision.

The Epigenetic Research Program (ERP): Basic Building Blocks

Evolutionary considerations for the analysis of societal development become apparently more and more outdated. Notions like "knowledge societies", "knowledge-based economies" and the like have been widely accepted and utilized as a prime "description device" for characterizing the contemporary "dynamics of societal developments". The core assumption in most of these knowledge-based approaches is that "knowledge" and/or "information" have become the predominant source of societal wealth, of international comparative advantages (THUROW 1996), and, thus, of shaping the development patterns for economies or societies in general. This, in turn, would suggest that a new and "emergent" feature for societal dynamics has come into existence which leaves practically no cognitive space for evolutionary considerations in economics, sociology or political science any more. The immediate issues to be addressed lies, thus, in the following three questions:

> Can one construct an *evolutionary* meaningful concept of "knowledge" which includes those processes and phenomena, normally analyzed within the context of "knowledge and information societies"?
>
> Is the appearance of "knowledge societies" to be regarded as a recent phenomenon which has to be investigated as a structural brake in contemporary societal dynamics alone?
>
> If no - can a generalized theory of evolution be built which integrates the complex of "knowledge and information" and which, thus, sheds new light on the societal dynamics, past, present and future?

The answer to these question will come out substantially on the affirmative side by offering a new perspective on the principal ways, societal differentiations and "knowledge-specializations" have co-existed over extremely long periods. More concretely, the present article will try to reach three ambitious goals simultaneously.

> *First*, a new transdisciplinary and generalized framework of "long-term stages" in evolutionary development will be presented which will be clearly situated *beyond* biology, economics or sociology, being applicable to all three domains without invoking, though, the dominance of one area over the other.
>
> *Second*, the new perspective, running under the heading of an "epigenetic research program" (ERP)[1], will move the notion of "knowledge" back to the

[1] For an extended version of the epigenetic research program (ERP), see MULLER 1996a,b. For special aspects of ERP, see MULLER 1997a,b,c,d,e.

center for the study of societal dynamics. Moreover, the concept of "knowledge" will be re-introduced in a way that can be utilized for societies from the distant past to the present time and beyond.

Third, the new perspective will produce new typological patterns on the co-evolution of "knowledge" and "modern societies" which have rarely met, so far, the appropriate recognition they deserve.

At this point, a lot of promises have been put forward. It is time to introduce the basic premises which will help to arrive at the stated three goal domains.

1. A Generalized Theory of Evolution: Core-Heuristics of the Epigenetic Research Program (ERP)

The first part of the article will be exclusively devoted to the presentation of seven core-heuristics which, taken together, stand at the center of the epigenetic approach. These core assumptions have been laid out in much greater detail in MÜLLER 1996a,b and will be summarized in a very brief, albeit concise manner.

1.1 A Generalized Notion of Evolutionary Systems

For any type of empirical analysis, the notion of "evolutionary systems" becomes, quite naturally, of paramount importance. Since not all developmental or growth processes should be qualified as evolutionary ones, a criterion of demarcation becomes necessary differentiating between evolutionary ensembles from other types of systems. One of the least controversial, though almost tautological criteria for evolutionary systems stresses a profound dualism in their modes of production and reproduction between their "genotype" and their "phenotype"-levels. In biology, this distinction has a well-defined meaning, since, following FELDMAN 1988:43 and many others, the observable properties, structures and processes of an organism belong to its phenotype and the sequence of nucleotides, forming the DNA of an organism are qualified as its "genotype".

Within the epigenetic approach, a more generalized differentiation between these two domains will be proposed, differentiating, on the one hand, an array of "extended phenotype-levels" or, as they will be subsequently referred to, as "actor-network-levels" which are introduced as any observable, space-time unit with "operations" as well as with exchange and transfer relations with its environment and, on the other hand, "extended genotype-levels", or, alternatively, "embedded code-levels" which are to be qualified as any instruction or recipe-system with an indispensible role in the production or reproduction of an actor-netowrk ensemble.

Following the above quite general suggestion, an epigenetic analysis *must* be performed at two different main levels *simultaneously*, one being associated with embedded code processes and their variations and the other with actor-network developments. Stated as a heuristic device, any investigation within the epigenetic framework has to specify its basic ensembles in terms of embedded code-systems and of actor-networks. While the exact nature of the relations between these two basic domains remains a center of heated controversies in developmental biology (See e.g. DAWKINS 1995, GOODWIN 1995), the simple separation requirement is sufficient for the subsequent differentiations of these two basic areas for evolutionary systems.

1.2 The Epigenetic Square

Arranging the well known evolutionary "chains of becoming" in a slightly similar fashion to BENINGER (1986:63), one arrives at Table 1.1, where basically four stages of the *extremely* long evolutionary run have been identified, where each stage develops a characteristic interaction pattern between code-system levels and the actor-network levels.

While the exact nature of these interrelationships will be discussed in further detail in the final chapter of this article, Table 1.1 gives rise to a dimensional scheme (Table 1.2), where the relations between embedded code and actor network levels occupy the centre stage. This new scheme runs under the heading of the "epigenetic square" and can be considered as the *basic* element within the seven core heuristics. Moreover, the five epigenetic dimensions, building up the epigenetic square can be used for an evolutionary analysis in a wide variety of domains - be they biological, anthropological, economic or social in nature.

As one can see from the epigenetic square in Table 1.2, the five dimensions exhibit an interesting connection to the stages in Table 1.1, since the program as well as the decoding dimension have been laid out during the early stages of life already, whereas the implicit dimension is of comparatively younger origin (100 million years ago).

Finally, the encoding dimension must be considered to be a human achievement only, coming into existence with the gradual emergence of pictorial codes and written code systems. (See also DEACON 1997)

The basic heuristic device, associated with Table 1.2, can be written in a very general manner, demanding that *any* type of research within the epigenetic tradition must be conducted by utilizing the five dimensions of the "epigenetic square".

Table 1.1: The Long-Term Evolutionary Chains

YEARS AGO (logarithmic)	
	STAGE I: Code ⇔ Code Interaction (Genetic Code) C ⇒ N Generation (Genetic Code) C ⇔ C Recombinations (Genetic Code)
1 billion	"Cambrian Explosion"
100 million	STAGE II: Actor Network ⇔ Actor Network Interactions Learning by Imitations ("Implicit Knowledge") Tool-Utilizations, Communications N ⇔ N Recombinations
10 million	
1 million	
100.000	STAGE III: Actor Network ⇒ Code Productions Learning by Encoding (Constructions of Human Codes especially Natural Languages and Number Codes)
10.000	Non-Pictorial Scriptures N ⇒ C Recombinations
1000	
100 years	
10 years	STAGE IV: Actor Network ⇒ Embedded Code Systems Productions: Genetic Code (GC) ∠ Bio-Technology Language)[2]
100 years +	Evolutionary Information Processing Systems, Based on Actor Network- Interfaces and Machine Codes

[2] ∠ stands for a "transcription relation", implying that a specific code-system has been transcribed or, alternatively, translated into another code-system. "Transcription relations" occur quite frequently like in the case of "morse code ∠ language code", etc.

Table 1.2: Five Basic Epigenetic Dimensions

Action-Patterns and Their Interactions and Adaptations

ACTOR NETWORK-DIMENSION

ACTOR NETWORK-LEVELS	N	⇔	N
	Decoding of	Co-Activation of	Encoding of
	⇑	⇕	⇓
	Programs	Action Patterns and Neural Programs	Programs
	DECODING DIMENSION	IMPLICIT DIMENSION	ENCODING DIMENSION
EMBEDDED CODE-LEVELS	C	⇔	C

Programs and Their Interactions and Adaptations:

Genetic, Neural, Human Code Systems, Machine Codes

DIMENSION OF PROGRAM POOLS

1.3 "Embedded Code-Systems" and "Actor Networks" as Generalized Basic Concepts

Following the core heuristic, specified above, an additional conceptual instrument can and must be utilized, namely two core concepts for each of the two main evolutionary levels. For the code levels, a unified concept of "embedded code systems" has been proposed, whose main definitional requirements can be summarized in the following manner. An embedded code system has to exhibit -

INDIFFERENCE OF CODE ELEMENTS - exchangeability of specific "marks" of a basic component in a code system

FINITE DIFFERENTIATION - a decidability in principle whether a given mark belongs to a specific code-character

COMBINATION OF CODE-ELEMENTS - the formation of composite sequences of code-elements

COMPARATIVE ADVANTAGES - evaluations of code-sequences in terms of a "fitness measure"

DYNAMIC EMBEDDEDNESS - the embeddedness of a changing code-system in a wider environment

Likewise, the network levels have to use a single unifying concept across various domains, namely, not particularly surprising, the notion of "actor-networks" which have to fulfil the following five conditions -

VARIABILITY OF COMPONENTS - the composition of networks with highly heterogeneous classes and numbers of actors

INTERNAL EXCHANGES BETWEEN NETWORK-COMPONENTS AND EXTERNAL TRANSFERS WITH THE ENVIRONMENT - observable and measurable exchange and transfer relations between network nodes as well as between a network and its environment

COMBINATION OF ACTOR-NETWORKS - the formation of larger actor-networks, consisting of smaller ones

COMPARATIVE ADVANTAGES - explanation of network movements in terms of "attractivity/utility/fitness measures"

SIMULTANEOUS CHANGES - the dependence of the change in a network node from changes in other network components

Two remarks must be added immediately in order to clarify the differences and similarities between these two concepts.

First, the differences between both core concepts are comparatively weak since, following Mario Bunge (1977, 1978, 1983a,b), embedded code systems as well as actor networks both qualify as "systems" in the established sense of the word. Due to their *systemic* character, both levels of investigation can be combined in a rather convenient and straightforward fashion.

Second, the differences between these two different types of levels should be qualified more as epistemological ones than as ontological in character. In the end, the separations between ensembles at the code levels and formations at the network levels turn out to be, basically, a functional one, differentiating "recipe-collections" of various forms - genetic, neural, humanly encoded, machine-based - as units at the extended code levels and processes within the various (re)production domains as actor-networks at the network levels.

It must be added, at this point, that the two basic concepts - embedded code systems (ECS) for the extended code levels and actor networks (AN) for the extended network levels - are sufficient to analyze *any* context, in which knowledge, information or scientific production may play a central role. In other words, current utilizations of "knowledge" like -

domains of discourse

theoretical content

"justified true belief"

results of learning processes

scientific state of the art

can be articulated and rephrased in terms of ECS- and AN-interactions. (For a detailed discussion, see MULLER 1996a:142pp.) Whatever determines the shape and the dimensions of "knowledge-based proceses", they can be formulated within the epigenetic framework, too.

Table 1.3: A World of Embedded Code-Systems

DOMAIN	CODE-SYSTEM	CODE-ELEMENTS	EXTENDED CODE-ORGANIZATION
		EPIGENETIC REGIME I	
BIOLOGICAL AND HUMAN	Genetic Code	Four Bases: Adenin, Cytosin, Guanin, Thymin	Double Helix-Configuration
		EPIGENETIC REGIME II	
BIOLOGICAL AND HUMAN	Neural Codes	"Mental Agents" or "Neural Groups"	Cognitive Architectures within Actors
		EPIGENETIC REGIME III	
HUMAN "LIFEWORLDS"	Natural Languages	Letters of an Alphabet	Grammars
HUMAN "LIFEWORLDS"	Number Codes	Sets of Various Numbers $\{N\}$, $\{\Re\}$, etc.	Algorithms
HUMAN "LIFEWORLDS"	Pictorial Codes	Symbols from a Symbol-Library	Picture Programs[3]
HUMAN "LIFEWORLDS"	Musical Codes	Musical Notes	Musical Schemes
HUMAN "LIFEWORLDS"	Rule-Codes	Rule-Components	Encoded Rule Systems
		EPIGENETIC REGIME IV	
HUMAN "LIFEWORLDS"	Scientific Language in	Letters of an Alphabet, Numbers, Bio-Technology (Biotech-Code)	Grammars, Transcriptions, Strings
HUMAN "LIFEWORLDS"	Machine Codes	Strings, Alphabets	Grammars, Translations

[3] So far, very few explicit picture schemes are available at the moment, one of the most prominent being ISOTYPE (International System of Typographic Education) by Otto Neurath, Gerd Arntz et al. in the 1930's. (MÜLLER 1991b,c) It should be added though that the early code-systems within human history had been devised as pictorial or symbolic codes (WHITE 1995, CALVIN 1996)

1.4 A Generalized Framework for the Emergence of "Variations"

Sticking to the format of a meta-theoretical core framework, one must be prepared to find a *universal* mode of recombinations *across* different embedded code systems and *across* actor-networks:

The central point lies in a definition of "recombinations" - the generalized successor of the classic idea of "mutation" - across the multiplicity of levels. Here, the following set of requirements must be fulfilled for changes in any type of evolutionary system:

Full-scale *change* potential for an *embedded* code-system or actor-networks consists in having a rich repertoire of *recombination operators*, following them recursively, applying them at the meta-level, and modifying them accordingly. [4]

For the general case one can identify six conditions which must be present simultaneously.

> The *first* set of basic requirements is marked by the "rich repertoire-condition" which states that *successful* recombinations are dependent on a "requisite variety" (Ross Ashby) of the embedded code system or the actor networks. In other words, an embedded code-system with only random mutations as sole source of recombinations must be considered as a *very* poorly equipped recombination repertoire, whereas a "pandemonium of recombinative demons" across different levels fulfills the first requirement in an optimal way.
>
> The "rich repertoire-requirement" needs, *second*, the availability of *code-spaces,* which should have, in the general case, a single distinctive feature, namely a comparatively *large* area of unrealized code-sequences and, thus, a *high* potential for new sequences.
>
> The central area for recombinations resides, however, in the *third* requirement, namely in the availability of *recombination* operators which are able to generate in a recursive manner, starting from an initial scheme, new code-strings or programs at the extended code levels - or new action patterns at the extended netwotk levels. For the general case, one is able to distinguish at least ten recursive operators which, following mostly Douglas R. Hofstadter (1995:77),

---

[4] The sentence above is a variation on a definition which Douglas R. Hofstadter has proposed for "creativity" -

> Full-scale creativity consists in having a keen sense for what is interesting, following it recursively, applying it at the meta-level, and modifying it accordingly. (HOFSTADTER 1995:313)

It will become one of the main targets within the present recombination-chapter to demonstrate the *very* close "family resemblances" (Ludwig Wittgenstein) between recombinations at different levels of code-systems, including, especially, the phenomenon of scientific creativity as a particular case in question.

can be recombined by using some "adding operations" and which, then, can be subsumed under the headings of Table 1.4:[5]

The requirements *four* and *five* demand a sufficient degree of flexibility - a capacity to *salient* adaptations (requirement four) - as well as of efficiency in approaching the target domains within a relatively *small* amount of time (requirement five).

Finally, a *control*-capacity as well as a sufficiently powerful *support* system must be present which are not only able to secure the partial gains reached so far, but which, furthermore, develop at least *some* "gate-keeping"-functions and safe-guards against detrimental trajectories (requirement six) ...

Table 1.4: A General Summary of Recombination Operators in Embedded Code Systems - and beyond

Adding:	the integration of new building blocks into an existing scheme
Breaking:	the differentiation of at least one scheme into two disjunctive building blocks
Crossing-over:	the breaking of at least two schemes and their merging into a new ensemble
Deletion:	the destruction of a specific building block from a set of schemes
Duplication:	the repeated insertion of at least one identical scheme
Inverting:	the making of copies with an opposite sequence of elements
Merging:	the integration of at least two existing schemes into a new one
Moving:	the shifting of code-elements or of established boundaries
Replacing:	the substitution of a code-element by another one
Swapping:	the movement from a level L_i to a different level L_j

The important point which *cannot* be over-emphasized lies in the *universality* of these recombination operations *across* various embedded code-systems - and *across* the many levels of actor networks.

5 In the following enumeration, terms like "building blocks", "scheme" or "code-elements" will be used simultaneously. In order to avoid a possible misunderstanding, it should be added that these three expressions refer to different degrees of complexity in an embedded code-systems, from simple code-elements like letters to code-strings up to the level of programs or programs of programs ...

1.5 A Generalized Framework for Processes of Diffusion

Like in the case of recombinations alias "mutations" or "variations", a richer conceptual apparatus is built up for the "selection" side of the epigenetic approach which has been generalized into a unifying "diffusion framework". The essential point to be added lies, very generally, in a family of evaluation measures f_i which, for reasons of convenience, may all be assumed to lie within the interval [0,1]. The evaluation measures must fulfill the following requirements:

First, they have to be applicable to both main epigenetic levels and, above all, to the recombinations within actor-networks and within embedded code systems.

Second, the evaluation measures should not be an all or nothing 0-1 attribution only but allow for small incremental changes between the [0,1] interval.

Third, the evaluation measures must exhibit a non-trivial linkage to the reproduction of units under consideration and, thus, to the population dynamics under consideration.

It becomes easy to see that the paradigmatic examples from a selectionist or genetic perspective, relying on "fitness" as evaluation measure, are contained as a special and relatively restricted case. Especially within economics and the social sciences, evaluation measures based on utilities, attractivities (MÜLLER/HAAG 1994) or on comparative advantages are widely used and fulfill upon closer inspection the three basic requirements, stated above.[6] Moreover, the overall *potential* for "diffusion mechanisms", based on the essential role of the evaluation measures, can be summarized *via* a small generalized diffusion story.

THE GENERALIZED DIFFUSION-STORY

> The starting point lies in the diffusion of a new ensemble - either at the level of actor-networks or of embedded code-systems - which has come into existence at some point within a spatio-temporal domain$_{C,N}$. Due to its *comparative advantages* (attractivity, fitness, strength, utility ...), the new ensemble is reproduced more rapidly and is recombined and improved in a variety of additional ways. *Via* these rapid replications, secondary, tertiary or quartary

[6] Take as a reference example from the *social* domain a school system with various types of schools as basic dual level components of an actor network, namely the national system of schools. In a series of applications, an attractivity measure has been developed which was built on synergy factors like agglomeration and saturations, on the relations to the employment sphere or on the likely effects towards the university system. Moreover, this attractivity measure for various school types was *directly* linked to the ecological dynamics of school types since higher attractivities exerted a push/pull effect on pupils, leading, thus, to higher than average growth rates and, consequently, to higher than average reproduction rates for more attractive school forms. For more details, see HAAG/MÜLLER 1992, MÜLLER/HAAG 1994.

processes of adaptation are induced, which change the ecological domain$_{C,N}$ at times in a very significant fashion. Since the potential for further expansions of this new ensemble is more and more diminishing and will result relatively seldom in an all-eliminative outcome, further expansions will reach saturation limits. As a consequence, the comparative advantages change their basic direction from expansion to optimization and further changes lead to an optimization of the new ensemble and move it close to its "dominant design" ... Depending on the overall structuration of the spatio-temporal domain$_{C,N}$, the development pattern will exhibit a rich variety of shapes, ranging from logistic S-shaped diffusion to a quasi-cyclical pattern - clockworks with quasi-periodic successions of expansionary and optimization stages - or to an irregular succession - "bubbles" with no systematic succession of expansionary and optimization stages ...

At this point, it is interesting to note that the two most influential evolutionary accounts on economic development - the Schumpeterian vision - and on scientific revolutions - the Kuhnian framework - can be seen as domain specific instantiations of one and the same "basic structural story", following the quasi-periodical trajectories, just outlined above. More concretely, a few recombinative operations of substitution lead to the following developmental version, which is clearly very closely associated to Joseph A. Schumpeter:

ECONOMIC LONG SWINGS

The starting point lies in the diffusion of a new ensemble of basic-product innovations, propagated by a cluster of new economic actor-networks - mainly firms - which has come into existence mostly at the periphery of the existing distribution of economic activities. Due to its comparative advantages, the new ensemble of basic product-innovations is reproduced more rapidly and is recombined and improved in a variety of additional ways. *Via* these rapid replications, secondary, tertiary or quartary processes of economic adaptation are induced, which change the economic landscape at times in a very significant fashion. Since the potential for further expansions of this new ensemble of basic product-innovations is more and more diminishing and acquires a shrinking share of the total economic ensemble, further expansions will reach saturation limits. As a consequence, the comparative advantages change their basic direction from expansion to rationalization, since further changes will lead to massive process-improvements of the new ensemble and will move it close to its "dominant design" ... After a period of successful "optimizations", an increased search for radically new alternatives sets in, leading, thus, to a quasi-cyclical development pattern - to Schumpeterian clockworks with quasi-periodic successions of "expansionary" and "rationalization" stages ...

Performing, once again, a very small number of substitution operations, one arrives at the subsequent diffusion story in which the majestic Kuhnian clockworks have come into full swing.

THE STRUCTURE OF SCIENTIFIC REVOLUTIONS

> The starting point lies in the diffusion of a new ensemble of basic-paradigms, propagated by a cluster of new science-based actor-networks - mainly research units - which has come into existence mostly at the periphery of the existing distribution of scientific activities. Due to its comparative advantages, the new ensemble of basic paradigms is reproduced more rapidly and is recombined and improved in a variety of additional ways. *Via* these rapid replications, secondary, tertiary or quartary processes of scientific adaptation are induced, which change the scientific landscape at times in a very significant fashion. Since the potential for further expansions of this new ensemble of basic paradigms is more and more diminishing and acquires a shrinking share of the total science ensemble, further expansions will reach saturation limits. As a consequence, the comparative advantages change their basic direction from expansionary problem solutions to "design improvements", since further changes will lead to massive methodological improvements of the new ensemble and will move it close to its "dominant design" ... After a period of successful "optimizations", an increased search for radically new alternatives sets in, leading, thus, to a quasi-cyclical development pattern - to Kuhnian clockworks with quasi-periodic successions of "expansionary" and "program optimization" stages ...

It goes almost without saying that both versions of diffusion clocks, the Schumpeterian and the Kuhnian clockwork, are subject to a rich variety of complex models, ranging from dynamic networks of the type of "master-equations" to neural networks, adaptive systems or to conceptualizations in terms of "self-organized criticality".

1.6 Multiplicity of Units for the Extended Code and the Extended Network Levels

In order to stick to the format of a small overview of the epigenetic core program, the sixth heuristic can be summarized in a *very* short manner: The units of evolution, according to the epigenetic program, are distributed over a rich multiplicity of different "building blocks" both across the extended code and across the extended network levels.

In other words, building blocks, capable of evolutionary development, can be constituted in a *practically* infinite number of ways, ranging, confined to the extended network levels alone, from individuals, households, groups, economic sectors, art groups, research units to cities, regions, nations and the like.

Table 1.5: A General Overview of the Multiplicity of Building Blocks within the Extended Code and the Extended Network Levels

			MULTIPLE SPACE-TIME-LEVELS$_N$ MACRO$_N$/MESO$_N$	
		Global S/M/L	National S/M/L	Regional S/M/L[7]
	MULTIPLE BUILDING BLOCKS			
	High	$Field_1$	$Field_2$	$Field_3$
MACRO$_N$	Medium	$Field_4$	$Field_5$	$Field_6$
	Low	$Field_7$	$Field_8$	$Field_9$
EXTENDED NETWORK LEVELS				
	High	$Field_1$	$Field_2$	$Field_3$
MESO$_N$	Medium	$Field_4$	$Field_5$	$Field_6$
	Low	$Field_7$	$Field_8$	$Field_9$

			MULTIPLE SPACE-TIME-LEVELS$_N$ MICRO$_N$	
		Wide F/P/M	Medium F/P/M	Small F/P/M[8]
	MULTIPLE BUILDING BLOCKS			
EXTENDED	High	$Field_1$	$Field_2$	$Field_3$
NETWORK	Medium	$Field_4$	$Field_5$	$Field_6$
LEVELS	Low	$Field_7$	$Field_8$	$Field_9$

			MULTIPLE SPACE-TIME-LEVELS$_G$ MACRO$_C$/MESO$_C$	
		Global S/M/L	National S/M/L	Regional S/M/L
	MULTIPLE BUILDING BLOCKS			
	High	$Field_1$	$Field_2$	$Field_3$
MACRO$_C$	Medium	$Field_4$	$Field_5$	$Field_6$
	Low	$Field_7$	$Field_6$	$Field_9$
EXTENDED CODE-LEVELS				
	High	$Field_1$	$Field_2$	$Field_3$
MESO$_C$	Medium	$Field_4$	$Field_5$	$Field_8$
	Low	$Field_7$	$Field_8$	$Field_9$

			MULTIPLE SPACE-TIME-LEVELS$_C$ MICRO$_C$	
		Wide F/P/M	Medium F/P/M	Small F/P/M
	MULTIPLE BUILDING BLOCKS			
EXTENDED	High	$Field_1$	$Field_2$	$Field_3$
CODE-	Medium	$Field_4$	$Field_5$	$Field_6$
LEVELS	Low	$Field_7$	$Field_8$	$Field_9$

---

[7] S, M and L stand for short-, medium, and long-term processes at the extended phenotype and at the extended genotype levels. For closer details, see MÜLLER 1997a.

[8] F, P and M are conceptualized in a weak analogy, refering to fento-, pico- or micron-processes. Again, closer details can be found in MÜLLER 1997a.

1.7 Self-Referentiality and "Second Order-Investigations"

Finally, the last core heuristic of the epigenetic program refers, once again very generally summarized, to the recombinability of the existing six core-heuristics into a self-referential manner so that probably a most fascinating class of scientific problems like -

Code-systems of code systems, diffusion of diffusion, emergence of emergence, evolution of evolution, function of functions, models of models, networks of networks, recombinations of recombinations, -

can be successfully analyzed with the conceptual tools and relations developed so far.[9]

2. The Epigenetic Research Program: Additional Building Blocks

Having completed the theoretical core {TC} of the epigenetic approach, it becomes a legitime move to ask for the potential explanatory power or, alternatively, the explanatory "cash value" of this new perspective. At this point, a cautionary intermediate step must be introduced, stating in very general terms four *additional* basic elements which must be available in the case of research programs capable of scientific explanations. Referring to a large amount of contemporary theorizing on theories in the philosophy of science field (DONOVAN/LAUDAN/LAUDAN 1988, STEGMULLER 1981, SNEED 1991, BALZER/MOULINES/SNEED 1987), it seems reasonable to demand that any explanatory research program for structures and processes within a particular space-time $domain_i$ needs to specify five, at least partially independent ensembles:

$$RP = \langle \{TC\}, \{SpM\}, \{IA\}, \{TM\}, \{M\} \rangle$$

More concretely, any scientific research program, and, *a fortiori*, the epigenetic research program, must accomplish, aside from specifying a conceptual core, four major building blocks in order to arrive at a complete explanatory framework:

> *First*, a specific model or a class of formal models must be specified which are applicable to the $domain_i$ under consideration.

> *Second*, the realm of "intended applications" has to be delineated, providing general instructions both on the spatio-temporal as well as on the domain

[9] Again, restrictions in space prevent a fuller description of this specific point which, however, has been laid out in greater detail in MÜLLER 1997a.

specific restrictions and limitations with respect to the applicability of the core-heuristics and of the group of special models.

Third, a special module, labeled as "transfer module$_i$", must be laid out which comprises all heuristic devices and assumptions necessary for the application of the conceptual core as well as of {SpM} to the field$_i$.

Fourth, a set of measurements is needed, comprising quantitative or qualitative data as well as observation statements which summarize the empirical patterns, available for the domain to be explained.

From these general explanatory requirements, it becomes easy to deduce that the epigenetic approach, outlined so far, lacks at least four additional major components. It will become the main task of the subsequent chapters to present some clues on the structure and dimensions of these four epigenetic companions to the seven core-heuristics, presented in the previous chapter. (For closer details, see again MÜLLER 1996a)

2.1 Families of Complex Models as {SpM}

The first additional building block can be summarized in a very short manner, stating that the models, associated with the epigenetic program, are co-extensive with the emerging classes of complex models which have been laid out in Table 2.1. From here, one can easily see that these models share a set of unusual features like -

complex formal structures (e.g., non-linearity) or complex aggregation procedures

non-trivial arrangements with respect to the input-output-transformations

a high degree of applicability in heterogeneous domains, ranging from the natural sciences to the social sciences

2.2 Intended Applications: A Short Summary

The realm of "intended applications" of a research program specifies three basic types of *general* utilization devices, necessary for the implementation of {TC} and {SpM}. The three main questions, associated with the intended ERP-applications, have the following form.

Which types of general arrangements does the ERP-program require within its descriptive or explanatory contexts?

Table 2.1: Families of Complex Models for the Epigenetic Approach

TRADEMARKS	CORE-DOMAINS AND FIELDS OF APPLICATION	CORE CONCEPTS, HEURISTICS
Adaptive Systems and Control Theory	Biology, Engineeering, Economics, Sociology et al.	Anticipatory Systems, M-R Systems (Metabolism-Repair Systems) et al.
Artificial Life	*Artificial Intelligence*, Robotics, Biology et al.	*Subsumption* architectures; Cellular Automata; Viral Replications et al.
Autopoiesis	*Biology*, Artificial Intelligence, Theories of action, *et al.*	Organisation/ Structure; Closedness, Autonomy; Recursiveness; Observer-dependence et al.
Cellular Automata	*Engineering*, Physics, Biology, Demography, Sociology, Ethics et al.	von Neumann neighborhood, Moore neighborhood et al.
Chaos-theory	*Dimension-theory*, Meteorology, *et al.*	*Strange Attractors*; Mandelbrot-Set; Julia-Set; Ljapunov Coefficients et al.
Classifier Systems and Evolutionary Programming	*Engineering*; Artificial Intelligence, Biology, Management Science Economics *et al.*	Classifier Rules; *Bucket Brigade Algorithm*; *Cross-over* et al.
Complexity Theory	Computer Architecture, Artificial Intelligence, Linguistics, Biology, Sociology et al.	Deterministic Turing machines, NP-Problems et al.
Dissipative Structures	Nonequilibrium Thermodynamics, *Chemistry, et al.*	Disturbance-parameters; Brüsselator et al.

Table 2.1: Families of Complex Models for the Epigenetic Approach (continued)

TRADEMARKS	CORE-DOMAINS AND FIELDS OF APPLICATION	CORE CONCEPTS, HEURISTICS
Evolutionary Gametheory and Rational Choice	Biology, Neuro-physiology, *Sociology*, *et al.*	Evolutionary Stable Stra-tegies (ESS) et al.
Group Theory	*Mathematics*, Quantum Theory, Chemistry, Psychology, Sociology et al.	Groups, Symmetry Operations, Symmetry Groups et al.
Hypercycles	*Biochemistry*, Chemistry, *et al.*	Families of Nonlinear Equa-tion Systems et al.
Neural Networks	*Computer Science*; Neuro-Sciences, Arti-ficial Intelligence, Cognitive Science, *et al.*	*Delta rule*; *Back propagation algorithms* et al.
Population Dynamics	*Biology*, Ethology, Demography, Econo-mics, Sociology et al.	Models of Selec-tion, Predator-Prey-Models et al.
Self-Organized Criticality	*Physics*, Geology, Meteorology, Economics et al.	Recursive Power-Functions; Critical Thresholds, etc.
Synergetics	Laserresearch, *Physics*, Pattern Recognition, Che-mistry, Sociology, *et al.*	Masterequation; Fokker-Planck-Equation; Slaving Principle; Control- and Orderparameters, et al.
Theory of Catastrophes	*Differential-topolgy*, Biology, Sociology, *et al.*	Families of Generic Equa-tions; Typology of Bifurcations et al.

Which types of cognitive advances may lead to an adaptation of the core-heuristics or of {SpM} within the epigenetic research program?

What is the organizational profile of the epigenetic research program or, alternatively, what is the preferred scientific group composition for ERP?

In answering these three basic questions, seven particular answers or general application heuristics are presented which, taken together, constitute the {IA}-class of ERP.

First, the descriptive and the explanatory ERP-arrangements can be summarized, on the one hand, *via* Table 2.2 and, on the other hand, *via* three basic explanatory requirements which, moreover, could be qualified as *necessary* conditions for the construction of evolutionary explanations in science.

With respect to the *descriptive* apparatus, the following summary may serve as a useful reference point since it combines and integrates the seven theoretical core-heuristics (epigenetic architecture (1,2), building blocks (3), recombinations ((4), evaluation measures (5), multiplicity of units (6) and, although not explicitly recognizable, the second order applicability (7)).

Table 2.2: Descriptive Application Requirements of the ERP-Program $\{IA_1\}$

	UNITS	CHANGES
SYSTEMIC COMPONENTS:	Types of Building Blocks; Types of Reproduction; Dual Level-Architecture	Average Reproduction Requirements; Types of Recombinations; Comparative Advantages/ Disadvantages
ENVIRONMENTAL COMPONENTS:	Types of Building Blocks; Types of Reproduction; Dual Level Ar-Chitectue	Average Reproduction Requirements; Types of Recombinations; Comparative Advantages/ Disadvantages
SYSTEM-ENVIRONMENT RELATIONS:	Types of Internal and External Relations within the Dual Level Architecture; Types of Internal and External Disturbances	Changes of Internal and External Relations within the Dual Level Architecture; Changes of Internal and External Disturbances

For *evolutionary* ERP-*explanations*, three basic necessary conditions can be specified which must be met simultaneously, namely –

(1) the availability of a complex explanatory framework, selected from the class of complex models

(2) the integration of an "evaluation measure" which occupies a non-trivial role within the *explanans*-part

(3) the integration of explanatory-elements from *both* main epigenetic levels, *i.e.* from the actor network levels *and* from the code levels {IA_2}

To provide a concrete example, an explanation of the movement of pupils within the Austrian education system can be qualified as *evolutionary* (for more details see HAAG/MÜLLER 1992, MÜLLER/HAAG 1994 and MÜLLER/HAAG 1998) since

(1) the explanatory framework comes from the fields of "master equations" in Table 2.1 (non-linear dynamic networks within the "synergetics family)

(2) an "evaluation measure" – attractivities for various school types – have been provided in a clearly *non*-trivial manner

(3) explanatory elements stem both from the code-levels (school regulations with respect to legal and illegal transitions between school types) *and* from the actor network levels (e.g., relations of a specific school type to the employment sphere)

Second, for the relations between {TC} or {SpM} with advances in the scientific knowledge base, one may specify -

Close ties with the evolution in *complex modeling* which implies a strong modification pressure in terms of the enumeration of complex modeling approaches presented under Table 2.1 {SpM} {IA_3}

Close linkages to the current status of *material* frameworks, especially in the areas of evolutionary theory, including artificial life, of the cognitive sciences, of linguistics, of artificial intelligence since advances in these domains may lead to modifications with respect to the (re)production of basic units, to their basic conditions and to their comparative advantages {IA_4}

Close links with advances in *methodology*, especially in the fields of philosophy of science, especially, but not exclusively, of the structure of research programs, of new methodologies for transdisciplinary research, of "theory testing", etc. {IA_5}

Third, with respect to the organization of scientific units within the ERP-framework, a very general remark can be provided, stressing the Mode II character (GIBBONS et al. 1994, NOWOTNY 1995, 1996) of the entire approach:

> The organizational profile of ERP should exhibit a high degree of inter- or transdisciplinary group composition, an interface between basic research and applied science, establishing, thus, a *unity* between the context of application and the context of discovery. $\{IA_6\}$

Finally, the "intended ERP-applications" can be assumed as unusually wide and general, culminating in a rich variety of ways, especially in "empirical" applications *and*, due to its firm rooting in the modeling realm, in "possible world-utilizations" or, alternatively, in simulations. $\{IA_7\}$

Thus, the scope of ERP assumes a *very* generalized application profile which might offer, due to its heterogeneous domains, an interesting basis for a well-integrated "life science" of transdisciplinary nature.

2.3 Transfer Modules: Two Selected Examples

Due to the generalized applicability, the epigenetic program must carry within its basic constituents a rich package of so-called "transfer modules" which contain all relevant *additional* heuristics, necessary for doing epigenetic research within a *special* domain. The subsequent page will contain two of a meanwhile larger number of transfer modules, namely the one for National Innovation Systems and the second one on "knowledge based organizations" from an epigenetic point of view.

For National Innovation Systems (NIS), the following "transfer module" has been developed:

> A systemic demarcation, differentiating between various NIS-types (NIS I, NIS II, NIS III, NIS-S, etc.)
>
> Two basic NIS-perspectives: "NIS-ensemble power" (stocks) and "NIS-distribution power" (linkages, flows)
>
> Two types of indicators: "performance indicators", across two or more epigenetic dimensions, "local domain indicators", characteristic for a specific epigenetic dimension
>
> Data generation: a comprehensive questionnaire for innovations and transfers (ASIT)
>
> Structurally identical explanation sketches for "Schumpeter clocks" and "Kuhn clocks"

Catalytic NIS-policies: basic background assumptions

Catalytic NIS-policies: applications for specific regional arrangements

In the case of "knowledge based organizations", the following additional specifications have been undertaken which, in conjunction, constitute the organizational "transfer module" of ERP:

Specification of the "internal knowledge bases" of organizations

Demarcation of the "external knowledge bases" of an organization

"Implicit knowledge" in organizations: main characteristics and empirical data generation

The basic concept of "organizational profiles" for the identification of the homogeneity or the heterogeneity in organizations

Data generation: a comprehensive questionnaire for innovations, communication and information technology infrastructure; implicit processes; conflict patterns; communication processes, etc.

Specification of four main types of "knowledge based organizations"

The basic concepts for a new type of "scenario analysis" in organizations

With these additional transfer heuristics, a comprehensive package can be built up which, in conjunction with {TC} as well as {SpM} form an appropriate ERP-basis for the analysis in the evolution of modern organizations - or of National Innovation Systems.

3. Generalized Typologies for Evolutionary Dynamics

Having completed a summary of ERP, the question with respect to its potential relevance for the analysis of socio-economic problem domains could be answered in a variety of ways. One can point out for example that ERP has been successully implemented already in areas like -

National Innovation Systems (New Framework, Organization of Indicators)[10]
Long-term Development Patterns in Education (Non-Linear Network Models)[11]

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[10] On the NIS-part, see especially MÜLLER 1996a,b.
[11] See MÜLLER 1997.

Foreign Firms and their Innovation Behavior (Neural Networks)[12]
Complex Organizations (Study on the Austrian Red Cross)[13]
Households and Social Stratification[14]

In all these examples, ERP has been applied by following the core heuristics, especially the "epigenetic square" and its five basic dimensions, by developing appropriate "transfer modules" and by generating a rich flow of empirical data. Instead of specifying a single application in greater detail, the final part of this article will demonstrate the potential usefulness of ERP by presenting a list of typologies.

These new schemes are, on the one hand, closely associated with the core heuristics and offer,on the other hand, some new insights on the co-evolutionary type of societal pattern formation in the very long run.

3.1 Four Epigenetic Regimes

The second ERP core-heuristic, specified above, turns out to be sufficient for the introduction of a new concept, namely the notion of "epigenetic regimes". More concretely, "epigenetic regimes" are characterized as distinctive evolutionary, or, alternatively, epigenetic periods in time and space, sharing three features simultaneously: a *predominant* "knowledge base", a *primary* domain for variations or, alternatively, of innovations, a *characteristic* relationship between extended code and network levels and, finally, a "speeding up" in evolutionary time-scales.

What Table 3.1 as well as the subsequent descriptions will demonstrate, lies in the potential usefulness of this typology especially as reference point for current processes of re-configurations and re-structurings. In closer detail, four epigenetic regimes can be distinguished and described in the following manner:[15]

EPIGENETIC REGIME I: Here, the main source of innovation lies within the genetic code systems which, through their recombinative repertoire, become the primary source for actor-network variations. Moreover, interaction patterns at the extended code levels turn out to be relatively simple and confined to the senso-motoric realm only. Thus, the epigenetic regime I is populated by, borrowing Daniel C. Dennett's term, "Darwinian creatures" (DENNETT 1997) and, moreover, by Darwinian evolution.

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[12] See FELDERER/HANISCH/MÜLLER/THURNHEIM 1997.
[13] See COLANGELO/FELDERER/HOFMARCHER/MÜLLER 1997, MÜLLER 1997.
[14] See for example MÜLLER 1997, MÜLLER/LInk 1997.
[15] One might add, in order to extend the idea of epigenetic regimes to the entire "history of life", an epigenetic regime 0, starting with the self-reproduction of macro-molecules up to the period of genotype/phenotype differentiations which, after all, has been by far the longest stage of life on this planet.

Table 3.1: The Four Long Epigenetic Chains of Becoming

	EPIGENETIC REGIME I	EPIGENETIC REGIME II	EPIGENETIC REGIME III	EPIGENETIC REGIME IV
EXTENDED NETWORK LEVELS	Simple Routines (Darwinian Creatures)	Simple Routines Implicit Routines (Learning, Imitation, etc.) (Darwinian Creatures) (Polanyi Creatures)	Simple Routines Implicit Routines (Learning, Imitations, etc.) Encoding Routines (Language, Formalisms, Music, etc.) (Darwinian Creatures) (Polanyi Creatures) (Piaget Creatures)	Simple Routines Implicit Routines (Learning, Imitations, etc.) Encoding Routines (Language, Formalisms, Music, etc.) Encoding Routines of the Genetic Code and of Machine Codes (Darwinian Creatures) (Polanyi Creatures) (Piaget Creatures) (Turing Creatures)
	⇧	⇧ ⇕	⇧ ⇕ ⇩	⇧ ⇕ ⇩ ⇩
EXTENDED CODE LEVELS	Genetic Programs	Neural Programs Genetic Programs	Human Code Systems Neural Programs Genetic Programs	Machine Codes Bio-Tech-Programs of the Genetic Code Human Code Systems Neural Programs Genetic Programs

Table 3.2: The Succession of Four Epigenetic Regimes

	DOMINANT "KNOWLEDGE BASE"	PRIMARY "SOURCE OF INNOVATIONS"	CHARACTERISTIC RELATIONSHIP BETWEEN DUAL LEVELS
EPIGENETIC REGIME I	Genetic Programs	Variations in the Genetic Code	Dominance of the Extended *Code*-Levels
EPIGENETIC REGIME II	Neural Programs	Learning and Imitative Routines, Communications, Tool-Utilization	Dominance of the *Interactions* between Extended Code and Extended Network-Levels
EPIGENETIC REGIME III	"Encoded Human " Programs (Texts, scriptures books, etc.)	Encoding and Decoding Routines of Human Code-Systems	*Weak* Dominance of the Extended *Network*-Levels
EPIGENETIC REGIME IV	"Encoded Programs of the Genetic Code" "Machine Codes"	Encoding Routines of the Genetic Code Machine Learning	*Strong* Dominance of the Extended *Network* Levels

EPIGENETIC REGIME II: Within the second epigenetic regime, the primary source of innovation moves up to the learning and imitation capacities of the organisms themselves which are able to change the "selection pressures" accordingly. Viewed in terms of "innovations", the second epigenetic regime produces a rich repertoire of "implicit" or "tacit" knowledge, of communication patterns within or between species, the utilization of tools and the like. The major type of evolution changes from a Darwinian one to a Baldwinian - and the dominant type of organisms are, in honor of Michael Polanyi´s stimulating explorations on "implicit knowledge", Polanyi-creatures.

EPIGENETIC REGIME III: While processes of communication and comparatively complex network formations have been accomplished under the old epigenetic regime already, a new type of epigenetic regime has come into existence, associated with the emergence of language which, in its fully developed format exhibits two novel features. First, language is the only type of communication system which is able to talk about itself. And second, language exchanges underwent a gradual process of "codification", leading, thus, to a new layer within the "program pools" or, alternatively, within the "knowledge bases".

EPIGENETIC REGIME IV: Finally, in recent decades a remarkable shift has been accomplished in two seemingly unrelated areas which are clearly moving along a converging trajectory. The first area is associated with the scientific encoding of the genetic code and, consequently, by itself with a new epigenetic regime in which the variations at the level of the genetic code become accommodated to the rhythms of the global societal development and, thus, to the actor network formations at the extended phenotype levels. As a second domain, communication and information machinery has been brought along an evolutionary trajectory since these machines, by now, can be clearly differentiated with respect to their "machine codes" and with respect to their surface capabilities. Thus, CIT-machinery is slowly in the process of building up a sufficient amount of diversity - a learning potential, maintenance and repair-systems, senso-motoric capabilities and the like - so that new evolutionary units, this time situated at the level of *self*-reproducing and *self*-maintaining machines - are emerging. "Turing creatures", equipped eventually with a "life-like" machine code-system, will turn out to be a major ensemble within actor-network formations IV and will increase, once again, the overall evolutionary speed.

3.2 Three Co-Evolutionary Movements in Modern Societies

The final chapter will demonstrate that the ERP-framework offers a variety of new ways to capture, even in a typological manner, the basic evolutionary development patterns of societies, past and present.

First, Tables 3.4 and 3.5 offer first hints on the "hidden co-evolution" between the two main evolutionary levels within the latest stages of the epigenetic regime III as well as during ist phase transition to the epigenetic regime IV.

Second, the epigenetic dimensions themselves offer, in an ideal-type manner, an interesting distribution of four basic formations of "knowledge societies".

Table 3.4: Main Evolutionary Network Stages in the Great Transformations of Modern Societies

SOCIETAL NETWORK FORMATIONS

Reciprocal Formations	**Redistributive Formations**		**Capitalist Formations**
Societies under Dominance of *Personal Exchanges*	Societies under Dominance of the *Political* System	⇒	Societies under Dominance of *Markets*

⇓⇓⇓⇓⇓⇓

THE GLOBAL DEVELOPMENTAL STORY

Gradual integration of reciprocal as well as redistributive societal formations; Global differentiation into three distinct regions: *core regions, semi-peripheries* and *peripheries.* Specific development patterns in each of the three global regions, reaching from differences in the world trade-relations to significantly different roles and capacities of national governments or to different compositions with respect to socio-economic status-groups or classes; Emergence of global instruments for coordinating and balancing the world-system, leading, in the *very* long run, to the development of global institutions and organizations; emergence of new types of "knowledge and information societies; Dense intra-systemic and inter-systemic networks in production processes; integration of global and local accessibilities, etc.

CAPITALIST TRANSFORMATIONS

Initial Phase I: 1450 - 1600:		*Irreversible Expansion*
Initial Phase II: 1600 - 1760:		*Consolidation*

Global Diffusion (1760 - 1920)

Industrial Revolution:	1760 - 1820
Prosperity	1780/90 - 1820
Global Diffusion:	1820 - 1913/20
Depression	1820 - 1842/50
Prosperity	1850 - 1870/73
Depression	1873 - 1893/96
Prosperity	1896 - 1913/20

Transnational Evolution (1920 - 1973)

Depression	1920 - 1938/48
Prosperity	1948 - 1966/73
Depression	1973 - 1993/97
Prosperity	1997 - ???[16]

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[16] For the special choice of periods, the selections have been undertaken with respect to the common upper and lower boundaries of "long swings". On this point, see especially FREEEMAN (1983/1986), FREEMAN/SOETE (1994) or KLEINKNECHT (1987).

Table 3.5: Main Evolutionary Code Stages in the Great Transformations of Modern Societies

SOCIETAL CODE FORMATIONS

Distributed Knowledge Production	**Centralized Knowledge Production**	⇒ ⇒ ⇒	**Capitalist Knowledge Production**
Knowledge Bases under No Protection of *Special Institutions*	Knowledge Bases under the Dominance of a Specific Knowledge Generating System	⇒ ⇒ ⇒ ⇒	Knowledge Production under Dominance of Specific State Segments and *Markets*

⇓⇓⇓⇓⇓⇓

THE GLOBAL DEVELOPMENTAL STORY

Gradual integration of distributed as well as centralized knowledge bases; Global differentiation into three distinct regions with respect to the (re)production and to the accessibilities of local or global knowledge bases: *Centers, Semi-peripheries* and *Peripheries.* Specific development patterns in each of the three global regions in the area of program-pools, ranging from differences in regional roles- and capacities for "knowledge production" at the level of firms and markets; Differential access to the knowledge bases in cognitive core-areas; Development of limited local knowledge traditions and "subversive knowledge" against the established forms of programs within cognitive core-areas; Emergence of new types of knowledge societies; Decisive steps toward globalized program pools due to the formation of the internet, integrating the global *and* the local program production, etc.

CAPITALIST TRANSFORMATIONS

Initial Phase I: 1450 - 1760: *Irreversible Expansion* and *Consolidation*

Global Distribution
(1760 - 1920)

Institutional Revolution: 1760 - 1820

Emergence of New Types of Universities (Combination of Research and Training)
Global Diffusion: 1820 - 1913/20

Gradual Recombination of R&D and Firms through Firm-Specific Research Laboratories
Transnational Evolution
(1920 - 1973)

Phase Transition from "Little Science" to "Big Science" Compounds

(1973 - ???)

New Stage, due to the Emergence of Bio-Technology and a Global "Knowledge Machinery"

Table 3.3: Types of Extended Code - Extended Network Development Patterns

	TYPE I	TYPE II	TYPE III	TYPE IV
C ⇔ C	+	-	+	-
C ⇒ N	+	-	+	-
N ⇒ C	+	-	+	-
N ⇔ N	+	+	-	-
C ⇔ N	+	+	-	-

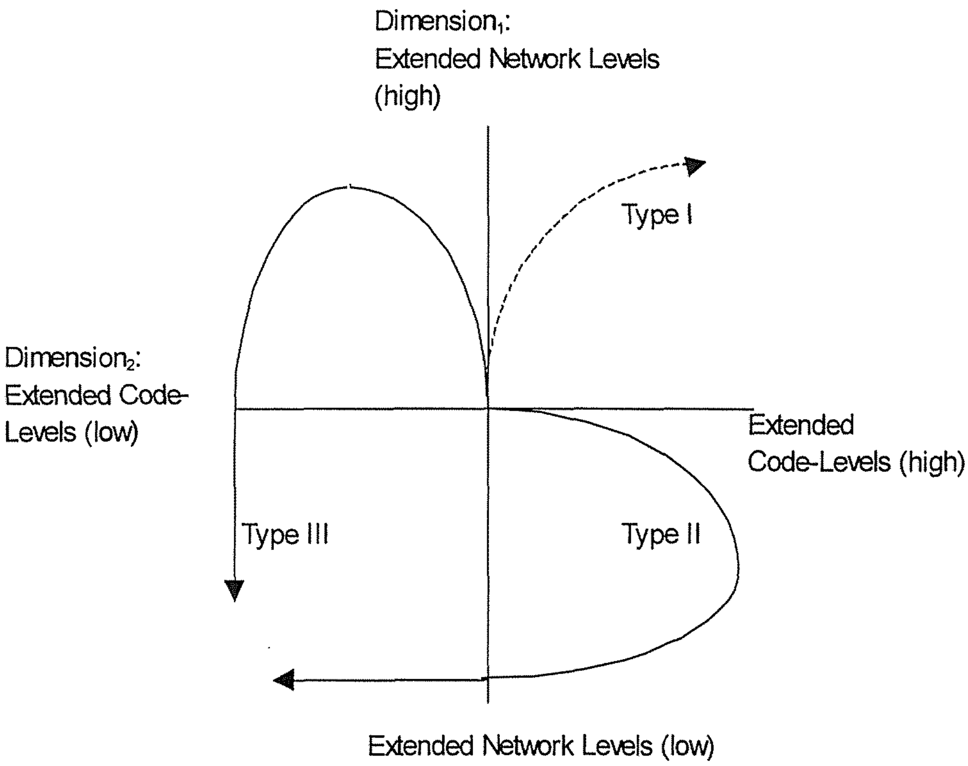
From Table 3.3, the four basic types can be described in the following manner.

Type I consists of those "happy co-incidences" with high performances both at the extended code and at the extended network levels. It must be stressed that strong growth processes simultaneously across levels should be considered as relatively infrequent occurrences to be identified, within a single region or nation, only at science and technology driven "catching up processes" like in the case of Germany between 1850 and the outbreak of World War I.

Type II can be identified in those arrangements where, on the one hand, basic overall C-indicators like TBP, the technology balance of payments or the GDP share of gross domestic expenditures on R&D rank significantly below the OECD-average and where, on the other hand, overall N-performance indicators like GDP growth, rate of unemployment, per capita income and the like are situated comfortably superior to the OECD-average. Taking Austria as a typical case in question, the TBP share amounts to 28% only and the GDP share for R&D is with 1.5% well below the 1993 OECD average of 1.78%, whereas unemployment is still to be considered as relatively low and annual GDP growth for the last twenty years clearly above the OECD averages. (FELDERER 1996) Thus, the second type poses, aside from an insufficient C-level "distribution power", a considerable "free rider" problem, reaping the high and medium tech benefits without an appropriate R&D investment in high and medium technology segments.

Type III, then, comprises a strong C-level position while being comparatively weak in N-performances. With the United Kingdom as typical example, one sees a typical problem of an inadequate N-level "distribution power" since the N-level "bottlenecks" prevent a higher return on R&D investment and a more successful propagation of the three fundamental P´s - programs, patents and prototypes - at the economic network domains.

Diagram 3.1: An Elementary Phase-Space for Dual Level Development Trajectories



Finally, Type IV is to be seen as the reference case in many peripheral regions of the Third World where both C-level and N-level performances remain at a depressed and low state. In terms of distribution power, it is advisable to classify the resulting overall constellation as a relatively weak "C-N distribution power". Here, "catching up" processes are in danger of running into C-level bottlenecks or N-level shortages simultaneously.

The discussion on main C-N types within the *global* knowledge and information system can be carried a step further by postulating, as a "grand conjecture", an additional typology of intertemporal development trajectories within an elementary C-N phase space.

Accordingly, "sustainable development patterns" possess only a *single* sustainable constellation of the Type I format which, however, cannot be assumed the standard or reference path. Both the Type II and the Type III configuration are, following the "grand conjecture", characterized by significant U-turns, undermining, thus, the relative successes either at the C-level (Type II) or at the N-level (Type III).

Table 3.6: Sustainable Development Trajectories

C+ N+	TYPE I (SUSTAINABLE, CO-EVOLUTIONARY UPWARD MOVEMENT)
C+ N-	TYPE II (NON-SUSTAINABLE, U-TURNS)
C- N+	TYPE III (NON-SUSTAINABLE, U-TURNS)
C- N-	TYPE IV (NON-SUSTAINABLE, CO-EVOLUTIONARY DOWNWARD MOVEMENT)

4. A Final Outlook

Having completed a preliminary summary of ERP, it seems reasonable to summarize the basic structure of the transdisciplinary ERP program format by contrasting it to the prevalent modes of bio-social theorizing which can be subsumed, as the final Table 4.1 demonstrates, under the heading of "me too-fallacies".

In sharp contrast to the analogy-building, modeling cultural domains *according* to an already available genetic core (bio $\Rightarrow$ social sciences), the ERP program assumes a radically different transdisciplinary structure which, above all, contains a *vertical* relation between a meta-level program and the context of applications. More concretely, the ERP program and its five basic elements can be captured *via* Table 4.2.

The final sentences in this introductory article will emphasize, once again, the usefulness and the high applicability of the epigenetic research program. Especially with respect to the current cognitive status in the social sciences, one has to emphasize the peculiar phenomenon that the separation between the kingdoms of "High Theory" on the one hand and of "High Empirical Research" on the other hand are hardly overcome or successfully bridged. Concluding with a very strong statement, ERP turns out to be one of the *very* few contemporary alternatives with a multiplicity of bridges, with a recursive design, integrating a manifold of isolated territories - theory and empirical research, complex modeling and data or biology and society - in a new transdisciplinary manner *and* with a rich variety of empirical applications ...

Table 4.1: "The Analogy Trap" for Integrated Bio ⇒ Social Sciences[17]

REQUIREMENT	GENETIC SYSTEM	CULTURAL SYSTEM
1. UNITS OF TRANSMISSION	Genes (Alleles Gene pool)	Memes (Allomemes, Culture pool)
2. SOURCES OF VARIATION	Assumed Random Mutation, Recombination	Deliberate or Random Innovation, Synthesis
3. MECHANISMS OF TRANSMISSION	Reproduction, Gametogenesis, Syngamy	Communication, Teaching Learning
Mode	Vertical	Vertical, Horizontal or Oblique
Ratio (Receivers/ Transmitters)	Fixed	Variable
4. PROCESSES OF TRANSFORMATION	Gene-Frequency Change	Meme-Frequency Change
Nonconveyance Forces	Mutation, Migration, Genetic Drift	Innovation and Synthesis, Migration and Diffusion, Cultural Drift
Conveyance Forces	Genic Selection Genetic Selection (N.e.)[18]	Cultural Selection Natural Selection Transmission Forces
Constraints	Organic Constraints (N.e.)	Cultural Constraints Social Constraints

[17] This table has been reproduced from DURHAM 1991:426.

[18] "N.e." stands, following DURHAM 1991:426, for "no equivalent", implying that no equivalent has been identified in the field of genetic systems to the "transmission forces" in the cultural domain.

Table 4.2: The Basic Structure of ERP

	EPIGENETIC RESEARCH PROGRAM		
META-LEVEL	THEORETICAL CORE: {Dual Levels, Five Epigenetic Dimensions, Embedded Code-Systems and Actor Networks as "Building Blocks", Recombination-Operators, Evaluation Measures, Multiplicity of Building Blocks, Second Order Applicabilities} SPECIAL MODELS: Families of Complex Models (Transdisciplinary Range of Applications) INTENDED APPLICATIONS: *General* Specifications for ERP-Applications		
	⇙	⇩	⇘
LEVEL OF APPLICATIONS	Transfer-Module$_1$ Set of Data $\{M_1\}$ Application$_1$ Natural Sciences	Transfer-Module$_k$ Set of Data $\{M_k\}$ Application$_k$ Eco-Sciences	Transfer-Module$_n$ Set of Data $\{M_n\}$ Application$_n$ Social Sciences (incl. Economics, Cultural Studies, Anthropology, etc.)

Embedded Code Systems (ECS): A Transdisciplinary Perspective from Genetics and Brain-Mechanisms to Symbols

Continuing the basic outlines of the epigenetic approach, the present part will highlight the unusual aspects of the ERP-core heuristics, especially the unifying notion of "embedded code systems" (ECS) and its application to heterogeneous fields like genetics, the "language of the brain" or scientific languages in closer detail. Once again, the transdisciplinary ERP-perspective should turn out to be capable of the following features:

> *First*, the concept of "code systems" and their "dynamic embeddedness" will occupy the central stage, yielding a unified platform for a rich variety of processes situated at the extended code levels.
>
> *Second*, the relationships and requirements, imposed on the concept of "embedded code systems" will bring to light an astonishing number of similarities and, even more importantly, of discrepancies between varieties of ECS.
>
> *Third*, due to the homogeneous and, above all, transdisciplinary conceptualization strategy, a most promising research trajectory will be opened up which is hardly mentioned in the contemporary debates on evolutionary sociology/economics, namely an integrated perspective for the emergence of *new* phenomena at the extended code-levels.
>
> *Fourth*, the general requirements especially for the "embeddedness-part" of embedded code systems will lead in the end to a surprising conjecture on the basic architecture of *human* language utilizations which, moreover, finds an astonishing support in the "neural constitution" of human brains.

It is the strong hope and conviction that the subsequent pages will be able to highlight some essential insights with respect to the "knowledge bases" not only of human societies, but with respect to a variety of "evolutionary kingdoms", ranging from the animal domains up to recent achievements in "machine learning" and "robotics".

1. Embedded Code Systems: General Requirements

The main-task for the following part consists, on the one hand, in an elaboration of a *transdisciplinary* conceptual apparatus for describing and analyzing various formations of embedded code-systems which, additionally, are able to integrate processes of knowledge production, learning, tacit knowledge, local adaptations, knowledge stocks and the like. With the title of the present chapter, it should come as a minimal surprise that the notion of *codes* and *embedded code systems* will be proposed as a unifying perspective which should secure the necessary bridging functions between genetic ensembles, neural groupings or linguistic entities, their storage and retrieval processes on the one hand and operations of innovating, learning and adopting on the other hand. "Codes" have been selected since, even on an *entirely* intuitive level, they fulfill six requirements simultaneously:

> *First*, in biology, codes as for example the DNA-code, play literally a *vital* role in the maintenance and in the production of organisms. Thus, embedded biological code-systems stand, under configurations specified below, in *very* close connection to biological problems of *reproduction, differentiation* or *maintenance*.
>
> *Second*, starting with McCulloch and Pitts, the code-like character of neural ensembles and, thus, of a "language of the brain" has been kept alive, leaving room for the possibility of a neural code system, fulfilling cognitive processes of maintaining, "storing" and activating action patterns. (McCULLOCH 1988)
>
> *Third*, codes have a long standing in areas like linguistics and semiotics and are able, consequently, to capture and to incorporate linguistic entities and structures as well. Consequently, code-systems are sufficiently powerful to account for the emergence and for the development of *languages*, human and otherwise.
>
> *Fourth*, code-systems have emerged in recent decades at the level of socio-technical systems, especially in the area of information processing machines, offering, thus, another vital new domain of application.
>
> *Fifth*, code-systems are closely related to fields like *information-theory* offering, in addition, the possibility for *formalized* investigations with respect to information contents, entropy, order, etc.
>
> *Sixth*, codes occupy a prominent role, especially in postmodern social sciences, for describing and analyzing communication processes, media, films, architectures, etc. Thus, code-systems can also be utilized for *non*-linguistic contexts of social, technical or economic environments. (ECO 1972, 1981, 1992, 1993)

Due to the sixfold application areas, "code-systems" should offer an extremely useful general tool in describing the domain of the extended code levels. Moreover, processes of "knowledge production", of local adaptations or of searching in "knowledge spaces" should be analyzable, after all, in a comparatively more encompassing manner, since a code-based perspective allows not only an extended *dual*-level investigation, but also an intricate *re-combination* of issues like codes, learning adaptations, reproduction or information. Thus, the setting up of a unifying framework will become a highly demanding research challenge since the exact requirements for a homogeneous code-based analysis *and* their entangled interactions within *any* type of extended actor networks are, following the current "me too-fallacies", largely adapted to the biological level alone. (See especially Table 4.1 in the previous article)

The inclusion of the domains of organisms, including humans, and the domain of human artifacts - books, solved mathematical problems or the encoded versions of advances in engineering - has been undertaken -

> by design, not accident, of course. It was to help set the stage for ... a Central Salvo: there is only one Design Space, and everything actual in it is united with everything else. (DENNETT 1995:135)

1.1 Five Basic Conditions for Embedded Code Systems

Thus, the present chapter will summarize in a brief and condensed fashion five essential ingredients which are necessary for the characterization of embedded code systems at the extended code levels. (See esp. GOODMAN 1973) Four of the five requirements are located at the level of code-elements, the fifth condition refers to the so-called "embeddedness-relations", i.e. to the *linkages* between code-systems and their wider environments.

> *Indifference of Code-Elements*; The *first* condition refers to the *exchangeability* of specific "marks" of a basic component or "character" in a code-system. Thus, taking the alphabetic code as reference point, A, *A*, 𝔄 or 𝐀 are clearly different marks for a specific basic character which, nevertheless, can be freely exchanged without distorting the code-*message*. Indifference is, thus, a typical *equivalence* relation, being reflexive, symmetric and transitive.
>
> *Finite Differentiation*: *Second*, the condition of *finite* differentiation refers to the decidability, in principle, whether a given mark belongs to a specific code-character - or not. Being strictly independent from the indifference condition, the requirement of finite differentiation asks for a code-system which, under normal conditions, possesses a *very* low rate of reproduction errors. Take, once again, the alphabetic code, then the following sequence of code- characters
>
> $$\{a, b, c\}$$
>
> should be *reproduced* by any system capable of code-retrieval and processing as

{a, b, c}

Combination of Code-Elements: The most essential requirement for code-systems, their *differentia specifica*, lies, *third*, in the *combinability* of code-elements or characters. Code-characters are able, via recombinations and a small number of basic operations, to produce new composite sequences. Moreover, code-characters can be integrated into larger sequences and can be synthesized as programs which serve an indispensable *construction-* or *recipe-*function[1] in the *production* of organisms, species, socio-technical complexes, socio-economic systems, etc. The following chapter will bring a more elaborated summary of the three necessary characteristics in the *combination* of code-characters.

Evaluation Measures: *Fourth*, combinations and recombinations of code elements should become evaluable in terms of *attrcativity/fitness/strength functions f*. Stated in a loose fashion, combinations and recombinations should be assigned different "degrees of comparative advantages", ranging from simple nominal arrangements [(no comparative advantages, small degree, medium degree, high degree, maximum degree of comparative advantages), (maximum degree of comparative *disadvantages*, ..., no comparative advantages/disadvantages, ..., maximum degree of comparative *advantages*)] to ordinal and, finally, to cardinal ensembles, defined over the interval [0,1] or, alternatively, [-1,+1].

Embeddedness: Understood in a wide and metaphorical sense, the *fifth* and final requirement refers to the necessity for code systems to be *dynamically embedded* in a larger surrounding whose production and reproduction depends, however, *crucially* on the code-system itself. Thus, the "embeddedness condition" refers to the *dual* level character of evolutionary systems and, consequently, to the *connections* between code-based domains and code-dependent processes at the extended network-levels which, again *very* loosely formulated, are *dynamically interwoven* and *entangled* with each other.

It will become the main task in the third part of this article to analyze the so-called "embeddedness-relations" in greater detail. It will be shown, in the end, that the embeddedness-relations hold the key for a partially new understanding of the constitution and the dynamics especially in human societies.

---

[1] Thus, programs should be placed, within the "metaphor space", in *close* distances to concepts like production, constitution, construction ... and in a *long* distance from terms like "representations", "imitations" and the like ...

1.2 Combinations within Embedded Code Systems: "Grammars", "Programs", "Media" as Generalized Concepts

The next step in the elaboration of a generalized notion of embedded code systems consists in a condensed discussion of the third requirement for embedded code-systems, namely the combinability-condition. Here, a set of rules on relative frequencies of code-components, on start- and termination-conditions is able to generate large classes of code-sequences. In sum, an ECS needs, aside from a repertoire of code-characters, additional provisions and rules for code-strings and the continuation of code-strings ...

Sticking, for the time being, to the domain of natural languages[2], the starting point in the transformation of an endless chaotic sequence of code-elements into an embedded code-system lies in a complex rule-system for the elementary combination of code-characters into small sequences of such characters, i.e. into code-strings and, finally, of strings to well-formed sentences, etc. Since a heterarchic architecture of such a rule-system would be extremely hard to come by, especially in real-time, a different evolutionary path has been chosen for the "language lottery" (LIGHTFOOT 1986, 1991) which exhibits a clear-cut differentiation of several code-levels.

> At the basic level of alphabetic characters, rules for cluster-formation transform single letters into compounds or syllables which form the elementary two string-, three string-, four string-, n-string-components of natural languages.
>
> At the level of *compounds* of syllables or, alternatively, of well-formed *strings*, a rich dictionary can be built up, consisting in the case of natural language, of a truly *infinite* number of "words", since a mode of "recombinations through combinations" can be set up which, like Cantor's diagonalization method, creates, by necessity, new combinations *not* included in existing dictionaries ...
>
> At the level of words, an extremely important rule system or *grammar* can be established for the transformation of words into word-sequences or, alternatively, sentences by linking and directing the patterns of words, the starting conditions, the end-conditions, etc. (See, e.g., WINOGRAD 1983)
>
> Furthermore, a variety of code-specific genres, or, following Douglas R. HOFSTADTER 1997:134, of "media"[3] has been developed, which combine the

---

[2] It must be immediately added that the restriction to natural languages occurs simply for reasons of simplicity and of an exemplar-guided procedure. In later parts, the language-independent requirements for programs, etc. will be laid out.

[3] "Genres" might be equated with the notion of "linguistic medium", proposed recently by Douglas Hofstadter (HOFSTADTER 1997). He states that "linguistic medium" should be understood as "any set of attributes, whether hopelessly vague or very precise and sharp, that someone might try to respect in a piece of writing" (HOFSTADTER 1997:134p.)

> set of well-formed sentences into special forms ranging from "narratives" to the literary fields (short stories, novels, plays ...), to the scientific area (articles, scientific books, ...) ....
>
> Finally, at the extended *network* levels, a manifold of "language games" has emerged, is continuing to emerge and will do so in the future while at the same time a large quantity of such language games falls into oblivion. As a KIS-relevant example, one may think of the enormous number of professions and their systems of practices which have effectively disappeared in the course of socio-economic evolution. (For an interesting summary, see PALLA 1994)

Following Daniel C. Dennett, the metaphorical notion of a "pandemonium of demons" can be employed where each of the demons is operating at a specific level, and where their *interaction* produces, after a period of internal *competition* and *selection*, a specific output which fulfills apparently *some* optimality criterion.[4] Thus, the notion of a "grammar" G will be understood, in a slightly unusual manner, as the *total* set of production rules $G = \{PR^{NL}\}$ for a natural language, ranging from syllable formation to the level of syntax and, finally, to the level of language games. In short, a grammar will be conceptualized as the *total* set of procedures to set the "pandemonium of demons" in a mode of *successful* operation.

Having introduced the term "grammar" in a *very* encompassing manner, the next concept, namely that of *programs*, will be used in a *non*-standard way, too. Contrary to conventional definitions of programs as a set of rules aimed at the solution of a particular problem, i.e. as an algorithm, which can be run or executed on a computer (BREUER 1995:13), programs are to be understood in a much wider sense, comprising *any* grammatically well-formed code-arrangements *and* its *embedded* relations. The following set of clearly meta-theoretical definitions, applicable to biological as well as to socio-economic domains, will be proposed:

> *Utilizable programs* - any well formed, grammatically valid string-arrangement of an embedded code-system ...
>
> *Utilized programs* - any well formed, grammatically valid string-arrangement of an embedded code-system which is *used* within its embedded environment ...[5]
>
> *Algorithmic programs* - any well formed, grammatically valid string-arrangement of an embedded code-system which can be implemented and processed on a computer ...

---

[4] It should be added that the sentence "Any *spoken* output is an optimal one" would be an outright tautology. Here, however, the sentence should be read as "Any spoken output is the *result* of an internal bidding process" which makes a substantial and highly *non*-trivial contribution to the basic *constitution* of utterances.

[5] A library consists, following the above definitions, of a comparatively large amount of *potential* programs, with a small subset proper of *actual* ones ...

> *(Re)productive programs* - any well formed, grammatically valid string-arrangement of an embedded code-system which has an essential and indispensable function in the *(re)production* of its embedded system - the paradigmatic example being the genetic program of organisms ...
>
> *Non-(re)productive programs* - any well formed, grammatically valid string-arrangement of an embedded code-system which has *no* essential and indispensable function in the *(re)production* of its embedded system.
>
> *Programs of programs* - any well-formed, grammatically valid string-arrangement of a well-formed, grammatically valid string-arrangement of an embedded code-system which is used within its embedded environment ...

Turning now to the final notion, namely to that of *genres* or, alternatively, of *media*, it should be emphasized, first, that "media" refer to "clusters" or "types" of specific programs. Thus, "scientific media" are to be understood as programs which are subject to additional, genre-specific constraints. Here, a set of *weakly* defined and, by necessity, *fuzzy* production rules has been worked out over the last centuries, leading to a repertoire of core-rules and core-requirements for each of these media respectively. Thus, in the domain of scientific media, the important groups lie in the area of "articles", "books", "research reports" and the like where each of these science media can be characterized by a *specific* set of production rules.

In this manner, an important number of different code-configurations has been introduced, ranging from simple alphabets and strings to absolutely *vital* notions like "(re)productive programs". The distinctive advantage of the approach, chosen so far, lies primarily in two areas:

> *First*, the overall *evolutionary* background has remained in its full power, since programs both of the reproductive and the non-reproductive variety occupy the center stage at the code-levels.
>
> *Second*, a *meta*-level perspective has been successfully retained which, even after the introduction of many code-specific terms like grammars, programs, strings *et al.*, can be applied to many different levels, ranging from the genetic code to the world of Morse-codes, ASCII-codes, pictorial codes or social rule codes.

In a variation to Mario Bunge's "A World of Systems" (1978), the "Worlds of Embedded Code-Systems" refer to a universal feature of biological or socio-economic-environments. Moreover, one of the probably surprising points in the discussion on basic code-requirements lies in the fact that the five basic conditions are sufficient to identify a *large* number of code-systems at *various* levels, ranging from the biological code, to the code of alphabets, of musical schemes, of numbers and, finally, to the code of codified social rules.

1.3 Code-Spaces and Evaluation Measures

The next basic feature of embedded code-systems to be discussed at some length consists in the elaboration of code-specific *spaces.* The following quotation, focusing on the code-space of the genetic code serves as an useful introduction both for the concept of spaces and for one of the peculiar features of code-spaces, namely the striking discrepancy between the *potential* space-dimensions and the *actually* occupied space-regions:

> Suppose we consider a haploid organism with N different genes, each of which comes in two versions, or alleles, 1 and 0. With N genes, each with the two alleles, the number of possible genotypes is now familiar: 2^N. The bacterium E.coli living merrily in the intestines, has about 3000 genes; hence its genotype space might have 2^{3000} or 10^{900} possible genotypes. Even PPLO, pleuromona, the simplest free-living organisms with only 500 to 800 genes, has between 10^{150} and 10^{240} potential genotypes. Now consider diploid organisms, with two copies of each gene. Plants may have 20.000 genes. If each has two alleles, the number of diploid genes is 2^{20000} for the maternal chromosomes times 2^{20000} for the paternal chromosomes, or about 10^{12000}. Clearly, genotype spaces are vast; even for a modestly long genome, there are an astronomical number of states it can assume. Any population of a species represents at any time a very, very small fraction of the space of its possible genotypes. (KAUFFMAN 1995:163f.)

With this quotation, it becomes relatively straightforward to introduce the concept of "code-spaces" since it can be defined for all code-systems as the set of all possible configurations of code-characters. Thus, taking the 26 letters of the alphabet, and strings of four characters only, the resulting code-space is of the moderate size 26^4 or 456976. Allowing, however, a number of strings in the range of 10^6 (like the present set of articles) and, moreover, roughly 74 *additional* code-components like {, . ? " - ' ( ) [ ] { } $\geq \alpha \beta \chi \Theta \Sigma \subseteq$... } and the extremely important character for an *empty* space, the resulting code-space CS becomes *transcomputable* due to its size of CS $\approx 10^{10\,000\,000}$. Thus, it is, by (almost) all standards, *certain* that the present explorations on code spaces and on the extended code-systems will remain *highly* original since it is *impossible* to be reproduced in exactly *this* format, including the following three *erors* (the third one is *self-rferential*!) ...

Thus, the most important point with respect to the construction of code-spaces lies in the specification of the code-elements N and the number of code-strings E which, then, define the code space CS as -

$$CS = N^E$$

It is important to add that code-spaces can be constructed within any type of embedded code system, including the genetic code, the "neural code", natural languages, music and the like.

Moreover, codes can be operative on a multiplicity of levels, generating, aside from primary structures, secondary, tertiary, quartiary ... levels which contain regular code-sequences, too.[6] The distinctive advantages offered via secondary, tertiary, ... n-ary levels need hardly be emphasized. Two main groups of advantages will be briefly mentioned.

> *First*, multiple levels allow for a highly differentiated network of *control*-relations since higher level strings and programs can serve as control instances for lower levels. Through level differentiation, higher levels can act on lower ones which, in turn, take influence on the lowest levels ...
>
> *Second*, multiple level organization makes a dense encoding of "information" possible which would be impossible to achieve in an accumulative single level-manner.[7]

In this manner, hierarchical rules and dense encodings can take place, transcending the one-dimensional and linear forms which have become typical for natural language encodings.

Having established a multiplicity of levels *within* code spaces of a given code-system, the next step consists simply in the attribution of evaluation-measures for various code-spaces. In a metaphorical introduction, code-spaces can be seen, alternatively, as a specific *landscape* of an embedded code-system which should be evaluable in terms of an *attractivity/fitness/strength function* f, a *basin of attraction* S in which $f(S) = 1$ and an *evaluation measure* which, in its simplest form, involves only a mapping from strings to 0 and 1.

> At S, where $f(S) = 1$, it (the evaluation measure, K.H.M.) orders the system simply to stop; at all other strings, the command is to mush on. (BERLINSKI 1986:321)

---

[6] For an elegant graphical version, consisting of four levels, see D.R. HOFSTADTER (1985b:563) where the following messages have been encoded at four different levels:

> *Die Globalstruktur - bestehend aus den Buchstaben 'M' und 'U' - ist eine Quartärstruktur, dann besitzt jeder dieser Teile eine Tertiärstruktur, die aus 'HOLISMUS' und 'REDUKTIONISMUS' besteht; dann existiert das entgegengesetzte Wort auf der Sekundärebene, und ganz unten ist die Primärstruktur, wieder das Wort MU, endlos wiederholt.* (HOFSTADTER 1985b:*Ibid.*)

[7] An instructive example can be provided by early systems of counting large quantities of animals where a multi-level organization managed to encode even four or five digit numbers of cattle. How? Simply by one person being responsible for counting from 1 to 9, a second person for the registration of two digit occurences 10, 20, 30, ..., a third person being in charge of three digit numbers, etc. For an extremely interesting history on number systems from an evolutionary point of view, see esp. IFRAH (1989).

In (almost) all cases of embedded code-systems, the evaluation measure must become more diversified, differentiating not only between 0 and 1 but between small intervals *within* the 0-1 domain. Thus, attractivity/fitness/strength should not be considered -

> an all-or-nothing affair; f thus takes values, let us say, between 0 and 1. Scanning every new string, the evaluation measure selects those strings s_i such that $f(s_i) > f(s_{i-1})$. These the system retains until it finds a string superior in ... (attractivity/fitness/strength). The result is a sequence of strings that ascends in (attractivity/fitness/strength). At S, as before, the system stops.(BERLINSKI 1986:322)

For biological and, *a fortiori*, for societal domains, the notion of attractivity or fitness landscapes can be given no precise and well-defined meaning. Even in the case of the genetic code, attractivity/fitness/strength -

> applies principally to an entire organism. It has components of fecundity, fertility and other factors leading to reproductive success. These include complex issues such as the frequency of each genotype variant of the organism in the population, the density of each genotype variant in a region, and even the entire ecosystem with which each organism interacts. Therefore, in the general context, it is difficult to assign a fitness to a gene or even to a genotype, since all these factors depend upon the other organisms in the population. (KAUFFMAN 1993:37)

Nevertheless, the search for appropriate attractivity or fitness landscapes must be considered as a highly desirable research goal, at least in an exploratory manner ...

"Coupled" or, alternatively, "rugged attractivity or fitness landscapes" are built up, not surprisingly as configurations with code-strings of length N - genes in the genotype, amino acids in a protein, letters in words, words in a sentence, sentences in stories, musical notes in a tune where -

> each part makes a ... contribution which depends upon that part and upon K other parts among the N. That is, K reflects how richly cross-coupled the system is. In the geneticist's term, K measures the richness of epistatic interactions among the components of the system. (IBID:40)

It would go well beyond the scope of the present conceptual introduction of attractivity or fitness landscapes to present a summary of the basic features of coupled landscapes between the extremes of K = 0 with unipeaked configurations and highly erratic, random landscapes with a multiplicity of small local peaks for K = N - 1. Suffice it to say that highly intriguing and fascinating dynamic features of adaptations and "hill climbings" can be recorded especially in the case of *small* K's. (K = 2, 3, ..) (KAUFFMAN 1993, 1995)

"*Multiply* coupled attractivity or fitness landscapes", the configuration of *highest* relevance in the case of societal domains, consists of ensembles, *integrating* attractivity or fitness landscapes at the code as well as on the network levels. Here, the NK-structure is replaced by at least a multiply coupled $N^C K^C (N^N K^N)$-type where, in a variation to Kauffman's NK-description -

> each part at the code levels makes a ... contribution which depends upon that part and upon K^C other parts among the N^C at the code level as well as on network parts N^N and their co-determinative factors K^N. That is, K^C, K^N reflect how richly cross-coupled the systems at the code and network levels are. In reproductive systems, K^C and K^N measure the richness of interactions among the components of the system.

One point should be added to the above recombination of Kauffman's original quotation. Especially in socio-economic systems with their multiplicity of embedded code-systems, the *coupling* of attractivity or fitness $landscapes_C$ and attractivity or fitness $landscapes_N$ may seem an unusual or even unwarranted phenomenon. The next chapters on different forms of ECS will make it clear that the *rapid* successes in the evolution of socio-technical $systems_{C,N}$ are *directly* linked to the *cross*-level adaptation processes within code-system variations *and* actor-network recombinations - *and vice versa* ...

1.4 Basic Dynamics for ECS

Having established the smooth, the rugged or even the bizarre attractivity or fitness landscapes for any given code-system, the next point will elaborate some highly characteristic dynamic features of embedded code-systems as well as the emergence of code-specific *drifts*. The essential question asks simply for the *principal* ways of movement, of "hill-climbing" and of "hill-descending" within attractivity or fitness landscapes at the extended code levels. *Very* generally speaking, the following four conditions can be identified which become necessary for any *dynamically* embedded code systems.

> *First*, embedded code systems, especially more complex ones like those used by humans, are processed within a *recursive,* internal *state*-determined organization, in which the output of internal processings becomes the most essential input for subsequent operations. With respect to the genetic code, the closed production cycle has been identified, under the heading of the "Central Dogma of Molecular Biology" (Francis Crick), as the *prime* organizational feature. But also with respect to human code-processings like reading, probably the most astonishing characteristic from the viewpoint of cognitive architectures

lies in the *almost totally* internal organization of the relevant processes of de-coding.

Second, an important dynamic feature for an ECS lies in the *nature* of adaptation processes, distinguishing very generally between an *asymmetric* pattern of "early experimentation and later standardization". Following Stephen Jay Gould (1989), an ECS must be seen as a very *special* survivor in the lotteries called "Life" -

> Major lineages seem able to generate remarkable disparity of ... design at the outset of their history - early experimentation. Few of these designs survive an initial decimation, and later diversification occurs only within the restricted ... boundaries of these survivors - later standardization ... Maximal initial disparity and later decimation give the broadest possible role to contingency, for if the current taxonomic structure of life records the few fortunate survivors in a lottery of decimation, rather than the end result of progressive diversification by adaptive improvement, then a replay of life's tape would yield a substantially different set ... and a later history making perfect sense in its own terms but markedly different from the one we know. (GOULD 1989:304)

Thus, ECS are definitely *not* the final result of a long "cone of increasing diversity", capitalizing step by step on its *partial* successes by staying at the levels of attractivity/fitness/strength reached so far and, consequently, by exploring and accepting new local solutions with a comparatively higher degree of comparative advantages.

Third, a successful dynamic ECS will proceed in all probability in a *de*-composite fashion, safe-guarding the system from too *powerful* disturbances from outside. For a *sustainable* tinkering process, a prime requirement consists, phrased in a post-modernist fashion, in the recursive de-construction of the overall outside "influences" into small subsets with comparatively fewer and simpler modes of changes and with relatively short time-intervals for the successful completion.

The most prominent metaphor for such an evolutionary path has been provided by Herbert A. Simon in his highly illuminating narrative of the two watch-makers or, in a typical "variation on a thema", of two programmers.[8]

> Two programmers assemble fine programs, each program containing ten thousand lines. Each programmer is interrupted frequently to answer the

[8] For the original version of two watchmakers, see SIMON 1977:248.

> phone. The first has organized his total assembly operation into a sequence of subassemblies; each subassembly is a stable arrangement of 100 lines, and each program, a stable arrangement of 100 subprograms. The second programmer has developed no such organization. The average interval between phone interruptions is a time long enough to assemble about 150 lines. An interruption causes any sequence of lines that does not yet form a stable system to fall apart completely. By the time he has answered about eleven phone calls, the first programmer will usually have finished assembling a program. The second programmer will almost never succeed in assembling one - he will suffer the fate of Sisyphus: As often as he rolls the rock up the hill, it will roll down again.

Finally, a *fourth* requirement for a successful dynamic ECS can be identified by demanding a *distributed solution* for the so-called *frame-problems*. While this particular point will be dealt with towards the end of the article in a more explicit fashion, the general requirement for dynamically interwoven code-systems lies in the availability of self-organization mechanisms or, alternatively, distributed solutions for code-based aggregation or integration problems. While, by necessity, a successful general *solution* to the "frame-problem" cannot be provided, it can be demanded, nevertheless, that embedded code-systems have a rich repertoire of strategies for combining, integrating and recombining different code-sequences. Thus, the problems lie primarily in the finding of *salient* selections, depending on the distribution of "code elements" as well as on the states of the embedded field and its wider environment.

In this manner, four basic conditions have been set up to "switch" a code-system into an embedded dynamic configuration, generating its highly specific drifts and, moreover, its reproductions and recombinations at the level of its *embedded* code-environment.

1.5 The Combination of ECS and the Emergence of Hyper-Complexity at the Extended Code Levels

A final characteristic already visible in Table 1.4 lies in the *combination* of embedded code-systems into integrated ensembles, consisting of two or three well defined ECS. Consider the following examples which may seem trivial at first, but which turn out to be highly interesting when viewed from a *code*-based perspective.

> Performing a work task in an organization (like supervising a machine-controlled production process), making a telephone call and drawing symbols on a piece of paper ...

Doing scientific routine work (like reading the present article), listening to music through headphones and thinking of radically new research designs for code systems and actor networks ...

Driving a car from A to B (as part of a work-task), listening to music (background) and communicating at the same time ...

These three examples exhibit the possibilities for code-combinations at the actor network levels. At the same time, these three seemingly trivial instances make it clear that the integration of different code-based activities has its definite capacity limits and barriers. Take the following variations to the above cases -

Performing a new work task in an organization (like supervising a new machine-controlled production process), *neglecting* the ring of the telephone and making notes of the observed process on a piece of paper ...

Doing creative scientific work in silence and *refusing* to communicate with someone else ...

Driving a car from A to B (as part of a work-task) under adverse weather-conditions like heavy fog and *restricting* communication processes to the road conditions only ...

These three modifications should be sufficient to demonstrate, on the one hand, the inherent limitations in complex code-processing capacities. On the other hand, the long-term development pattern clearly points into the direction of *integrating* embedded code-systems into new comprehensive forms. This point, while extremely interesting, must be confined to a single sentence on the emergence of new code-systems which run under the headings of "multi-media systems", "hyper-text" and the like where the combination of code-systems will be used, almost by necessity, for an evolutionary hill-climbing with one of the most efficient tools, namely *via* the help of the multiplicity of level-device, creating, "as we go along", secondary, tertiary, ... n-ary platforms for encodings ...[9]

[9] A highly intriguing history could be written by focusing on the phase transitions from single code-based activities to multiple ones. Radio and television, to mention two prime examples, are well in the process of changing into a mode of *easy* combinability with different code-based activities like reading, talking, writing and the like ...

2. Recombinations in ECS

The next major area of transdisciplinary investigation consists in the universal problem of recombinations at various levels of embedded code-systems (ECS). Sticking to the format of a meta-theoretical framework, the following pre-requirements must be laid out:

> *First*, one must be prepared to find a *universal* mode of recombinations *across* different code systems at the extended code levels ...
>
> *Second,* the recombination mechanisms can be described in a homogeneous manner for the extended *network*-levels, too ...
>
> *Third*, one may identify, in one of the most fascinating "second-order" research fields (Heinz von Foerster), namely in the area of the "evolution of evolution" or, alternatively, of "recombinations of recombinations", an epigenetic pattern, too, leading, over the *extremely* long run, to a more refined and complex recombination repertoire. Nevertheless, the clockworks for changes of the second-order type, are set at a vastly slower pace than the evolutionary changes and development patterns in organisms, ecosystems, let alone in the code-based areas of human life-worlds.

The starting point lies in a definition of recombinations across the multiplicity of code-system levels. Accordingly, the following set of requirements must be fulfilled for code-based changes in any ECS-type:

> Full-scale *change* potential for an *embedded* code-system consists in having a rich repertoire for recombinations with comparative advantages, following them recursively, applying them at the meta-level, and modifying them accordingly. [10]

The six basic requirements for recombinations in embedded code-systems, and, one may add, for actor-networks as well, which can be extracted from the definition above need further elaborations and more specific in order to render them operationally accessible.[11]

---

[10] The sentence above is a variation on a definition which Douglas R. Hofstadter has proposed for "creativity" –

Full-scale creativity consists in having a keen sense for what is interesting, following it recursively, applying it at the meta-level, and modifying it accordingly. (HOFSTADTER 1995:313)

It will become one of the main targets within the present recombination-chapter to demonstrate the *very* close "family resemblances" (Ludwig Wittgenstein) between recombinations at different levels of code-systems, including, especially, the phenomenon of scientific creativity as a particular case in question.

[11] It must be added that recombinations may cover the whole range of changes for a given component from comparative advantages (innovations) to comparative disadvantages (denovations). For more precise definitions on this point, see MÜLLER 1996a.

2.1 Recombination Operators

For the general case, the six recombination conditions which must be present simultaneously are independent of specific domains and even of the main evolutionary code or network levels. Since the entire article focuses, however, on embedded code systems alone, the ECS-domain will occupy the entire "article space".

> The *first* set of basic requirements is marked by the "rich repertoire-condition" which states that *successful* recombinations are dependent on a "requisite variety" (Ross Ashby) of the embedded code system. In other words, an embedded code-system with only random mutations as sole source of recombinations must be considered as a *very* poorly equipped recombination repertoire, whereas a "pandemonium of recombinative demons" across different levels fulfills the first requirement in an optimal way.
>
> The "rich repertoire-requirement" needs, *second*, the availability of *code-spaces,* which should have, in the general case, a single distinctive feature, namely a comparatively *large* area of unrealized code-sequences and, thus, a *high* potential for new sequences.
>
> The central area for recombinations resides, however, in the *third* requirement, namely in the availability of *recombination* operators which are able to generate in a recursive manner, starting from an initial scheme, new code-strings or programs. For the general case, one is able to distinguish at least ten recursive operators which, following mostly Douglas R. Hofstadter (1995:77), can be recombined by using some "adding operations" and which, then, can be subsumed under the following headings[12]-
>
> > *Adding*, the integration of new building blocks into an existing scheme ...
> >
> > *Breaking*, the differentiation of at least one scheme into two disjunctive building blocks ...
> >
> > *Crossing-over,* the breaking of at least two schemes *and* their merging into a new ensemble ...
> >
> > *Deletion*, the destruction of a specific building block from a set of schemes ...

[12] In the following enumeration, terms like "building blocks", "scheme" or "code-elements" will be used simultaneously. In order to avoid a possible misunderstanding, it should be added that these three expressions refer to different degrees of complexity in an embedded code-systems, from simple code-elements like letters to code-strings up to the level of programs or programs of programs ...

Duplication, the repeated insertion of at least one identical scheme ...

Inverting, the making of copies with an opposite sequence of elements ...

Merging, the integration of two or more schemes into a new one ...

Moving, the shifting of code-elements or of established boundaries ...

Replacing, the substitution of a code-element by another one ...

Swapping, the movement from a level L_i to a different level L_j ...

The important point which *cannot* be over-emphasized lies in the *universality* of these recombination operations *across* various embedded code-systems.

At the level of the *genetic* code, operations like *inversion*, *adding, crossing-over* or *replacing* occupy, as will be shown later on, an important role in the generation of *new* recombinations.

Within *natural languages*, recombinations occur in practically *all* utilization contexts, leading to the creation of new words by merging, adding, replacing ... operations, of replacing words in very specific contexts with new inverted ones of recombining phrases into new ensembles *via moving*, *swapping, crossing-over* ...

In *social rule-systems*, a recombinative operation like *crossing-over* can be identified, for example, in a surprising number of ways, yielding two different and, following Holland´s "schema-theorem" (1992), probably *more* useful specialized rules ...

Within the *scientific* system, the recombinations, leading to new research programs follow, as will become clear in the final chapter of the present section, operations like *swapping*, *merging*, *adding*, *replacing* ... too, whereby new and potentially more fruitful problem solutions, research trajectories, research agenda or research agenda for research agenda ... come into view ...

In the *music* domain, "variations on a thema", aside from being a musical genre in itself, offer a powerful route for the re-arrangement and re-configuration of music-*programs* ...

In *socio-technical* systems, operations like *adding*, *breaking*, *replacing* or *merging* play, quite naturally, a central role in the construction, adaptation and reconfiguration of established programs into new ones ...

The requirements *four* and *five* demand a sufficient degree of flexibility - a capacity to *salient* adaptations (requirement four) - as well as of efficiency in approaching the target domains within a relatively *small* amount of time (requirement five).

Finally, a *control*-capacity as well as a sufficiently powerful *support* system must be present which are not only able to secure the partial gains reached so far, but which, furthermore, develop at least *some* "gate-keeping"-functions and safe-guards against detrimental trajectories (requirement six) ...

This small set of examples has paved the way, hopefully, for a truly meta-theoretical or, alternatively, transdisciplinary recombination or, alternatively, invention perspective, relying entirely on a small class of recombination operators only.

2.2 Recombinations of ECS

The following chapter will recapitulate the main points and features of recombinations in *embedded* code-systems by applying them to three different domains, namely to the genetic code, to "neural programs" in brains and to the realm of scientific languages. Thus, the main target of this chapter will lie in a demonstration of the usefulness of the conceptual apparatus developed so far, despite the long distances which separate a morphogenetic field in biology from the present concerns for scientific creativity. Nevertheless, it will turn out as a highly rewarding research task to continue the construction of a meta-evolutionary approach on the constitution and on the development patterns in complex embedded systems since an astonishing number of *similarities* between recombinations in genetics and other types of code-recombinations will be brought to light.

2.2.1 Recombinations within the Genetic Code

The main focus in the section on the genetic code lies in a brief discussion of *some* of its main characteristic features, especially its recombinative capacities. In doing so, the close family resemblances between reconfigurations at the code levels of biological and socio-economic systems should become more transparent and recognizable. Of its central characteristics, some of them are too well known to be recapitulated here in greater detail. Consequently, they will be compressed into a small listing, starting with the code-*elements*.

The genetic code consists, *first*, of triplets from four bases, adenin, cytosin, guanin, uracil, which form a codon like UUU, GGG, AUU, CCU and the like ...

Second, triplets are the necessary basis for producing one out of a total of twenty amino acids like glycin, alanin, prolin, valin, isoleucin, leucin, serin, histidin, arginin and the like ...

Third, the genetic code is a *degenerate* one, since the codons GGU, GGC, GGA *and* GGG encode the production of glycin, GCU, GCC, GCA, GCG the "genofacturing" of alanin ...[13]

Fourth, the sequence of codons follows a *continuous* pattern without blanks or commas between the different triplets. What is present however, is a set of termination triplets, mainly starting with uracil bases like UAA, UAG or UGA ...

Fifth, the genetic code is *almost* context-free and, thus, *almost* universal. In recent years, some deviations to the universal encoding schemes from triplets to amino acids have been identified, for example in mitochondrial DNA of humans where AGA and AGG which normally encode the production of arginin act as a stop-symbol.

With respect to the recombinative capacities of the genetic code, one may distinguish, aside from single random mutations and random replication errors, between two modes of reconfigurations.

On the one hand, the genetic program for the production of new "phenotypes" is the result of a standard procedure of *crossing over*, i.e. the breaking of two strands of chromosomes and their merging into a new ensemble.

On the other hand, one finds at least five additional systematic ways of rearrangements in the genetic program.

Sticking to the general recombination operators, introduced above, they can be subsumed under the following headings (HENNIG 1995:485) -

Breaking or *Translocation*, the breaking of at least two schemes or chromosomes into new building blocks ...

Deletion, the destruction of a specific building block from a set of schemes ...

Duplication, the repeated insertion of at least one identical scheme ...

---

[13] It is highly informative to note that even in the case of the genetic code, the *semantic* requirements for code-systems which have been put forward by Nelson Goodman, are *not* fulfilled ...

> *Inverting*, the making of copies with an opposite sequence of code-elements ...
>
> *Merging* or, *Fusion*, the integration of at least two existing schemes into a new one ...
>
> *Moving* or *Transposition*, the shifting of building blocks into a new place ...

In this manner, a surprisingly rich repertoire has been identified which is responsible for the persistent genetic changes in plants and organisms, simple, complex and otherwise ...

2.2.2 Recombinations within the Neural Code

The second pool according to the epigenetic architecture is constituted by neural encodings or, alternatively, by neural programs. In order to make a clear distinction to the previous part, a specific action pattern to be found both in animals or humans will be selected as paradigmatic example, namely the dominance relations, defined "in terms of the direction of approach-retreat interactions between two individuals" (CHENEY/SEYFARTH 1990:29). In the case of male vervets one may observe the following patterns -

> If one vervet ... is dominant to another when competing for food, the same animal will also be dominant when competing for grooming partners, mates, or resting sites. If one animal is dominant to another in approach-retreat interactions, she will also be dominant in fights. Finally, in most vervet relationships the subordinate both grooms the dominant and forms alliances with her at higher rates than vice versa. (CHENEY/SEYFARTH 1990:30)

A similar action pattern with a large cluster of homologies *cannot* be observed, however, in a close relative to vervets, namely in baboons -

> Among male baboons ..., dominance relations are quite unpredictable from one context to the next. (IBID.)

Likewise, dominance relations between female and male vervets follow a context-dependent relation of *indeterminacy* as well -

> Among vervets, dominance relations between males and females are similarly context-dependent. (IBID.)

Here, one is clearly confronted with an emergent behavior which, in all probability, must be at least partly independent of the *genetic* code since it is restricted, despite an (almost) identical genetic configuration, to a subset of a subset of the species only. What one can observe in this case, is a *special* relation between a consistent action pattern$_N$, being -

> not only consistent across contexts but also transitive: if A is dominant to B and B is dominant to C, A is invariably dominant to C (IBID.) -

and a corresponding *neural* ensemble$_C$ which, following Gerald M. Edelman, may be labeled as a "neural group", a *group* of "neural groups" ... (EDELMAN 1987, 1990, 1992) or, following recent exploration in Artificial Intelligence, in Cognitive Science or in Artificial Life, as "mental agents" (Marvin Minsky) or as "neural drafts" (Daniel C. Dennett). Moreover, for purposes of a consistent terminology *throughout* the epigenetic parts, the term "building blocks$_{C,N}$", or "schemes$_{C,N}$" will be reserved for the characterization of ensembles *across* the extended code and the extended network levels whereas the notion of "neural groups" (neural programs, mental agents, neural drafts) will be applied for the extended code levels and the concepts of "action patterns", "routine patterns", "tasks" (Rodney A. Brooks), action (routine) sequences or "eigenbehaviors" will be used for its extended network counterparts. The important transdisciplinary point to be discussed within the present context lies in the applicability of the *general* recombination operators to the case of neural groups. The following list offers an interesting *neural* perspective on recombinations, making use, in a purely *formal* description of the varying composition of neural ensembles -

> *Adding*, the creation of a larger neural group by integrating new neurons or another group ...
>
> *Breaking*, the differentiation of an established neural group into two separate ones ...
>
> *Crossing-over,* the breaking of at least two neural groups *and* their merging into two new ensembles ...
>
> *Deletion*, the destruction of specific neurons within a neural group ...
>
> *Duplication*, the (re)production of identical neural groups (especially important, due to the tremendous complexity barrier between the human genome and the resulting complexity of the human brain)
>
> *Inverting*, the complete reversal of the linkage structure between a neural group ...
>
> *Merging*, the integration of two neural groups to a new and more complex one ...

Moving, the process of "horizontal" transfers through lateral recursions and re-entries ...

Swapping, the process of "vertical" transfers via recursions and via re-entries with a control-level ...

Replacing, the substitution of a specific neural group by another one ...

Thus, recombinations within the "neural pool" follow the same type of operational analysis which can be performed for the development of new or emergent phenomena at the gene pool-levels too.

2.2.3 Recombinations within the Scientific Code

Finally, a third set of ECS-recombination types will concentrate on scientific languages and, more specifically, on innovative changes within established fields of inquiry. Three "creative destructions" from the rich Austrian tradition in philosophy of science and mathematics – Gödel's Theorems, the program of the Vienna Circle and Popper's "Logic of Scientific Discovery" - will demonstrate that the short list of recombination operators offers a new and interesting way of describing scientific revolutions at the extended code levels.

For Gödel's "Incompleteness Theorems", analyzed according to the list of recombination operators, the following transformation steps have become essential:

Dissonance in cognitive space, the foundational debate in mathematics (logicism, intuitivism), the challenges posed by the Hilbert-program ...

Replacing, the substitution of an established mode of numerical coding through a new coding procedure, the Gödel-numbering ....

Swapping, the utilization of the Gödel-code for numbers for axioms and theorems of number-theory itself ...

Meta-Level-control, the selection of a research-heuristic which, within the history of modern mathematics, has proven to be very successful in the generation of paradoxes, namely the route of self-referential constructions ...

Merging, the integration of multiple levels and a homogeneous coding-scheme with a well known building block for producing paradoxes, i.e. with self-referentiality ...

It should be added that the recombination or creativity operations described above capture apparently the essence of the construction of Gödel's proofs.

> The first key-idea is the deep discovery that there are strings of TNT (Typographical Number Theory, a notation scheme developed by D.R. Hofstadter, K.H.M.) which can be interpreted as speaking about other strings of TNT; in short, that TNT, as a language, is capable of "introspection" or self-scrutiny. This is what comes from Gödel-numbering. The second key-idea is that the property of self-scrutiny can be entirely concentrated into a single string; thus that string's sole focus of attention is itself ... in my opinion, if one is interested in understanding Gödel's proof in a deep way, then one must recognize that the proof, in essence, consists of a fusion of these two main ideas. Each of them alone is a master stroke; to put them together took an act of genius. If I were to choose, however, which of the two key ideas is deeper, I would unhesitatingly pick the first one, the idea of Gödel-numbering.(HOFSTADTER 1982:438)

The second creative achievement from Austria's First Republic is given by the "unified science" program of the Vienna Circle, as it has been developed from the late twenties onward and as it has been institutionalized in six large conferences on the "unity of science" from 1935 in Paris to 1940 in Cambridge, Mass. Here, verificationist or testability linkages have been demanded between a basic or protocol-language on the one hand and higher theoretical terms, expressions, relations or functions on the other hand. Moreover, this so-called *physicalist* program, named, *inter alia*, to honor the ongoing revolutions in physics, has been forcefully applied in the areas of cultural sciences and psychology for which a time-space-based protocol-language has been, especially within the intellectual backgrounds of the German speaking world, a typical *non*-entity. Relying on the recombination-operators specified above, the following transformation steps can be distinguished.

> *Basic structure of cognitive space* – a splitting of cognitive spaces into "idiographic domains" and "nomothetic areas" or, alternatively, into natural sciences and cultural or mental/spiritual sciences ("Geisteswissenschaften")
>
> *Exploration in cognitive space*, the extension of a new tool, i.e. the "new logic" of Frege, Russell and Whitehead, for the analysis of the languages of science ...
>
> *Ordering of cognitive space*, the search for a set of universally applicable principles, criteria and standards which despite the dualism of cognitive spaces can be utilized within the natural sciences *and* within the social sciences.

> *Merging*, the integration of natural sciences and social sciences under the heading of a universal scientific language ...
>
> *Adding*, the specification of a special class of empirical sentences, the so-called protocol-sentences which should serve as the basic language both for the natural as well as the social sciences ...
>
> *Moving*, the shifting of a space-time language into the domains of the cultural sciences and psychology ...
>
> *Breaking*, the partitioning of statements into empirically meaningful ones and their syntactically or semantically ill-defined counterparts. As a special point of controversy, large segments of contemporary metaphysics, especially of proponents of right wing-Hegelianism or Heidegger's *Sein und Zeit,* have been included in the second class. Moreover, wide segments of the psychology of the time has been deemed in need of reformulation and reconfiguration according to the physicalist approach ...

Given the Vienna Circle-program, the transition to the *third* major intellectual achievement is easy to undertake, since a single property in cognitive space and only two creativity operators are needed to account for it:

> *Dissonance in cognitive space*, the irrelevance, at least in Popper's view, of the criterion of verification for problems of theory selection or scientific growth ...
>
> *Inverting*, the shift from verification to falsification ...
>
> *Breaking* the separation of the domain of "meaningful statements" into two disjunctive domains, namely into falsifiable statements like the "General Theory of Relativity" on the one hand, and into unfalsifiable statements like those to be found in Marxism, in psycho-analysis of the Freud-variety, Adler-offspring, Jung-adherence ...

This small set of examples should establish a sufficient understanding that the basic requirements for recombination operators in general and the specifications for scientific recombinations in particular offer an interesting way of analyzing creative breakthroughs by utilizing the essential operators and the recursive manner of transformations leading from an initial configuration to the final innovative outcome.

In this manner, an important "missing epigenetic link" has been built up, bridging the gaps between genetic codes on the one hand and action patterns, including encoding routines by scientists, on the other hand. Due to the extended code pools of -

Genetic Code (internal) ⇔ Neural Programs (internal) ⇔ Natural Languages (external)

and due to the extended network lineages from -

Metazoa ⇔ Vertebrates ⇔ Humans

it becomes possible to identify well integrated ensembles of different types of embedded code systems at the extended code-levels and species, socio-technical systems or societal formations (both for animals, animats and humans) at the extended network levels.

3. Public Embeddedness Domains

So far, the discussion has focused on some elementary meta-theoretical ECS-architectures. Turning to the problem of code-*processing* from a transdisciplinary point of view, the most prominent obstacle for a *generalized* understanding of embedded code-systems lies in the field of human languages. Here, the limited *accessibility* of human code-operations as well as the asymmetric *relations* between observable performances and the *internal* ways of code-generation have produced a rich discursive "protective belt" which has acquired the status of a *persona obscura*. The important and essential code-processing activities, the *primary* components like intentions, goals, decisions, desires, value-adherences, habitus-distinctions ... are located *within* persons and the *secondary* elements like actions, the observable practices and routines but also the code-elements themselves have a *derivative*, *second*-best status only. The important moves are undertaken, so it seems, within a sphere of *private* or *internal* code-operations which manifest themselves only in small traces and remnants - like "das Flügelrauschen der Gottheit" (NEURATH 1981:359).

The alternative which will be proposed during the subsequent departures[14] can best be summarized with the help of a guiding metaphor, first proposed by Ludwig Wittgenstein, the tale of beagles, boxes and the conditions of the possibility of communication processes. (WITTGENSTEIN 1971:PI 293)[15] With the help of the Wittgensteinian metaphor, an

[14] As a general orientation, the planned departure may be seen as a typical *Austrian* expedition which takes three "strong statements" of the "linguistic turn" very seriously, namely Otto Neurath's vision - *In der Wissenschaft gibt es keine 'Tiefen'; überall ist Oberfläche,* Ludwig Wittgenstein's specific "fact finding mission" - *Die Welt ist die Gesamtheit der Tatsachen, nicht der Dinge* - and, finally, Heinz von Foerster's descriptive device - *Die Logik der Welt ist die Logik der Beschreibung der Welt.*

[15] Wittgenstein's original tale has the following format:

alternative foundation of embedded code domains comes into view which assumes an *inverse* relation on "meaning", "accessibility", "intentional stance", "values" and the like. Here, various forms of an *inter*-subjectively distributed societal "consensus" as well as *highly* specific *clusters* of action-sequences or, in Wittgenstein's words, "forms of life" become the important *external* stabilization components$_N$ which guarantee the "functioning" and the "continuity" of code-operations, communicative and otherwise. Moreover, the conventional construction, relying on the *private* or *internal* view on embeddedness domains, will be confronted with the strictly *un*-solvable problem of finding solutions to a specific class of problems within a *sufficiently* small amount of time ...[16]

For any *external* or, alternatively, *public* conception of embeddedness domains however, a most serious obstacle arises due to the following constellation: Public embeddedness domains imply, among other consequences, strictly *non-causal* types of "internal-external relations". More concretely, seemingly internal factors like "intentions", "decisions", "rules" and the like *cannot cause* or generate a specific outside behavior. (WITTGENSTEIN 1971:PI 172 - 175, passim) Rather, "intentional", "rational", "motivational", etc. explanations must be considered as quasi-analytical description devices, linking two *external* ascriptions at different degrees of generality. *Abandoning* the *causal* efficacy of internal domains however, leads to a well-known conundrum, philosophical and otherwise, with respect to the absence of necessary and sufficient *attribution* conditions. Generally, the paradox assumes the format -

Specific Action Pattern : High Variability of Interpretations

Specific Interpretation : High Variablity of Action Patterns

Thus, the main parts in the present chapter will be devoted to a dissolution of this paradoxical configuration (See also WITTGESTEIN 1971:PI 198) and to an operationally sound foundation for *public* embeddedness domains.

Angenommen, es hätte Jeder eine Schachtel, darin wäre etwas, was wir 'Käfer' nennen. Niemand kann je in die Schachtel des Andern schaun; und Jeder sagt, er wisse nur vom Anblick seines Käfers, was ein Käfer ist, - Da könnte es ja sein, daß Jeder ein anderes Ding in seiner Schachtel hätte. Ja, man könnte sich vorstellen, daß sich ein solches Ding fortwährend veränderte. - Aber wenn nun das Wort 'Käfer' dieser Leute doch einen Gebrauch hätte? - So wäre er nicht der der Bezeichnung eines Dings. Das Ding in der Schachtel gehört überhaupt nicht zum Sprachspiel; auch nicht einmal als ein Etwas: denn die Schachtel könnte auch leer sein. - Nein, durch dieses Ding in der Schachtel kann 'gekürzt' werden; es hebt sich weg, was immer es ist. (WITTGENSTEIN 1971:PI 293)

Phrased within an epigenetic terminology, the upshot of the Wittgensteinian tale lies in the emphasis on *public* beagles which are easily accessible and observable by competent observers. Beagles *within* boxes - the metaphor for an internalist view - are, so the Wittgensteinian position, an insufficient basis for language games.

[16] For more details especially on this point, see the last chapter in Part IV.

A promising starting point for a successful inversion of embeddedness domains comes from the neuro-sciences where one has furnished an astonishing and highly counter-intuitive experimental result, namely the *interpretative* role of the Cartesian demon *alias* "interpreter" (Michael S. Gazzaniga) even in the total absence of any support from perceptual data ... To make the last sentence more understandable, a reference must be made to the so-called "split brain-research" where patients, suffering from epilepsy, have been undergone a complete removal of the *corpus callosum*, *i.e.* of the nerve fibers connecting the two brain hemispheres. Experimental research with split brain patients or split brain animals has produced a large number of astonishing and highly counter-intuitive results.

The experimental setting in the specific example to be discussed assumed the lateralization of pictures to one hemisphere only. More concretely, the left hemisphere, associated with the right eye, "saw" the picture of a claw whereas the right hemisphere "recognized" the picture of a snow scene. In turn, the probands were asked to solve two simple selection problems. They were confronted with a set of additional pictures from which they had to choose the two ones that fits best to the context they had seen previously. The most appropriate answer for the left brain scene was a chicken, the most likely response to the right brain-context had been a shovel.

> After the two pictures are flashed to each half-brain, the subjects are required to point to the answers. (GAZZANIGA 1985:72)

And the results?

> A typical response is that of P.S., who pointed to the chicken with his right hand and the shovel with the left. After his response I asked him, 'Paul, why did you do that?' Paul looked up and without a moment's hesitation said from his left hemisphere, 'Oh, that's easy. The chicken claw goes with the chicken and you need a shovel to clean out the chicken shed.'
>
> Here was the left half-brain having to explain why the left hand was pointing to a shovel when the only picture it saw was a claw. The left brain is not privy to what the right brain saw because of the brain disconnection. Yet the patient's very own body was doing something. Why was it doing that? Why was the left hand pointing to the shovel? The left brain's cognitive system needed a theory and instantly supplied one that made sense given the information it had on this particular task. It is hard to describe the spell-binding power of such things. Manipulating mind variables is awesome. (IBID.)

The special point of this experiment lies in its peculiar variation of an "other minds" problem *within* one and the same person. Visual inputs (the winter landscape) which are processed within an *isolated* half-brain *without* language competencies lead, quite naturally, to an *ad-*

hoc interpretation of a specific action (the choice of a shovel) on part of the other half-brain *with* language competencies ... It can be asked whether this special configuration of an isolated "bicameral mind" (Julian Jaynes) can be generalized into a basic vision of a *modular* or a *multi*-cameral mind in which language operations become entangled in a far more "superfluous" and "interpretative" manner.

> We're always making up stories ... and relating only the best candidate - which is, if things are going well, the true story. The patients who confabulate aren't lying, in the usual sense of the word. They probably relate the best story that they were able to construct from the data available to them and think it true ... It shows you that our memories are not like tape recordings which keep the events in an immutable sequence; we remember the elements by recognition, and recall the sequence by ties between these elements. But each recognized element has usually been seen before, and combinations have likely occurred in various orders ... (CALVIN 1990:53p.)

The above quotation should not be seen as ammunition for the "unreliability" of memories, human or otherwise. On the contrary, the whole argument by Calvin can be interpreted as support for far-reaching *revisions* and *revulsions* in the *overall* perspective for phenomena like memory, meaning, understanding with respect to their embeddedness domains. A similar point has been raised a long time ago by Ross W. Ashby or Heinz von Foerster already, since, in their view, memory should be interpreted as -

> the irreducible uncertainty of an observer with incomplete knowledge of the present internal state of a non-trivial machine (say, a living organism), which the observer interprets as a property of the machine. (FOERSTER 1995:312)[17]

The *upshot* of the Foerster-quotation lies, similar to Calvin´s emphasis on "story telling" in the demand for a *radical* revision with respect to the status of internal performances and internal mechanisms ...

Following the point of observer-dependencies, "internal stances" like the "intentional stance" (D.C. DENNETT) become a highly *successful* way of *external* or *public* ascriptions which can be evaluated in terms of their predictive or retrodictive surplus value. Thus, the "intentional stance" will in all probability retain its everyday status in a strikingly similar manner as, say, the Ptolemean world-view which despite being overcome and replaced within astronomy, is still widely used in everyday contexts - metaphors of the sun going down or the bad moon rising are still *strongly* entangled in everyday descriptions. In a similar manner, other "internal stances" like the *emotional*, *normative*, *learning* or *decision making* ones, will retain a prominent role in everyday communications, including the scientific ones.

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[17] For a similar point of view, see also WATZLAWICK (1992:17).

Since the internal processes *within* subjects and their "manufacturing of meaning" are considered as a sufficiently inhomogeneous basis, the external perspective leads from the worlds "within" to the worlds "out there"; to well-structured societal ensembles - to *specific* public routines in small social groups and communities, to *fixed* observable practices in organizations, to *specific* accessible standardizations in large societies, in sum, to different levels of "forms of life" in "public domains". (Ludwig Wittgenstein).[18]

The general "grand vision" for *public* embeddedness domains for human code systems comes, not surprisingly, from Ludwig Wittgenstein – and, in a powerful Wittgenstein interpretation, by Saul Kripke. (see also KRIPKE 1985, KOETHE 1996) In a nutshell, the external approach can be summarized in the following way:

> ... The community attributes a concept to an individual so long as he exhibits sufficient conformity, under test circumstances, to the behavior of the community ... The entire game ... would lose its point outside a community that agrees in its practices ... The set of responses in which we agree, and the way they interweave with our activities, is our *form of life* ...

These domains - community specific "consensus" and "forms of life" at the levels of actor networks – constitute a rich variety of *public* embeddedness domains which are directly linked to the code-processing operations at the extended code levels. More specifically, one can find a complex set with ten areas which fulfill the necessary characteristics of sufficiently restricting and limiting code-productions and the range of possible code-exchanges.

> *First*, *agreements* in practices, or, following the epigenetic terminology used so far, *implicit* routines, can be enlisted as the first *public* embeddedness domain. *Specific* utilization contexts for words, sentences and other code-configurations which are recursively interwoven into the fabric of societal interactions qualify as a major *public* embeddedness domain. Moreover, this particular domain can assume two different forms, ranging from actor-actor interactions and community specific agreements ("implicit knowledge_1") to actor-environment (nature, materials, machines ...) interactions ("implicit knowledge_2")

---

[18] "Forms of life" can be conceptualized at different P-levels *within* a specific species (or in a more subtle understanding at different G-levels, too). Thus, "form of life" must not be equated with just the sum total of a *gemeinsame(n) menschliche(n) Handlungsweise.* (WITTGENSTEIN 1971:PU 206)..

When one says that to imagine a language is to imagine a form of life ..., it is included in and implied by this statement that there are a number of forms of life and not just one. And just as surely this does not mean the cow-like, fish-like, dog-like and so on, but rather other human behaviour, other societies, real or imagined. (HALLER (1988b:134).

Second, following especially Wolfgang Stegmüller (1986), *core-* or *paradigmatic examples*$_{1,2}$ (actor-actor routines, actor-environment practices) qualify as another vital public embeddedness domain since paradigmatic$_{1,2}$ examples are able to serve as a *common* reference point for learning and adaptation processes, especially, but not exclusively, for the language acquisition of young children. Moreover, the delicate operations of attributing emotions, intentions, meanings, rules, understanding and the like make it almost imperative that these emotions, intentions, meanings, rules, understanding and the like have a widely distributed repertoire of *paradigmatic* examples.

Third, criteria$_{1,2}$ can be enlisted as another ingredient for public embeddedness domains since external, easily accessible and observable criteria become of tantamount importance especially for the attribution of "internal stances" like intentions or emotions. Thus, *public* criteria for emotions like rage, happiness, fear, anger, for understanding chess, for speaking a foreign language but also for wood carving, for taming animals, etc. are essential ingredients in the identification and in the assessment of specific routines as well as of the language productions, associated and "entangled" with these practices.

Fourth, symptoms$_{1,2}$ qualify as another easily accessible and observable public embeddedness domain once again, but not exclusively, in the case of a seemingly "internal vocabulary", ranging from emotions to sicknesses or ailments. While the distinctions between symptoms and criteria seems, at times, to be a superficial one, it can be argued that symptoms, in contrast to criteria, do not qualify as necessary or sufficient conditions for a particular phenomenon, but serve as probable hints or clues for such a phenomenon. Moreover, symptoms and criteria stand in a permanent dynamic relationship of mutual exchanges since criteria can change to symptoms and *vice versa*.

Fifth, codified ("explicit") *agreements* in *practices* or routines$_{1,2}$ based on *encoded* rules may be quoted as another important *public* embeddedness domain. Here, the restricting component lies in the co-existence of specific routines$_{1,2}$ and a repertoire of corresponding codified rules, *connected* with specific practices. Once again, explicit routines$_{1,2}$ become an important restriction on the range of possible language games as well as on the speech production, associated with them.

Sixth, *rituals*, defined here as the *combination* of *constant* or *fixed* code-sequences (extended code-levels) and/or *specific* or *fixed* action patterns (extended network-levels), can be named as another "public domain" ingredient in societal settings. Rituals are, under normal circumstances, linked to code-systems in manifold ways like in the case of *greeting*, *entering* a room (knocking from without, response from within, entering the room, greeting ...) or, to restrict the list of examples to just three, the extremely interesting code and action system of *dancing*. (For a short introduction on dance-codes, see TUFTE 1990:114p.) In *this* manner, rituals form another essential part of the public embeddedness domains or, alternatively, of the "cement of society". (ELSTER 1989, SOME 1993)

Seventh, one has to add *operationally* defined and highly *standardized* forms of attributions and exchanges, including, for example, money, measurements, *constants* especially in the natural sciences, etc. which have found their way into dictionaries, encyclopedias, thesauri, weight and measurement-tables, scientific textbooks ... These areas fall clearly under *public* embeddedness domains since they serve as fixed points for a tremendous amount of practices in economics, everyday life, in the scientific arena, etc. Moreover, with standardized exchanges, measures, weights and units like ampere, ohm, calorie, British thermal unit (BTU), volt, newton, decibel, astronomical unit, carat, gallon, coulomb, becquerel, candela, kelvin ... one will be confronted with the peculiar phenomenon that only a *very* small part of the population will be able to reproduce the exact dimensions of say, a coulomb (6.23×10^{18} electrons) or an ampere (a unit of electric current equivalent to a flow of one coulomb per second).

Eighth, *institutions*, i.e. codified *general* rules, norms, legislation, etc. form another important segment of *public* embeddedness domains. Here, institutions can be loosely defined as *widely* distributed ensembles at the extended code-levels.[19] Thus, school-legislation counts as a paradigmatic example for an institutional arrangement in which common standards and goals, distributed *throughout* a national school-system, are defined, *independent* and irrespective of the peculiar fact that each school is composed of *different* pupils, *different* teachers or a *different* administrative personnel ...

Ninth, *organizations* form another essential component of *public* embeddedness domains. In contrast to institutions, organizations can be loosely defined as *dual*-level *spatio-temporal* systems, having their spatio-temporal exits and entrances, with an organizational "knowledge base" at the extended code levels *and specific* practices at the extended network levels. Thus, schools count as a paradigmatic example for an organization in which common standards and goals

[19] For a similar definition, see SJÖSTRAND (1995:28) who defines institutions as -

> *a social construct for a coherent system of shared and enforced norms.* (IBID).

are to be achieved, by each of the many organizational school-units in a variety of ways *compatible* with the "institutional substructure" or the "institutional bases". Again, organizational settings, the organizational knowledge bases, etc. constitute an important public embeddedness domain which imposes *restrictions* on the range of possible code productions and exchanges ...

Tenth, an extremely important addition has to be made, namely the description potential with respect to code-utilization contexts or settings. Take, as a prime example, "speech-acts" or "language games" in everyday-life configurations, then one finds an astonishing rich field of investigations which have *rarely* been touched upon so far within the social sciences. Take the following listing from Douglas R. Hofstadter on "surface-tests" in the speech production alone and on the potential for detecting underlying "deep-structures" or "generative mechanisms" -

> looking at *word frequencies* (*e.g.*, ... is 'the' the most common word? ...are some low-frequency words used unnaturally often? ...);
>
> observing sensitivity to *tone* (*e.g.*, are formal and slang expressions in the input text understood? is humor based on improper mixtures of tone understood? ...);
>
> examining *types of errors* (*e.g.*, misspellings, transposition errors, improperly used words or phrases, blends of all sorts ...);
>
> examining *word flavors* as a function of subtle details of the context (*e.g.*, what contextual pressures lead to choosing 'jock' over 'athlete', or vice versa? to saying 'lady' as opposed to 'woman'?...);
>
> examining *level of abstraction of word choices* (*e.g.*, what pressures lead to choosing between 'Fido', 'the dog' and 'some mammal'? ...);
>
> looking at *default assumptions regarding gender* (*e.g.*, what kinds of circumstances lead to generation of agent nouns with feminine endings, such as 'heroine', 'millionairess', or 'farmette'? ...);
>
> observing how *throwaway analogies* are understood and generated (*e.g.*, is the abstraction hidden in remarks ... interpreted correctly and instantly? are such remarks produced in the standard contexts that would call for them?);

observing how *throwaway counterfactuals* are understood and generated (*e.g.*, is the subtle blend implicit in remarks such as 'I wouldn't have felt that way if I'd been my father' ... interpreted correctly and instantly? ...);

paying attention to *timing data* (the speed taken to generate the output can be used to make some inferences in the mechanisms behind the scenes) (HOFSTADTER 1995:489f.)[20]

More generally, small and even *tiny* deviations in the flow of speech, unspectacular, though characteristic changes in word orders, small movements of a finger, a specific position while sitting in a chair ... qualify as embeddedness domains *too,* since in all these instances an explanatory framework can be built up, leading to speech processing programs which produce small and even *tiny* deviations in the flow of speech, unspectacular, though characteristic changes in word orders ...

With the inclusion of rarely explored observable behavior patterns with respect to code-utilizations[21], the *main* public embeddedness-domains for human code-systems have been identified. Starting with the general Wittgenstein-Kripke vision of agreements in responses and "forms of life" within public domains, one gets an operationally highly diversified set of

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[20] In a similar manner, another set for "surface features" can be identified in the area of *body movements.* Here, a variation of the Hofstadter-quotation leads to research tasks like -

> looking at *frequencies* of movements (*e.g.*, ... slight movements of the head towards another person or away from someone? ...are some unusual finger-movements recorded unnaturally often? ...);
> observing sensitivity to *tone* (*e.g.*, are formal and slang expressions in the input text understood? is humor based on improper mixtures of tone understood? ...);
> examining *types of divergencies between speech and body movements* (*e.g.*, agreeing on a proposal completely, while slightly shaking one's head, turning away from one's opponent, etc.);
> examining *movement flavors* as a function of subtle details of the context (*e.g.*, what contextual pressures lead to choosing a specific change in one's sitting position compared to the previous configuration? ...);
> examining *level of complexity of movement choices* (*e.g.*, what pressures lead to choosing a complex movement, consisting of a coordinated effort between head, finger, arm and leg-movements instead of a simple change in the left hand only? ...);
> looking at *specific movements regarding gender* (*e.g.*, what kinds of gender-specific circumstances lead to certain types of movement patterns in case of, say, a male or a female person entering a room? ...);
> observing how *throwaway movements* are understood and generated (*e.g.*, is the "message" hidden in someone's body movements ... interpreted correctly and instantly? are such movements produced in the standard contexts that would call for them? ...);
> paying attention to *timing body movements* (the speed taken in lifting one's arm to point into a specific direction can be used to make some inferences on the interaction pattern between motoric and language performances behind the scenes)

[21] One of the rare examples in the social sciences lies in the field, called "objective hermeneutics". (OEVERMANN et al 1979, 1983a, 1983b)

public embeddedness areas which, in sum, put essential restrictions on the possible (re)production of code-sequences:

implicit routines
paradigmatic examples
external criteria
external symptoms
rule-based routines
rituals
standardizations
institutions
organizations
observable surface features of code-utilizations

Thus, ten highly diversified families of *public* embeddedness-domains have been found which constrain, aside from the grammars of embedded code-systems themselves, possible code-operations *within* actor network-levels. At this point, it becomes tempting to ask whether these domains can be ordered in a more stringent and coherent manner - and whether these ten groups can be seen as a comprehensive and exhaustive enumeration of public embeddedness domains.

> *First*, using, once again, the epigenetic distinctions between extended code levels and extended network levels, one arrives at a first dimension which distributes public embeddedness domains over the evolutionary important dual level scheme.
>
> A *second* dimension, under the heading of varying degrees of *organizations*, refers to distinctions between spatio-temporal settings with a *high* density of codified rules, norms, entrance and exit boundaries, etc. and spatio-temporal settings with *low* or *zero* densities of codifications, *open* access, etc.

These two dimensions lead to the subsequent Table 3.1 where one can find a morphologically ordered ensemble of embeddedness domains.

With respect to outer *limits* and *boundaries* of public embeddedness domains, especially in the case of rule-systems, of intentional attributions, of emotional ascriptions and the like, one is led almost inevitably to the question whether, for example, a solitary islander of the Robinson Crusoe variety -

Table 3.1: A Morphological Space for Public Embeddedness Domains

	DIMENSION$_2$ EXTENDED EPIGENETIC LEVELS *C*-LEVELS	 N-LEVELS
HIGHLY ORGANIZED SETTINGS	Codified Rules Codified Norms Codified Goals and "Missions" Codified Rituals Codified Criteria Codified Standardizations Codified Paradig- matic Examples Standardizations *Surface Features of* *Programs* in the Domains of Rules, Norms, Goals, Rituals, etc.	"Implicit Routines$_{1,2}$" *Paradigmatic* *Examples$_{1,2}$ for* Rules Norms Goals and "Missions" Rituals, Criteria, etc. *Surface Features of* *Routines* in the Domains of Implicit Practices$_{1,2}$, Paradigmatic Examples$_{1,2}$, etc.
DIMENSION$_1$ DEGREES OF ORGANIZATION		"Implicit Knowledge Routines$_{1,2}$" *Paradigmatic* *Examples$_{1,2}$ for* Rituals Rules (Norms), etc.
ZERO-ORGANIZED SETTINGS	A *Small* Repertoire Of Codified Norms, Rituals, Rules, Paradigmatic Examples, etc.	*Surface Features of* Routines in the Domains of Implicit Practices$_{1,2}$, Para- digmatic Examples$_{1,2}$, etc.

> cannot be said to follow any rules, no matter what he does? I do not see that this follows. What does follow is that if we think of Crusoe as following rules, we are taking him into our community and applying our criteria for rule following to him. (KRIPKE 1985:110)

Whether attributions from an "intentional, emotional ... etc. stance" should be applied to domains *outside* human communities, no *a priori* answers can be provided, neither with respect to the Robinson Crusoe-problem nor with respect to animal behavior or in relation to machine activities (NEUMAIER 1987). All that can be shown from the current ECS-point of view, are the shifting boundaries for "internal" ascriptions which, over the last decades, have seen a remarkable extension towards higher organized animals and even plants. In these at times highly intriguing instances (CHENEY/SEYFARTH 1990, GRIFFIN 1992, MORTON/PAGE 1992, SERPELL 1986), a separate decision has to be made on the inner- or the outer limits of rule following, intentional attributions, emotional ascriptions, or, more generally, of the adequacy or the inadequacy of the so-called "internal stances" ...

4. Embeddedness at the Edge of Chaos: The NP $\Rightarrow$ P Conjecture

The remaining pages will be devoted to an unusual *strengthening* of the externalization-perspective developed so far. The basis for the subsequent explorations is marked by the simple and uncontroversial statement that code-processing in human languages or, more pragmatically, in language games, allows for relatively *quick* real time realizations despite the practical infinity of code spaces. After all, communication processes *are* interwoven and entangled within large sequences of day to day routines and practices. Moreover, despite the vast dimensions of code spaces with a vast number of possible trajectories, the problem of code-acquisitions has been and is *successfully* solved by the young population between the age of one to ten throughout *all* societal formations, past, present and, in all probability, future.

The central point in the final part of the ECS-article lies in establishing a "conjecture" which accounts for both a priori *very* improbable successes. Moreover, this particular conjecture will demonstrate once again that there are no differences in principle between the operations and *external* attractivity/fitness/strength in genetic code-systems, in neural code-arrangements - and in the processing or understanding of a text, a symbol, a picture, a book, a piece of music ... The criteria for an adequate code-processing happen, in all three major program-pools, within the *public* domains of actor-networks and their environments. Although highly counter-intuitive at first sight, an adequate understanding of human languages is marked by the same type of symmetry-condition which can be applied to *any* type of embedded code system, human and otherwise:

> Wenn man aber sagt: 'Wie soll ich wissen, was er meint, ich sehe ja nur seine Zeichen', so sage ich: 'Wie soll er wissen, was er meint, er hat ja auch nur seine Zeichen. (WITTGENSTEIN 1971:PI 504)

In order to present the corresponding "conjecture", it will be fruitful to start with a broad analogy from a special domain in the information sciences and complexity theory. Take a *typical* NP-problem, namely the "traveling salesman-problem" (DEVLIN 1994, WAGNER 1994), then the following complexity barrier comes into play.

> For just a few elements ($C \leq 7$) and, consequently, a *small* number of combinations between them, the problem at hand remains trivial and can be solved in a *very* short time. Changing however, to large configurations ($C \geq 1000$), consisting of more than thousand components and a *vast* number of possible combinations too, the problem spaces *cannot* be explored in a reasonable amount of time. In the case of the traveling salesman, no *efficient* algorithm has been found so far which would solve the problem at hand in *polynomial* time.

A *trivial* mechanism for transforming this particular type of NP-problem into a P-type configuration can be provided by imposing a sufficiently large amount of restrictions on the network configuration.

The NP $\Rightarrow$ P-Transformation (Traveling Salesman, Simple Version):

> A *very* large map ($C \geq 1000$), consisting of a *very large* number of possible choices for links makes a *comprehensive* exploration into the required regional spaces impossible - "the problem spaces *cannot* be explored in a reasonable amount of time". Instead, in order to guarantee relatively quick *real-time* solutions, a large amount of intersubjectively *easily* accessible and, thus, of *external* restrictions can be imposed on travel sequences, transforming the choice of routes into a solvable problem. Thus, the NP-character of the traveling salesman-configuration is transformed into a P-class problem of "lower or higher complexity" ($C \leq N$), depending on the overall number of restrictions (with N *considerably* smaller than the original network of $C \geq 1000$) ...[22]

In other words, *due* to the NP-character of the large-scale versions of the traveling salesman problem, the *only* path for quick "real time solutions" lies in the proliferation of a *large* number of externally *fixed points* and *restrictions* in form of standardizations, fixed sequences and the like ... Only these *pre*-fixed and constant domains are able to guarantee that, on the one

[22] "Edge of chaos" and sufficient complexity" refer both to the same phenomenon, namely to a state, allowing "both stability and flexibility". (KAUFFMAN 1995:86)

hand, *appropriate* choices can be accomplished in a small amount of time and that, on the other hand, processes of finding the *appropriate* choices can be learned successfully in a comparatively short amount of time, too.

Assume, additionally, that the reductions of network complexities are imposed in a *fuzzy* version, with probabilities and probability distributions over the external restrictions.

The NP $\Rightarrow$ P-Transformation (Traveling Salesman, Fuzzy Version):

> A *very* large map ($C \geq 1000$), consisting of a *very large* number of possible choices for links makes a *comprehensive* exploration into the totality of regional spaces impossible - "the problem spaces *cannot* be explored in a reasonable amount of time". Instead, in order to guarantee relatively quick *real-time* solutions, a large amount of intersubjectively relatively *easily* accessible *fuzzy external* restrictions can be imposed on travel sequences, placing travel choices at the "*edge* of chaos". Thus, the NP-character of the traveling salesman-configuration is transformed into a P-class problem of "sufficient complexity" ($C \leq N$), where N is *considerably* smaller than the original network of $C \geq 1000$ ...

At this point, it seems very reasonable to ask for the linkages between the problems of a traveling salesman and the *externality* approach to embedded code systems. But the required analogy can be established in a straightforward way since in the case of natural languages too, one is confronted with code elements, code spaces, comparative advantages, evaluation measures and the like - and the problem, to find an "optimal solution" of code-elements, given specific initial conditions IC.

> For just a few code elements and, consequently, a *small* number of combinations between them, the problem at hand remains trivial and can be solved in a *very* short time. Changing however, to large configurations ($C \geq 3000$), consisting of more than 3000 code elements and a *vast* number of possible combinations too, the problem spaces *cannot* be explored in a reasonable amount of time. In the case of natural languages, no *efficient* algorithm has been found so far which would solve the problem at hand in *polynomial* time.

Again, a trivial mechanism for transforming any type of NP-type language problem into a P-type configuration lies in the availability of a sufficiently large amount of restrictions on the network of nodes.

The NP $\Rightarrow$ P-Transformations (Human Language, Simple Version):

> A *very* large code space (C ≥ 3000), consisting of a *very large* number of possible choices for links, makes a *comprehensive* exploration into the totality of code spaces impossible - "the code spaces of a natural language *cannot* be explored in a reasonable amount of time". Instead, in order to guarantee relatively quick *real-time* solutions, a large amount of intersubjectively *easily* accessible and, thus, of *external* restrictions can be imposed on code sequences, transforming the choices for code elements to a solvable problem. Thus, the NP-character of the human language configuration can be transformed into a P-class problem of smaller or higher complexity ($N \leq C \leq N + L$), depending on the number of imposed restrictions (and with N, L *considerably* smaller than the original number of $C \geq 3000$) ...

Thus, the "NP ⇒ P Conjecture" assumes that the imposition of a *large* amount of *external* or *public* restrictions on operations within embedded human code systems has become the stable evolutionary (epigenetic) strategy to overcome the complexity and, equally important, *learning* barriers inherent in human ECS.

The "NP ⇒ P-Conjecture" (Human Language, Fuzzy Version):

> The *hyper-complexities* of embedded *human* code-systems, consisting of a *very large* number of possible operations, make a *comprehensive* exploration into the resulting code spaces impossible - "the problem spaces *cannot* be explored in a reasonable amount of time". Instead, in order to guarantee relatively quick *real-time* solutions in day to day code operations as well as sufficient "inputs" for processes of code-acquisitions and learning, a large amount of externally easily accessible and, moreover, of *fuzzy* restrictions has been imposed on code operation modes. Thus, the NP-character of code operations is permanently transformed into a P-class problem of "sufficient complexity", based on a large number of *fuzzy external* restrictions. Aside from code-specific grammars, these fuzzy restrictions are distributed over the ten *external* embeddedness domains discussed above, *i.e.*, over implicit routines, paradigmatic examples, criteria, symptoms, codified rules, rituals, standardizations, institutions, organizations, observable surface features in the contexts of code-utilizations ...

One possible support for the "NP ⇒ P-Conjecture" comes from the neuro-sciences where, in recent years, the role of rituals and standardizations has been emphasized very strongly.

> We should not lose sight of the fact that symbols are still extensively tied to ritual-like cultural practices and paraphernalia. Though speech is capable of conveying many forms of information independent of any objective supports, in practice there are often extensive physical and social contextual supports that affect what is communicated. Language acquisition still relies on an extensive

> gamelike ritualization and regimentation of the symbol acquisition context, although the child's uniquely human computational supports enable this process to take place without explicit reductio ad absurdum grounding of all symbols and possible combinations in the system. (DEACON 1997:407p.)

A second interesting justification of the "NP $\Rightarrow$ P Conjecture" can be given *via* a simple demonstration that a respectful number of philosophical paradoxes is based upon variations or recombinations of the basic NP $\Rightarrow$ P architectures.

First, take as starting point a well-known philosophical "uncertainty principle", namely Quines *Indeterminacy of translation* which has been characterized by Quine, *inter alia*, in the following manner.

> There can be no doubt that rival systems of analytical hypotheses can fit the totality of speech behavior to perfection, and can fit the totality of dispositions to speech behavior as well, and still specify mutually incompatible translations of countless sentences insusceptible of independent control.(QUINE 1975:72).

It should be added that with respect to the translation domains one does not even need two different languages and an inconclusive lexicography, with or without *fact of the matter.* Upon closer inspection, an *identical* problem arises with respect to two native speakers within the same language community. Even more, for one and the same(?) person at two different points in time "rival systems of analytical hypotheses can fit the totality of speech behavior to perfection, and can fit the totality of dispositions to speech behavior as well". Consequently, mapping Quine's "indeterminacy paradox" into the NP $\Rightarrow$ P configuration, one is confronted with the following situation.

a multiplicity of specific solutions for "translations"
a relatively small explored region of translations within a practically infinite translation space
"equivalence" of translations
no guarantee for optimal solution

Apparently, Quine's "Indeterminacy Principle" arises as a sheer consequence of the overall NP $\Rightarrow$ P configuration, since a *multiplicity* of *equally satisficing* solutions belongs to one of the necessary core-attributes of successful NP $\Rightarrow$ P transformations. Why? Simply because the *fuzzy* character of restrictions allows under normal circumstances for a *multiplicity* of *equivalent* solutions when assessed in terms of available evaluation measures.

Second, Quine's *Indeterminacy*-relation for translations turns out to be strikingly similar to another philosophical riddle, namely to Goodman's "new problems of induction" which result, by and large, from sufficiently available "degrees of freedom" in attributing strongly contradictory hypotheses to a given set of "observational data". Here, the NP $\Rightarrow$ P configuration is deliberately "violated" by a recombinative operation of *adding* a new type of time-sensitive attribute. Not surprisingly, the resulting P-configuration guarantees, by *necessity*, the *strict* equivalence of rival inductive hypotheses.

a multiplicity of specific solutions for inductive hypotheses (by adding a new class of time-dependent concepts)
strict equivalence of *contradictory* inductive hypotheses
no guarantee of optimal solution

Third, adding to these two paradoxes the Wittgensteinian conundrum of "rule-following", one finds, once again, the following configuration –

a multiplicity of specific solutions for rule-attributions
a relatively small number of utilized rules within a practically infinite rule space
equivalence of rule-attributions
no guarantee of optimal solution

Moreover, the solution to the so-called "rule paradox" is accomplished, according to the overall Wittgenstein/Kripke/Stegmüller-vision, *via* the imposition of fuzzy restrictions (agreements, paradigmatic examples, forms of life, etc.) which have been summarized within the previous chapter already.

Fourth, Hume´s paradox of the intertemporal *non*-transferability of inductive hypotheses can be transformed quite easily into the overall NP $\Rightarrow$ P reduction format. Here, however, the overall configuration is slightly altered since one of the essential restrictions, namely the transferability of an inductive hypothesis along time, is put into question. According to Hume, no rational justification, due to its unavoidable *past*-dependency, can be provided for such a move. Here, the answer must emphasize the conventional, traditional or context-dependent character of public restrictions. The habitual and, at times, *not* rationally justifiable type of external restrictions belongs to the *basic* NP $\Rightarrow$ P architecture.[23]

Apparently, these four paradoxes arise out of the practically *infinite* possibilities within the code spaces of natural languages – and out of the fuzzy character of necessary *public* restrictions, imposed on these spaces to render them functional for day to day communications. Consequently, the conjectures, emerging from the four paradoxes, lie, on the one hand, in the structural *similarity* of the four philosophical problems by David Hume, Nelson Goodman, Ludwig Wittgenstein and Willard v. O. Quine, being variants of an underlying NP $\Rightarrow$ P reduction architecture (fuzzy version) and, on the other hand, in the

[23] It must be mentioned at this point that the reference to *traditions* and *established* practices does not preclude the possibility of a *rational* justification of inductive practices. The important point to emphasize lies in the large amount of *conventional* elements inherent in *any* type of "inductive routines"

indispensable role or, alternatively, in the necessity for *sufficient*, easily accessible *public* restrictions of language complexities.

In other words, the *only* evolutionary *stable* path for *satisficing* "real time solutions" lies in the proliferation of a *large* number of external *fixed points* and *restrictions* in the form of criteria, standardizations, rituals and the like ... Moreover, only these *temporarily* fixed and constant domains are able to guarantee that processes of code-acquisitions, code learning and finding the *appropriate* attributions can be learned successfully in the life-course of a few years only. After all, children in the age of five or six years exhibit a *rich* repertoire of attributing different types of "internal stances" to humans, play toys, trees, flowers, animals ..

The problem behind an appropriate understanding of code-understanding lies, thus, in finding *salient* answers to the number of relevant choices. The final arbiter for *salience* lies, however, in the long evolutionary history at the actor-network levels which, following Richard Dawkins has achieved means and ways for "taming chance" -

> To 'tame' chance means to break down the very improbable into less improbable small components arranged in series. No matter how improbable it is that an X could have arisen from a Y in a single step, it is always possible to conceive of a series of infinitesimally graded intermediaries between them. However improbable a large-scale change may be, smaller changes are less improbable. And provided we postulate a sufficiently large series of sufficiently finely graded intermediaries, we shall be able to derive anything from anything else ... (DAWKINS 1986:317)

In a generalized version, *any* form of life "has" its *specific* "basins of attractions", its "fixed points", its "landscapes of comparative advantages/attractivities/fitness/strength" with their *local* maxima and minima ... Moreover, these "basins of attraction" exhibit all the essential dynamic characteristics like a sensitivity to initial conditions, discontinuous changes and "jumps", multiple *local* equilibria, etc.

Code processing and language games, they turn out to be neither fixed and pre-programmed action-sequences nor self-contained and closed monads "without windows". On the contrary, *all* our embedded code-games have a high potential for recombinations *and* for errors. Take a sentence like the following which has occupied a *local* maximum for a *very* long time-span -

We are *satisfied* that the earth is *flat*.[24]

---

[24] A variation to Wittgenstein's -

We are satisfied that the earth is round (WITTGENSTEIN 1971:ÜG 299)

For thousands of years and for a large number of societal ensembles, explorations in cosmology and astronomical reasoning, justifications in everyday questions and answers on the shape of the earth have led, after a sequence of steps, into this particular basin of attraction where additional questions, challenges and disturbances suffered the fate of returning into this particular region in cognitive space, *again and again, round and round* ...

Moreover, the following quotation, written in the years around 1950, makes the sensitivity to specific cognitive contexts as well as the drastic change in the shape of knowledge landscapes abundantly clear.

> Wir alle glauben, es sei unmöglich, auf den Mond zu kommen; aber es könnte Leute geben, die glauben, es sei möglich und geschehe manchmal. Wir sagen: diese wissen Vieles nicht, was wir wissen. Und sie mögen sich ihrer Sache noch so sicher sein - sie sind im Irrtum, und wir wissen es. Wenn wir unser System des Wissens mit ihrem vergleichen, so zeigt sich ihres als das weit ärmere. (WITTGENSTEIN 1971b: ÜG 286)
>
> Thus, like in the case of *We are satisfied that the earth is flat*, local maxima or, alternatively -
>
> > poles which indicate the endpoints of possible gradation (HALLER 1988:134) -
>
> have to be, in a *very* strong sense, the necessary "attractors" in cognitive space. Phrased in a different perspective, these poles or local maxima are, for the space and time *being*, the "blind spots" in particular forms of life. Around local maxima, blindness becomes *unavoidable*. An alternative way of putting this important point is the following variation, once again from Wittgenstein II, stressing the necessary blindness in these special areas of "certainty" (WITTGENSTEIN 1971:PI, p.261)

It would go well beyond the scope of the present article to justify the "NP $\Rightarrow$ P - Conjecture" in greater detail. One point, emphasized within the Austrian philosophical tradition especially by Otto Neurath or Ludwig Wittgenstein, lies in the relatively *short* chain of justifications for specific code-arrangements. After only several steps of challenges and justifications, one will reach a state of "dialectic equilibrium" where no more *additional* justifications can be provided. Based on a necessarily *insufficient* amount of "information", one *has* to justify whether a person understands a specific numeric sequence or not, whether a child has the ability to read, whether someone "understands" a foreign language, an artistic style, etc. And, as experience shows, the justification chains become relatively short *why* a particular decision has been undertaken ...

Table 4.1: A Gödelian Survey on the General Incompleteness of Dual Level Systems

MATHEMATICS	MOLECULAR BIOLOGY	SIMPLE MACHINES	SOCIO-ECONOMIC SYSTEM
Axiomatic Number Theory-System (NT)	Cells	Phonograph	Organization
"Perfect" System	"Perfect" Cell	"Perfect" Phonograph	"Perfect" Organization
String of NT	Strand of DNA	Record	Rule
String deducible by a given NT	Strand of DNA reproducible by a given cell	Record playable by a given phonograph	Task performable by a given organization
String *not* deducible by a given NT	Strand of DNA *not* reproducible by a given cell	Record *un*playable by a given phonograph	Task *not* performable by a given organization
Process of interpreting NT ⇒ Numbers	Process of transcription of DNA onto mRNA	Process of converting record grooves into sounds	Process of converting rule-sequences into work
Arithmetization N ⇒ meta-NT	Translation of mRNA into proteins	Translation of sounds into vibrations of phonograph	Transformation of rules into tasks
Gödel-Code (mapping from triplet of digits onto meta-NT)	Genetic Code (mapping from mRNA triplets onto amino acids)	Phonograph Code (mapping from external sounds onto vibrations of phonograph)	Organization Code (mapping from rules onto organizational tasks)
Inconsistency of NT	Destruction of the cell	Breaking of phonograph	Dissolution of an Organization
"Imperfect" NT	"Imperfect" Cell (a cell for which there exists at least one DNA strand which it cannot produce)	"Imperfect" phonograph (a phonograph for which there exists at least one record which it cannot reproduce)	"Imperfect" organization (an organization for which there exists at least one set of rules which it cannot reproduce)

One final hint will be provided which, *via* a rare type of a *Gödelian* exploration into the *general* incompleteness of systems, highlights one of the consequences of the NP ⇒ P reductions (fuzzy version). It might well be that the dense amount of examples on systems failures (see esp. GALL 1990) has as its *common* theoretical background an "Incompleteness Theorem" of the format -

"There always exists an unreproducible (code) program, given a particular (actor-network) system" ...

which can be seen as a corollary to the NP ⇒ P conjecture. In this view, the "Incompleteness Theorem" arises, quite naturally, out of the NP ⇒ P reduction architecture of large amounts of public *restrictions* –

"The large amount of public limitations on program utilizations produces a general constraint on their universal reproducibility, too"

And this "Incompleteness Theorem" can be applied to domains as diverse as organizations, bacteria, firms, machines or scientific institutes ... The following table (see Table 4.1) will give an introductory overview of at least *one* surprising equivalence which can be identified in socio-technical systems, molecular biology and mathematics. Following Table 4.1, one will detect in all probability a rather unexplored feature of dual level systems in general, namely their *necessary* "blind spots". (For more details, see HOFSTADTER 1982:532pp.)

At the end of the present paper, it must be sufficient to point out to the *overall* goal-orientation which has motivated the writing of the present set of two articles.

> What is your aim in the *alternative* constitution of "knowledge based processes"? - To show the disciplinary flies the exit from the traditional fly-glasses ...

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