M O RP H O G E NE SIS
O F
M E A NI N G

by

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Translated by Franson M ANJALI

Peter Lang, forthcoming

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MORPHOGENESIS OF MEANING

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TRANSLATOR â€™S INTRODUCTION

The present work was originally written as part of Jean **Petitot**â€™s *ThÃ¨se dâ€™Ã‰tat* defended in 1982. It was published in 1985 by the Presses Universitaires de France, Paris, in their series *Formes SÃ©miotiques* under the title *MorphogenÃ¨se du Sens. Pour un schÃ©matisme de la structure*. The second part of *MorphogenÃ¨se du Sens* was published in 1992 by the CNRS Ã‰ditions, Paris, under the title *Physique du Sens*.

The importance of **Petitot**â€™s original French publication can be emphasized on two counts. Firstly, it provides a deep philosophical elaboration of RenÃ© Thomâ€™s Catastrophe Theory (CT) proposed in the mid-seventies. In his preface to *MorphogenÃ¨se du Sens,* Thom acknowledges that the theory which had generated great hopes within the scientific community at the time of its launching ended up being merely â€œa set of recipes for modelingâ€ù, or a tool-kit for applied mathematics. He notes that thanks to Jean **Petitot**â€™s work

> â€œthe philosophical project underlying the whole enterpriseâ€¦has been specified, clarified, amplified, and above all restored to its rightful place within the grand philosophical and methodological tradition of the sciences, particularly the social sciences.â€ù

Secondly, and as for the workâ€™s significance in the social sciences, Thom

approvingly refers to **Petitot**â€™s catastrophist reworking of Jakobsonâ€™s structural phonology via the notion of â€œcategorical perceptionâ€ù, to his catastrophist modeling of the â€œlocalistâ€ù interpretation of the case category which functions as a sort of fulcrum between syntax and semantics (the localist idea has a history beginning from the Byzantines, Maxime Planude and Theodore of Gaza, to Charles Fillmore and John Anderson, via Louis Hjelmslev), and most importantly to his catastrophist schematization of Greimasian theory of semio-narrative structures.

MorphogenÃ¨se du Sens was a seminal work which exerted a deep influence on the different semio-linguistic schools: Greimasâ€™s and Coquetâ€™s French schools, Ecoâ€™s Italian school in Bologna, Urbino, and San Marino, Brandtâ€™s Danish school in Aarhus, Wildgenâ€™s German school in Bremen, and also Canadese schools in Montreal (Pierre Ouellet and Pierre Boudon) and QuÃ©bec (Gilles Ritchot and GaÃ«tan Desmarais). It has become a key reference and we think it is therefore a good thing to provide its English translation.

The present English version is strictly targeted to a â€œscientificâ€ù readership. As Jean **Petitot** says in his *Foreword*, the â€œcontinentalâ€ù philosophical digressions have been deliberately eliminated almost fully. In the process, those aspects of the book that had made it appear epoch-making in the mid- and late eighties may be found wanting in the English version, but the focusing on its scientific â€œhard-coreâ€ù may be more attractive and

advantageous, especially to those who are familiar with the dynamical modeling perspectives that have emerged in large numbers in the cognitive sciences in general during the nineties, even if its impact is yet to be felt on the generally slow-moving intellectual horizon of Linguistics (and Semiotics) in a clearly discernible form.

Jean **Petitot** told me he would prefer to see this pioneering work as a sort of â€œretrospective contributionâ€ù to the ongoing trends in dynamical modeling, or as a kind of reminder of a strong antecedent which was relatively original for the Anglo-American academic world during its period of euphoria with the Chomsky-Fodor type of formalist cognitivism as well as with other forms of logicism, and also as something that is capable

of providing certain fresh insights into the relatively new dynamical paradigm which has blossomed under the aegis of the â€œconnectionistâ€ research enterprise in cognitive science.

The central issue dealt with in this book is that of *structure*. More precisely, with the question of assigning a *physical and dynamical* basis to structure in linguistics and semiotics. The classical problem with structure has always been to conciliate its formal essence with its phenomenal filling-in, its discrete â€œformâ€ with its continuous â€œmatterâ€ (to use Hjelmslevian terms). For instance, the categories of linguistic structuralism, beginning with the phoneme, etc., are not conceived classically as natural categories, but merely as conceptual ones which are projected onto the real world. The methodological strategy employed in this regard is to suggest that the structural unit, irrespective of where it occurs, and particularly the phonemic unit, is a type subsuming one or more natural tokens, e.g., the phones. In a phonemic analysis, the differences between the phones are identified as distinctive or not. Once the phonetic / phonemic differences are identified, and the distinctive (phonemic) units established, the latter are arranged in paradigms, and are seen as being available for combinatory (syntagmatic) deployment. But the point that is missed in this classical formalist perspective is that there are no abstract categories in nature; categories are largely mental products resulting from a *process* of discretely dividing up the natural entities. These natural entities do not exist as such as *discrete* entities, but form part of a *continuous* substratum. Therefore, a formalization of the structural categories that exist merely as constructs is handicapped by the fact that it leaves behind the continuous and the natural substratum from which structure and its categories inevitably emerge.

Hence the importance of using dynamical models which can explain how *qualitative discontinuities* can emerge from the organization of the continuum, in such a way that it can be categorized and discretized. Catastrophist models yielded the first examples of such algorithms generating discontinuities. Using them, **Petitot** interpreted the qualitative and the privative oppositions that form the basis of Jakobsonâ€™s (phonological) distinctive feature analysis in terms of the catastrophes of conflict and bifurcation respectively.

The question of syntactic structure presents an even more interesting picture. Chomskyan axiomatics did go beyond the earlier â€œitem and arrangementâ€ approach in this domain, by introducing a principle of generativity, essentially based in two sets of rules, those of recursivity and transformation. The apparent autonomy of Chomskyâ€™s generative device in fact masks the rootedness of the syntax of natural languages in the structures of action and perception, in other words, the partial analogy that exists between the structure of language and the structure of the experienced external world.

An investigation of the core grammatical structure of natural language reveals not so much an infinite generativity of sentence structures as Chomsky had once claimed, but rather an auto-limitation imposed by the patterns of action in the external world and its perceptual reception by the language-user. Thomâ€™s first important intervention in linguistic theory was to question the â€œpure and simple idolatryâ€ of the formalist notion of generativity, and to insist on the need for explaining the auto-limitation of the generative capacity itself.

It is here that a grammatical analysis must turn to some of the non-formalist (and rather realist and semanticist) perspectives on the case-structures. More specifically, the actantial perspective of Lucien TesniÃ¨re and the localist theory adopted by Hjelmslev, Anderson and Fillmore become relevant. TesniÃ¨re had, in his â€œstemmaticâ€ analysis of the sentential syntax, granted centrality to the verbal node and regarded the noun phrases as â€œactantsâ€ that are â€œdependentâ€ on that central node. Sentence-**meaning** was understood, not as the resultant of a combinatorics of word-meanings, but as something configurationally available in a gestalt-like manner. It was composed holistically with the verb conveying the action part of the sentence, and the â€œactantsâ€ playing the role of participants in the action. TesniÃ¨re was explicit about the theatrical imagery (in fact he refers to â€œa little dramaâ€) while speaking of sentence-structure and its **meaning**. It is of interest for us to note here that such a view of the sentence and its **meaning** was precisely what was proposed by the early Indian grammarians in whose verb-centered analysis the term *karaka* is an exact equivalent of the Tesnierian â€œactantâ€. And moreover, for Bhartrhari, comprehension of sentence-**meaning** is equated with a gestalt-like perception, or *citra-jÃ±aana* (pictorial knowledge).

Hjlemslev too, pursuing his project of a pure structuralism arrived at a perspective not too distant from the above one. In his celebrated book *La catÃ©gorie des cas,* after presenting a historical survey of various views on the case-category , he concludes that case cannot be a logical category, but only a structural one. He fully embraces the localist

hypothesis of the cases coming down to us from the Byzantine scholars referred to above via the 19th century Kantian linguist WÃ¼llner. In the final analysis, the case is for Helmslev, a category that signifies spatial relations between two objects. He defines these relations along three â€œdimensions,â€ namely, Direction (Distancing and Nearing), Subjectivity-Objectivity and Coherence (with or without contact).

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Thom has applied CT to define the genesis of the grammatical (case) structures from the actantial dynamics (derived from TesniÃ¨re) on a spatial substratum. The set of seven elementary catastrophes functions as the founding principle for the deduction of the grammatical cases. As a characteristic example, Thom gives the following schemata for the Accusative case (or, the â€œactantial graphâ€ for capture):

where S_1 and S_2 stand for the paths, in time, of the actants, and *I* the point of intersection where the sudden disappearance of S_2 takes place.

The above actantial graph is just one of a list of 18 â€œarchetypal morphologiesâ€ that Thom has proposed, which are derived from the set of elementary catastrophes. These archetypal morphologies show more finely the correspondence between the topological graphs and the case structures. Thomâ€™s topologico-dynamical analysis of syntax-semantics thus involves a synthesis of the actantial syntax, the case grammar and the idea of **morphogenesis** coming from CT. The main philosophical import of Thom's theory is that it retains an essential continuity between the physical and the phenomenological modes of existence, something that the logicist approaches do not wish to do or are

incapable of doing. In the present case, the appearance of phenomenological difference is preceded by a physical process of differentiation of an initially continuous state to yield discrete entities.

Thus CT allows to deduce the qualitatively differentiated case-structures from a topologico-dynamic physical substratum. It provides a principle of identifying and categorizing the finite set of core grammatical (case) structures which in the natural world appear as infinitely varied occurrences of physical or physically-based actions. The main merit of **Petitot**â€™s work in this regard lies not in proposing the original intuition of the connection between the CT and case theory, but in meticulously establishing the place and the relevance of CT as a viable dynamical approach (what **Petitot** will rename as a morphodynamical approach), in contrast to the various formalist approaches, within contemporary linguistic theory. **Petitot**â€™s subsequent researches have established contacts with the dynamical approaches in linguistics present explicitly or implicitly in the works of Per Aage Brandt, Leonard Talmy, Ronald Langacker, and George Lakoff. But then linguistics is still to wake up to the fact that â€œmathematical linguisticsâ€ based on a logico-algebraic formalization which was fashionable during the fifties and sixties has virtually

given in to the â€œmorphodynamicalâ€ approach of the nineties that employs a sophisticated mathematical topology that can better handle the inherently dynamical and structural character of the core grammar of natural language.

Petitotâ€™s more recent work has focused on dynamic modeling in visual perception. An excellent paper which presents **Petitot**â€™s perspectives on grammar and visual perception is â€œMorphodynamics and Attractor Syntax: Constituency in Visual Perception and Cognitive Grammarâ€ that has appeared in *Mind as Motion - Explorations in the Dynamics of Cognition* edited by Robert F. Port and Timothy van Gelder (MIT Press, 1995). It gives a comprehensive picture of **Petitot**â€™s morphodynamical approach which is now very much part of the dynamical tradition of doing connectionist cognitive science, on either side of the Atlantic. **Petitot** would like to see it as a sort of synthesis between on

the one hand the European theoretical traditions of gestalt theory and structuralism, and on the other the American traditions of Cognitive Linguistics and the dynamical mathematical modeling towards a connectionist AI.

With regard to the analysis of semio-narrative structures (which comes down from V. Propp to A.-J. Greimas via C. LÃ©vi-Strauss), Jean **Petitot's** attempt has been to theoretically develop the inherent topological potential of the semiotic square by applying CT. This he does by providing a schematization of Greimasâ€™s structures of elementary signification and a catastrophist interpretation of the latterâ€™s actantial model of narrative structure. Applying the theory on Greimas's model, **Petitot** suggests that the relations associated with the qualitative and privative oppositions of the semiotic square could be schematized by means of the catastrophe of Conflict of minimal complexity and that of Bifurcation of minimal complexity respectively. This shift, he thinks is in tune with the topological potential of the square, and involves the abandonment of a logico-combinatory method which is not suitable for a method which must explain the emergence of the structure from a physical substratum. The main merit claimed for the catastrophist model in narrative semiotics is that it can schematize the â€œundefinable conceptsâ€ of the previous formalist framework. The â€œ**morphogenesis**â€ of the square can be modeled as a â€œprocessionâ€ of elementary catastrophes. At a more complex level, the entire â€œcanonical formulaâ€ of narrative structures as proposed by LÃ©vi-Strauss can be understood in terms of the schemas for two *coupled* qualitative oppositions, represented by a â€œdouble cuspâ€ (which is an intricated singularity).

The "conversion" that gives rise to the Greimasian actantial model from the syntactic operations on the content values is seen in terms of the actantial graphs associated with the elementary catastrophes. For example, **Petitot** shows that the conversion S âˆª O â†’ S âˆ© O (i.e., a state of disjunction between the Subject and the Object-of-value becoming a state of conjunction between the Subject and the Object-of-value) can be described by means of the actantial graph of â€œcaptureâ€. As regards the intentional and/or metapsychological dimension which defines the Subject-Object

relationship of the interaction, **Petitot** reminds us that Thomâ€™s archetypal morphologies are indeed actantial schemas deeply rooted in the behavioral structures of living beings.

Let me conclude with a personal note. This translation has taken a long period of gestation. It began as something of a hobby during a stay at Maison de lâ€™Allemagne, CitÃ© Universitaire, Paris, while pursuing post-doctoral studies in Linguistics at the Sorbonne. Subsequently, it became a very serious endeavour, with constant encouragement from Jean **Petitot**. But eventually, we let it grow from being a mere translation into a revised â€" and even a â€œrevisitedâ€ â€" version.

I must acknowledge sources of material support this translation project has received at various points during the last ten years: Maison des Sciences de lâ€™Homme, Paris, Indian Council of Social Science Research, New Delhi, and CNRS, Paris. I would like to particularly thank Monsieur Maurice Aymard, Administrator of the Maison des Sciences de lâ€™Homme for the faith he posed in me. The most concerted collaborative effort went into the making of this version of the book during my stay in 1997 at Maison Suger situated in the throbbing heart of Paris. It finally looked like nearing completion during Jean **Petitot**â€™s visit to the Indian Institute of Advanced Study, Shimla. It has been a great pleasure working with him.

Shimla, July 1999

PREFACE TO THE ENGLISH EDITION

This English version of â€œMorphogenÃ¨se du Sensâ€ looks more like a â€œrevisitedâ€ edition than just a simple translation. Indeed, Franson Manjali not only did a remarkable job but, due to his deep competence in cognitive linguistics, as can be evidenced from his book *Nuclear Semantics* (Bahri, 1991), he made many important suggestions which enabled me to improve upon the original text. This new version is now metaphysically â€œlighterâ€ and more completely focused on its scientific substance. The â€œcontinentalâ€ philosophical digressions have been almost completely expunged.

Supposing this book can have any relevance, I think it is mainly as a precursor of the works on topological and dynamical models which have became so widely accepted in the cognitive sciences during the nineties. Thirty years ago, the very idea that physico-mathematical models of this type could be developed for explaining perceptual, linguistic, and semiotic structures was not clearly understood. It was taken for granted that the only available formalization in the cognitive science fields had to be, for principled reasons, of a logico-algebraic and combinatorial type. In this context RenÃ© Thomâ€™s seminal idea of an alternative morphodynamical paradigm triggered off a true scientific revolution. It settled the basis for a dynamical approach to higher level cognitive tasks such as categorization and syntax.

As far as I know, it was Christopher Zeeman who introduced the first dynamical approach for explaining the links between neuroscience and psychology. In his seminal 1965 article *Topology of the Brain*, he introduced the key idea that brain activity must be modeled by dynamical systems on high dimensional configuration spaces of neural activities. Mental states were then identified with *attractors* of these dynamics, their

content with the topological structure of the attractors, and the flow of consciousness with a â€œslowâ€ temporal evolution of the neural dynamics. Consequently, the strategy for explaining mental phenomena was to use the mathematical theory of dynamical systems (global analysis) â€“ especially theorems concerning the general structure of the attractors and their bifurcations â€“ for drawing empirical conclusions from this dynamical perspective.

This strategy was very clearly outlined by Zeeman in his 1976 article, â€œBrain modelling*â€*Ù :

> â€œWhat is needed for the brain is a medium-scale theory. (...) The small-scale theory is neurology : the static structure is described by the histology of neurons and synapses, etc., and the dynamic behaviour is concerned with the electrochemical activity of the nerve impulse, etc. Meanwhile the large-scale theory is psychology : the static structure is described by instinct and memory, and the dynamic behaviour is concerned with thinking, feeling, observing, experiencing, responding, remembering, deciding, acting, etc. It is difficult to bridge the gap

> between large and small without some medium-scale link. Of course the static structure of the medium-scale is fairly well understood, and is described by the anatomy of the main organs and main pathways in the brain. (...) But what is strikingly absent is any well developed theory of the dynamic behaviour of the medium-scale.
>
> Question : what type of mathematics therefore should we use to describe the medium-scale dynamic ? Answer : the most obvious feature of the brain is its oscillatory nature, and so the most obvious tool to use is differential dynamical systems. In other words for each organ *O* in the brain we model the states of *O* by some very high dimensional manifold *M* and model the activity of *O* by a dynamic on *M* (that is a vector field or flow on *M*). Moreover since the brain contains several hierarchies of strongly connected organs, we should expect to have to use several hierarchies of strongly coupled dynamics. Such a model must necessarily remain implicit because it is much too large to measure, compute, or even describe quantitatively. Nevertheless such models are amenable in one important aspect, namely their discontinuities.â€Ù (Zeeman, 1977: 287)

It is precisely using these results of global analysis, bifurcation theory and singularity theory, that RenÃ© Thom worked out his research program leading from physics to cognitive sciences, including linguistics. His main idea was to use these tools for developing a unified mathematical theory of natural morphologies and cognitive structures.

He showed, first of all, that, insofar as it concerns the system of relations which links up parts within a whole, every structure is reducible to a (self)-organized and (self)-regulated morphology. But, as we will see in a detailed manner in this book, every morphology is itself reducible to a system of qualitative discontinuities emerging from the underlying substrate (be it physical, neural, purely geometrical, or even â€œsemanticâ€ù). The theoretical problem was therefore to build up dynamical mechanisms which were able to generate, in a structurally stable way, these discontinuities both at the *local* and the *global* levels.

Deep mathematical theorems have made possible a revolutionary strategy which can be called *dynamical functionalism*. Instead of first defining the generating dynamics *explicitly* and then deriving from it the observable discontinuities, one first describes the observable discontinuities geometrically and then derives from them a *minimally complex* generating dynamics. This minimal explicit dynamics must be conceived of as a simplification of the real implicit generating dynamics. This dynamical functionalism is not of a classical (e.g. Fodorian) type. Indeed, classical functionalism entails a strict separation between the cognitive and physical levels, the relation between the two being a matter of mere compilation and implementation. This is no longer the case in an emergentist (supervenient) approach. But dynamical functionalism is nevertheless a â€œtrueâ€ù functionalism in the sense that emergent structures share properties of universality which

are to a large extent independent of the specific physical properties of their underlying substrata.

Such an explanatory paradigm has been extensively developed during the

seventies and the early eighties. In physics, and particularly in macrophysics, morphodynamics has innumerable applications. They concern the mathematical analysis of the singularities and discontinuities which emerge at the macro level from underlying micro-physical mechanisms. Here is a very incomplete list : caustics in optics; phase transitions, symmetry breaking and critical phenomena; elastic buckling; defaults in ordered media; shock waves; singularities of variational problems; dissipative structures; changes of regimes in hydrodynamics, routes towards turbulence; deterministic chaos; etc. The main import of these mathematical models is to explain how the observable morphologies which dominate the phenomenologically experienced world can emerge from the underlying physics. They bridge the gap between physical objectivity and common-sense realism, a gap which arose in the aftermath of the Galilean revolution. In that sense, morphodynamics can be considered as the pure mathematical way leading to *qualitative physics*. More than ten years before the computational (Artificial Intelligence) approach was introduced, it showed that the informationally relevant and salient features of macro-physical processes are constituted by their singularities, their qualitative discontinuities and their critical behavior.

But one of the most significant achievements of Thomâ€™s paradigm concerned its application to cognitive processes such as perception, action and language. It gave an extraordinary new impulse to traditions such as Gestalt theory, phenomenology and structuralism. It was for the first time that, in cognitive and linguistic matters, *differential geometry could substitute formal logic* as the main mathematical tool.

But Thom and Zeeman proceeded as mathematicians, not in a â€œbottom-upâ€ù manner, from empirical data first to ad hoc models and, at the end of the line, to theoretical principles, but rather in a â€œtop-downâ€ù manner, from fundamental principles and mathematical structures to empirical data. The advantage of such a strategy was that their perspective was theoretically very well grounded and mathematically very strong. Their dynamical functionalism introduced a new level of functional architecture which could operate as a condition of possibility for the implementation of syntactic processes into the brain dynamics. The limits of such an approach were of course the lack of an effective computational theory to undergird it.

Since the early nineties things have radically changed essentially because dynamical models such as connectionist ones became computationally effective. One can now say along with Tim van Gelder, that the dynamical paradigm has become dominant relative to the logico-combinatorial one. I think that one of the main challenges of future research will be to synthesize the two paradigms.

So, basically this book can be read as a pioneering attempt to introduce morphodynamical models in structural linguistics and semiotics.

I would like to once again acknowledge my debt to Franson Manjali. The long discussions with him on this translation have proved to be a theoretically beneficial opportunity.

I want also thank my colleagues and friends Per Aage Brandt and Wolfgang Wildgen for having accepted this text in their Peter Lang series.

Indian Institute of Advanced Study
Shimla, April 1999

INTRODUCTION

1. This work is devoted to a study of the applications of Catastrophe theoretical modeling and of the epistemological issues deriving from it. We will be mainly concerned with the fields of structural linguistics and semio-narrative structures. The investigation proceeds at two levels. At the level of modeling we show that the topological and dynamical syntax conceived of by RenÃ© Thom allows us to tackle and even partially solve some of the main difficulties encountered in structuralism. [1] At the epistemological level, we examine the relevance of *geometric* notions in the language sciences, and conclude that they provide a *schematization* â€" in the sense of a *geometrization* of the **meaning** of theoretical concepts â€" of the theoretical categories of structuralism. We aim therefore at a *constitution* of the structural domain. Even though this constitution is not strictly of a physical order, to the extent it uses mathematics to reconstruct empirical phenomena, it is of a physical type.

2. From a detailed study of the various structural conceptions, we see that, whatever

the domain considered, we come up with a primitive concept of structure whose *formal* content has not yet been adequately mathematized.

(i) In the domain of biological organization, we have to understand how the function of parts in relation to a whole depends on their interdependent *positions*. If a structure can exist, it is because parts are determined reciprocally through a *dynamic process* which defines their *positional values*. This is what Geoffroy Saint Hilaire already called the principle of *connection*.

(ii) In the domain of perceptual organization, a similar problem is posed by the existence of *Gestalt structures*.

(iii) In phonology, the phonemes are conceived of as abstract discriminating units (*types*) which are equivalence classes of allophones (*tokens*). Now, these classes are also defined by an underlying principle of connection. They are obtained from the *categorization* of audio-acoustic substrata, and are positional values within phonetic paradigms.

(iv) In syntax, the primitive structures are constituted of reciprocally determined actantial places. [2] They also provide, though in a somewhat different way, positional values arising from connections. These connections are *semantic*, and not formal

[1] By â€œstructuralismâ€ù we mean here the tradition founded by de Saussure and further developped by Troubetzkoi, Jakobson, TesniÃ¨re, Hjelmslev, BrÃ¸ndal, LÃ©vi-Strauss and Greimas.

[2] We use here the terms â€œactantâ€ù, â€œactantialâ€ù, â€œactantialityâ€ù in the sense of TesniÃ¨re (1959) and Greimas (1966). These key words of European linguistics concern the semantic roles of case grammars.

relations. They belong to the form of content (in the sense of Hjelmslev). They are independent of lexical features and constrain the grammatical function of the terms they connect. They belong to a conceptual syntax, and not a formal one. Their content is purely positional.

(v) Finally, in the semiotics of narrative, Greimasian theory employs the phonological and the actantial models to explain semantic and syntactic organizations respectively. It

thus combines two structuralist conceptions, and considers semantics in a paradigmatic way (like phonology). The main problem is therefore to understand the linkages between them. The key idea is that of a â€œconversionâ€ of the semantic paradigms into actantial (syntactic) interactions, what is called in structuralist traditions the â€œprojectionâ€ of the paradigmatic axis onto the syntagmatic one.

In all these domains, structuralist theory depends crucially and ultimately on the *formal content* that must be ascribed to the category of connection, and thus on the mathematization of the concept of positional value. Only such a schematization can rightfully establish a â€œphysicsâ€ of structures. But it depends, in turn, on the invention of a *geometry of position* that can describe and explain the organization, the stability and the closure of elementary structures as well as the constraints imposed on their combinatorics. It depends on the construction of a new kind of general dynamics, of an original â€œ*analysis situs*â€, which still remains a tremendous challenge.

Indeed, as Buffon and Kant had observed, such an *analysis situs* â€œis totally lacking in our mathematical sciencesâ€. This â€œtotal lackâ€ has, until now, played the role of a sort of blind spot in our vision of rationality; it has been an â€œepistemological obstacleâ€ (in the sense of Bachelard) to the constitution of structural objectivity. It has made structuralist theories to keep swaying between psychological reductionism, idealist vitalism and logical formalism, three positions which are not acceptable except dogmatically. [1]

In linguistics, the formalist approach remains dominant. Based on the fallacious evidence, borrowed from logical positivism, that mathematics is a language which provides the most typical example of syntax / semantics relation, it reduces structures to mere formal combinations. Thus, it is forced to discard the concrete dynamical â€œorganicityâ€ of structures in favour of a system of abstract relations between terms. As the founders of the *Gestalttheorie* had remarked, this involves a reification of connections, which, by attributing to static terms all that in fact belongs to positional values, ignore the dynamical nature of structures. As far as structures are concerned, formalization is opposed to mathematization. Thus, there exists a conflict between the formal treatment of structures and their â€œmathematical physicsâ€. The former is associated with a formal logic

[1] See, sections I.2 and I.3.

of terms and relations while the latter refers to a dynamic topology of places and connections.

3. Catastrophe Theory offers the first instance of analysis situs of structures. It removes, at least in principle, the epistemological obstacle which has until now prevented the constitution of the structural objectivity. We intend to show that this theoretical possibility is also a pratical one.

4. We will reserve another work for a detailed elaboration of the catastrophist formalization of semio-narrative structures. [1] In the present work, we shall focus on some important theoretical questions regarding the above indicated issues.

In the first chapter we will present a problematized panorama of various critical issues of structuralism. We have tried to give the study as much theoretical opening as possible. We shall refer to structural biology, Gestalt theory, phenomenology and transcendental philosophy. This is necessary in order to trace the â€œmemoryâ€ù of the structuralist idea and to retrieve all its sharpness and amplitude. In Chapter II, we shall discuss in more detail the two basic structuralist conceptions, namely Jakobsonian phonology and structural syntax. This will allow us in Chapter III to revisit the foundations of Greimasâ€™s theory of semio-narrative structures.

5. The main part of this â€œphysicsâ€ù of **meaning** had been developed between 1972 and 1976. [2] If we have postponed its exposition till now, # it is because we stumbled upon philosophical difficulties concerning the epistemological status of the modeling of structures as *natural* phenomena. As we know, structures have been traditionnally understood in symbolic terms, that is as constituted of formal relations. A significant leap had to be taken to reach the naturalist conception. The main point is the following. In physical sciences, concepts are not only descriptive, but can also be transformed into algorithms for reconstructing the diversity of phenomena. If we take the structures of **meaning** as natural phenomena in a physicalist sense, we need to transform the structuralist concepts which describe them into algorithms for reconstructing their diversity.

[1] See **Petitot** 1992.

[2] See **Petitot** 1977b, 1977c, 1979c, 1979d.

[#] That is 1983.

This is how we were convinced that a â€œphysics of **meaning**â€ù has to be founded on a mathematical schematization of categories of structuralism. In order to stress this idea we have called our project a â€œschematism of structureâ€ù.

6. Assuming that our work has some interest and some originality, we hope we will be able to convince the reader that far from becoming obsolete, structuralism is on the contrary in the process of becoming a new frontier of science. We now have the possibility of extending the physical rationalism into a structural rationalism, mathematically founded, encompassing symbolic and semiotic orders. We now have the possibility, by extending natural ontology, of naturalizing **meaning** without any longer having to sway between its symbolic reification and its existential experience.

Torre Pellice, August 1983

[1] Our notion of schematism is not exactly that of Kantâ€™s transcendental schema. It concerns schematism as a â€œconstructionâ€ procedure for concepts.

CHAPTER I

PROBLEMATIC ASPECTS AND KEY ISSUES OF STRUCTURALISM

In this first chapter we shall describe methodically, though not exhaustively, some of the most significant aspects of dynamical structuralism (Section 1 and 2). This will lead

us to an inquiry into the conditions of possibility of mathematizing structures (Sec.3.1). As Gilles Deleuze has shown in a essay that we will discuss (Sec.3.3), the foundations of structuralism are *topological* â€" and not logical (Sec.3.2). Until now, the absence of such foundations have been obfuscated by speculative interpretations because of the lack of any adequate geometry (Sec. 4). In conclusion, we shall briefly summarize the principles of Catastrophe Theory (Sec. 5).

1. UNDERSTANDING â€œSTRUCTURE â€ù

Depending on the domain considered, the concept of structure can have quite different contents and epistemological values. In the case of a mechanical device, a construction, or a work of art, we can generally describe the structure in terms of its design. In the case of physico-chemical systems (e.g. crystals, macromolecules, etc.) we can also derive the structure from the interactions between its components. For example, the progress made in molecular biology and in microbiology has resulted in a decisive advance in the comprehension of the structure (stereo-chemical composition) of DNA chains, proteins, enzymes, membranes, etc. There are of course considerable experimental difficulties. Their solution requires highly sophisticated technologies of observation and reconstruction. But, in principle, even if one does not fully confuse the structure with the observed morphology, even if one considers the former as the organizing principle underlying the latter, the *ontological* status of the reconstructed structures is not at all problematical.

On the contrary, in other domains, such as naturalist biology (taxonomic, anatomical, morphogenetic), perception, anthropology or semio-linguistics, one encounters *non-material supervenient* structures, *abstract* forms of organization which are not directly reducible to systems of components in interaction. This simple fact raises considerable theoretical problems to the extent that we cannot any longer, without further inquiry, regard the structures as empirically given phenomena and objects of experience endowed with a predefined ontological status. The very *objectivity* of structures must

then be *constituted* as such and that is why, in all these cases, a deeper reflection leads us:

(i) to promote the organizational concept of structure to the level of a fundamental category of scientific thinking,

(ii) to investigate its objective value, and

(iii) to seek ways to mathematize its categorial content.

In naturalist and descriptive biological sciences, as in social sciences, structuralism represents a *rationalist* attitude, emphasizing the role of theory and formalization. Its point of view is opposed to empiricist reductionism as well as historicist evolutionism. The shifts from atomistic psychology to *Gestalttheorie*, from comparative and historical linguistics of the â€œneo-grammariansâ€ to Saussurian structural linguistics in Europe, or from â€œbehavioristâ€ linguistics to generative or cognitive grammars in the United States, from biographical and socio-psychological literary criticism to structuralist criticism, etc., are trends in the direction of a general philosophy of systems conceived as rule-governed wholes. In this sense, the horizon of structuralism is that of a theoretical description of *formal dependence relations* which â€œorganicallyâ€ connect the parts in a whole.

In so far as it is the ideal *form* of the organization of a substance, a structure is *not* a sensible phenomenon. Though it is invisible as such, its substantial realizations and its effects are observable and can be subjected to well-defined experimental procedures. In this sense, every structure is a theoretical object â€” and not a fact. If we want to avoid naive idealism, we have to constitute it as an object of experience, as a form emerging from the organization of the substrata where it is implemented. Thus, we encounter here a â€œfoundational aporiaâ€, to use RenÃ© Thom's expression. As Gilles Deleuze claims, a structure is â€œreal without being actual, ideal without being abstractâ€; it is a pure â€œvirtuality of coexistence which pre-exists beingâ€; it is â€œembodiedâ€ (implemented) in its substratum, but is never actualized as such. [1] The sensible expression of a structure is always a negation of its ideal essence. That is why, as Krzysztof Pomian observes, all structural approaches substitute the initial observed objects such as language, natural forms, etc. with pairs of objects whose ontological statuses are different:

> â€œparole and langue (Saussure), allophones and phonemes (Jakobson, Trubetzkoi), substance and form (Hjelmslev), systems of kinship and elementary structures of kinship (LÃ©vi-Strauss), performance and competence (Chomsky), empirical morphologies and their underlying dynamics (Thom), etc. Each of the first terms of these pairs (which one might call â€œrealizationsâ€) are accessible to sensory experience, or to

> observation, and their reality consists in this. Each of the second terms, the structures (â€¦) cannot by definition be perceived or observed; we grant them a reality on the basis of a demonstration, more or less rigorous depending upon the case. The relations between realization and structures are variable, but it is always the latter which render the

[1] Deleuze, 1973: 313. We will discuss Deleuze's views in section 3.3.

> former stable and intelligible. As a result, structures are defined as the sets of rational and interdependent relations, whose reality is demonstrated, whose description is provided by a theory, and which are realized by a visible or observable object whose stability and intelligibility are conditioned by them.â€ù[1]

Given such a status â€" ideal and non phenomenal in the classical sense â€", structures are thus ontologically ambiguous. As Umberto Eco asked:

> â€œIs the structure an object, in such as it is structured, or rather the set of relations which structures the object, and can be abstracted from it ?â€ù [2]

In fact, as *eidos*, a structure is not detachable from the substance where it is actualized. [3] But must we consider it as *given* or as *posited*? In the first case, one will tend to develop an *ontological* (realist) conception of structures while in the second, an *epistemological* (nominalist) conception.

Currently, the epistemological interpretation of the category of structure is dominant. It reduces structure to an operational concept whose reality is not ontological but only methodological. However, it should be stressed that all the major structuralists (Saussure, Jakobson, TesniÃ¨re, Hjelmslev, Piaget, LÃ©vi-Strauss, Chomsky, Greimas, and lastly, Thom) have been or are â€œrealistsâ€ù, even if they donâ€™t engage in a philosophical quarrel.

In fact, from an epistemological, methodological and â€œnominalistâ€ù perspective, the concept of structure can only be a *descriptive* concept, indeed empirically based, but epiphenomenal and devoid of any objective value of its own. Though operational, it is

nothing more than a theoretical construct, an artefact, and cannot by itself be a genuine scientific notion. In particular, it cannot contribute to the mathematization of phenomena. On the other hand, from a â€œrealistâ€ù perspective, it is a concept, though initially problematic, acquiring beyond its empirical validity, an objective value and a constitutive role. Via the schematization of its categorial content, it becomes a source of algorithms for reconstructing specific classes of phenomena.

If we wish to subject structuralism to a systematic historical â€œspectral analysisâ€ù, we must analyze at least the following trends.

(i) The dynamical structuralism of biological origin, which, starting in German philosophy with the *Naturphilosophie* and Goethe's *Morphologie*, has progressed, via Driesch and Dâ€™Arcy Thompson, up to Waddington's concepts of â€œmorphogenetic fieldâ€ù and â€œchreodeâ€ù. This dynamical structuralism is centered on the problem of **morphogenesis**.

[1] Pomian, 1981: 758.

[2] Eco, 1968.

[3] Cf. ibid.

(ii) The phenomenological and gestaltist structuralism which began early this century on the basis of Brentanoâ€™s works with Stumpf, Meinong, Ehrenfels, Husserl, KÃ¶hler, Koffka, Wertheimer, etc.

(iii) The linguistic structuralism resulting from Saussure's â€œepistemological breakthroughâ€ù. As we already stressed, it has become one of the basic paradigms in social sciences, be it in Phonology with Jakobson, in Anthropology with LÃ©vi-Strauss, in General Linguistics with TesniÃ¨re and Benveniste, or in Semiotics with Hjelmslev and Greimas. This structuralism is twofold:

(a) the â€œrealistâ€ù phenomenological structuralism of Jakobson which maintains close relations with dynamical structuralism and gestalt theory;

(b) the formalist structuralism (â€œmethodologicalâ€ù and â€œepistemologicalâ€ù) of Hjelmslev,

LÃ©vi-Strauss[1], Chomsky and Greimas who conceive of structures as â€œaxiomatizedâ€ù theoretical objects and solve the question of their ontological status by embedding them in genetically determined cognitive capacities.

(iv) The epigenetic and cognitive structuralism of Piaget.

(v) The â€œcatastrophistâ€ù structuralism of RenÃ© Thom, which is a profound synthesis of the concepts of **morphogenesis** and structure. It is the first approach to have succeeded in mathematizing structures as theoretical objects.

To get a more complete picture, we must also explain certain general problematics related to the project of structural rationalism. Of these, at least five appear to be essential.

(i) Experimental methods which provide an access to the structures. We have seen that structures are non material and ideal, and cannot be directly observed. A first method of access (advocated by LÃ©vi-Strauss) consists in analyzing the *transformations* of structures by variational procedures. Indeed, if a structure identifies itself with a global, internal, and rule-governed system of relations, then every local variation must imply a global transformation manifesting the structure. A second method (that of Chomsky's native speaker conceived of as a language automaton) involves the use of the traditional practice of introspection as part of the experimental procedure.

(ii) The relation between structure and function. Ever since the historic debate confronting Geoffroy Saint Hilaire's principle of connection with Cuvier's principle of functional correlation, there has been in biology a dialectical relationship between a physicalist attitude (mechanistic and materialist) endorsing a â€œmicromeristâ€ù reductionist conception, supporting active experimentation, rooted in physiology and, to day, of essentially neo-Darwinian inspiration, and a naturalist attitude, endorsing a holistic vitalist conception, supporting common sense observation, based on **morphogenesis**, and of a somewhat Lamarckian inspiration. But this debate is often a bit skewed, for the phenomena of adaptation (and in particular those of adaptive convergence and co-

[1] LÃ©vi-Straussâ€™ conception is more complex. It involves also Jakobsonian and biological structuralisms.

evolution) show that these two positions are rather complementary, and that it is impossible to privilege one against the other. [1] The real problem is rather to explain the complementarity itself.

(iii) The relation between structure and teleology (finality). One of the main reasons for disfavoring the concept of structure since long, has been essentially the fact that, as regards the systematic organization of parts in a whole, it is a teleological idea. To transform it into an operative scientific concept, we must â€œde-finaliseâ€ it. This is possible only by way of its mathematization.

(iv) The formalization of structures. It has become commonplace to say that the concerted development of general theory of systems, cybernetics, and formal ontology of relationships has enabled the â€œaxiomatizationâ€ of the concept of structure. But it must be emphasized that the mechanistic-formalistic approaches are largely insufficient. As we have seen, they are obtained only by a symbolic reification of structures. They cannot account for the dynamically self-organized and self-regulated emergent (supervenient) forms. In other words, they do not provide an answer to the critical question of the form-substance relationship.

(v) The levels of organization. Structure-function complementarity comes up at all levels of composition and observation. The central question is to define the objective reality of these levels and to understand their correlations.

In this first chapter, we will provide a preliminary sketch of these diverse issues. We will not speak of the â€œclassicalâ€ structuralism which forms part of the comtemporary scientific culture (Saussureâ€™s structuralism, Parsonsâ€™s structural-functionalism, Harrisâ€™s and Chomskyâ€™s structural linguistics, the structural analysis of economic equilibria etc.). [2] We prefer rather to focus on:

(i) the still largely unsolved theoretical problems concerning structuralism;

(ii) its morphological , phenomenological, and gestaltist â€œaccursedâ€ part;

(iii) the â€œrevolutionâ€ represented by the catastrophist turn.

[1] See, Delattre *et al.*, 1973.

[2] For an introduction to structuralism, see for instance the following works : Almansi, 1970; Bach, 1965; Badock, 1975; Barthes, 1966; Bastide, 1962; Benoist, 1975; Benveniste, 1966; R. Boudon, 1968, 1973; P. Boudon, 1981; Broekman, 1974, Cassirer, 1945; Chomsky, 1965; 1966, 1968; Damisch, 1973; Delattre, 1971; Eco, 1963; Ehrmann, 1966; Gandillac et al., 1965; Glucksmann, 1974; Greimas, 1966; Guillaume, 1979; Harris, 1951, 1970; Hawkes, 1977; HÃ©nault, 1979, 1983; Hjelmslev, 1968, 1971;

Jacob and Francone, 1970; Jakobson, 1971; Jakobson and LÃ©vi-Strauss, 1962; Katz and Fodor, 1964; Laughlin, 1974; Leach, 1976; LÃ©vi-Strauss, 1949, 1958, 1964-1971; Macksey-Donato, 1970; Maranda, 1966; Marin, 1977; Piaget, 1968; QS, 1973; Raccani and Eco, 1969; Robey, 1973; Saussure, 1915; Sebeok and Osgood, 1965; Segre et al, 1965, Viet, 1965.

2. MAIN TRENDS IN STRUCTURALISM : A BRIEF REVIEW

In this section we present a brief historical account on some major perspectives on the phenomena of (self-)organization. We are dealing with fields (biology, psychology, phenomenology, anthropology, and semio-linguistics) where the concept of structure is not only a descriptive tool but also a means of going beyond the conflict between the objectivist-reductionist explanations and the idealist-holistic ones (see section 1).

2.1. The aporia of organization in Kantâ€™s *Critique of the Faculty of Teleological Judgement*

I think we can locate the origin of the modern structural problematic in Kantâ€™s treatement of biological organization in terms of *finality* (Kant called it â€œthe internal finality of natural endsâ€ù) in his *Critique of the Faculty of Judgement*; more precisely in his demonstration that the theoretical comprehension of organization necessarily required two complementary principles (two â€œmaximsâ€ù of judgement), one reductionist, and the other holistic. Let us briefly trace his arguments. [1]

(i) Given the *a priori* structure of possible experience, we cannot admit of any objective finality in nature. Objectively speaking, nature is necessarily mechanical. In other words, reductionism is the only objectively valid thesis.

(ii) It is however an empirical fact that there exist in nature â€œnatural endsâ€ù, i.e. things which are â€œcause and effect of themselvesâ€ù, [2] in short, organized living beings. The

fundamental features of the natural biological ends are, according to Kant, **morphogenesis**, regulation (homeostasis), reproduction, and the adaptive relationship with the environment (external finality).

(iii) Now though Kant might have accepted that the progress of physics would, one day, explain mechanistically some of these features, he made the decisive remark that such an explication would still, for reasons *a priori*, be incomplete to the extent that it would not account for the *contingency* of the form of organized beings. For Kant, the contingency of form is part of the â€œspecific characterâ€ù of natural ends. Because it eschews the laws of geometry and physics, it can be understood only *reflectively* via the Idea (and not the category) of finality.

[1] See, **Petitot**, 1982d, for a more detailed account.

[2] Kant, 1790: 190.

(iv) The internal finality is not just organization, but *self*-organization. In a natural end, there exists a reciprocal determination between the parts and the whole. The structure is not that of a mechanism, but the effect of the idea of the whole determining the systematic unity of the form and the connection between parts. The organization depends therefore on a â€œformative forceâ€ù (*bildende Kraft*), which not being explicable mechanically, is not objective. That is why it is an â€œunfathomable qualityâ€ù, an â€œincommensurable abyssâ€ù where reductionism, though the only objectively valid maxim, should nevertheless be treated along with the holistic concept of finality.

(v) The reductionist and holistic maxims of judgment seem to be contradictory. They open out therefore to a natural â€œdialecticâ€ù. But, for Kant, the conflict is not a true antinomy for it concerns only maxims, i.e. prescriptions that a subject must follow for gaining knowledge. Maxims are only heuristics for the comprehension of phenomena. There would be an antinomy only if, moving dogmatically from reflective to determinant

judgement, we would use the idea of finality as a constitutive concept, as an objective category. But, even if it is only heuristic, the rational concept of finality is

> â€œas necessary for the *human faculty of judgement* as if it were an objective principleâ€ť.

(vi) For Kant, the possibility that a regulative Idea can have the same value as a categorial concept comes essentially from the finite (â€œdiscursiveâ€ť, â€œnon-intuitiveâ€ť) nature of our understanding.

Since Kant, things seem to have notably changed. But this is quite illusory. The epistemological obstacle masterly identified in the *Critique of the Faculty of Teleological Judgement* â€" namely, the principled impossibility of a physical explanation of the phenomena of **morphogenesis**, (self-)organization, and regulation â€" is still far from eliminated. Indeed, the advances in reductionist biology (molecular biology and neo-Darwinism) on the one hand, and in the techniques of cybernetic simulation on the other hand, have given us a lead. But we are still far from understanding how stable and self-regulated structures can emerge from a physico-chemical substratum. The difficulty is not so much experimental as theoretical. What we lack are concepts, not facts. It is only recently that in the physical (non-biological) cases we have been able to explain, using the theory of bifurcations of dynamical systems, how material media can spontaneously self-organize, either purely temporally (oscillating chemical reactions) or, spatio-temporally (spatial patterns of Belousov-Zhabotinsky

[1] Kant, 1790: 218 (our translation).

reaction, BÃ©nard's cells, etc.). [1] In this sense, biology still remains, as Jean Piaget had affirmed, â€œthe key to structuralismâ€ť.

2.2. Structuralism in Biology

In biology, the structuralist paradigm is a dynamical perspective that appeared whenever the idea of **morphogenesis** came up. Here, the concept of structure is inseparable from that of form. Therefore it has always been, until recently, tied up with the speculative concept of *entelechy* which goes back to Aristotle. This explains why it was rejected by the anti-Aristotelian reductionists.

The issue began with the *principle of spatial connection* between parts in a whole, introduced by Geoffroy Saint Hilaire, and later taken up by Goethe. In his long and patient meditations on plant **morphogenesis**, streching from 1770 until his death in 1832, Goethe sought not so much to understand the physico-chemical mechanisms underlying the formation of organisms, as to discover the principle by which an organism is what *it appears* to be. [3] He quickly came to the conclusion that what distinguishes an organism from a machine is the fact that in the case of an organism, the *external* appearance is governed by an *internal* principle producing the *spatial* (external) connections between parts. For Goethe, it was the understanding of this principle which constituted the central theoretical problem in Biology. However, though referring to an empirical phenomenon, the concept of connection is, as we see with Kant, only a â€œnoumenalâ€ù Idea, and not a â€œdeterminantâ€ù concept or category. Transgressing the argument of Kantâ€™s third *Critique*, Goethe put forward the hypothesis that there existed a *schema* for this Idea, which could share infinite concrete variations. To understand the response of organisms to stimuli as much internal as external, he seeks to determine their constitutive ideal principle, in other words, their *formative laws*.

Goethe gradually recognized this ideal principle *in the spatio-temporal unfolding of an internal organizing force*. According to him, it is this *â€œa prioriâ€ù entelechic* principle that rules the formation of natural ends. But one of the central results of the Kantian Critique is precisely that a noumenal Idea is, in essence, disconnected from space and time. Against Kant, Goethe thought of entelechy as a kind of â€œintuitive conceptâ€ù. Contrary to physics, where concepts are abstractions relative to the sensible world, for him the concept of structure was a real, concrete and perceptual entity. That is why

[1] See, for instance, Prigogine, 1980.

[2] Piaget, 1968.

[3] For this account of Goethe's conception, see Steiner, 1884. I thank Filomena Molder who introduced

me to this remarkable work.

entelechy can be an the intuitive concept and an efficient idea, which by unfolding itself spatio-temporally brings about **morphogenesis**.

Goethe's answer to the aporia of form in biology was of a speculative nature. It is one of the sources of vitalism. But nevertheless its epistemological value continues to be retained in contemporary trends of dynamical structuralism. As an example we can refer to the defense of structuralism in biology proposed by B. Goodwin and A. Webster, in line with the ideas of the great embryologist Waddington. [1]

Goodwin and Webster present a historical and epistemological analysis of the classical conflict between the structuralist and the neo-Darwinian points of view, the latter being the synthesis of the Darwinian evolutionary theory and molecular genetics. For them, structuralism is opposed to neo-Darwinian empiricism, not at the level of facts, but as a rationalist point of view in which a priori concepts, categories, and principles govern the explanation of empirical data. The central problems they address are those of form and **morphogenesis**. They investigate the *type* of categoriality necessary to make these concepts intelligible. Now, the main point is that, by its very evidence, the neo-Darwinian paradigm obscures the intelligibility of morphological phenomena. It reduces them to a by-product of evolutionary chance, denying thus any â€œlawsâ€ù of form.

This is essentially due to the fact that this paradigm confuses the concept of *control* with the category of *cause*. The genome controls the form and the development of an organism at the phenotype level. By acting on the genome one can therefore also manipulate its morphological effects. But this causal efficiency does not entail that there are no specific and autonomous constraints for forms. By identifying the genetic control of the phenotype with a determinant cause, the neo-Darwinian approach assumes that there is nothing to be explained other than the phenomenon of control itself: as Jacques Monod claimed, form is causally reducible to the primary structure of proteins, and all the rest is only a matter of thermodynamical processes of self-organization.

Neo-Darwinism is a materialist reductionism which privileges functional aspects,

reduces structural connections and positional organization of parts to a mere spatial contiguity, and subordinates the â€œinternal finalityâ€ to an â€œexternal finalityâ€, i.e., to adaptation and selection. It reduces structure to genetics. For it, structure is historically given , and has only an evolutionary necessity as the epigenetic expression of its genetic programme.

Structural rationalism denounces the inconsistency of making history not only the cause of evolution, but also that of *stability* and *invariance* of species. [2] According to its view, an organism is not only a genetically controlled system, but also a structure, that is

[1] See Webster, Goodwin, 1981; Waddington, 1956, 1957. For the opposite, neo-Darwinian point of view, see, for instance Danchin, 1977.

[2] On this question, see also Gould, 1977, Gould, Eldrege, 1977.

a totality organized by a system of internal relations satisfying some *â€œlawsâ€ of form*. The realm of organized beings manifests a certain necessity. The structures are neither irreducibly diverse, nor the arbitrary result of evolution.

The fundamental tenet of structural rationalism is that the expression of the genotype into the phenotype cannot be completely understood unless we introduce some sort of *positional information* controlling cellular differentiation. In organized beings there would be a *positional efficiency*, the position selecting metabolic regimes by triggering the right genes. It is the understanding of such positional information and efficiency which constitutes the central theoretical problem of dynamical structuralism.

In the Waddingtonian theory of morphogenetic fields and â€œchreodesâ€, the main characteristics of structural organizations are the following: [1]

1. dynamical genesis, self-regulation and structural stability;
2. equipotentiality: structures are not mere systems of interaction of components, but include a reciprocal determination of *places* (positional values);
3. equifinality and homeorhesis (epigenotype according to Waddington): development is itself structurally stable as a process, and its final state is largelly

independent of its initial state;

4. the closure of the elementary structures and the existence of constraints, or â€œlawsâ€ of form;

5. â€œgenerativityâ€ of forms and the production of complex structures from a closed set of elementary ones.

All these concepts are categories governing morphological phenomena. Their categoriality (which as we shall see later is more â€œlinguisticâ€ than physical) determines the type of theory we need to render intelligible the morphological and dynamical concept of structure. We see that the main problem is to give them an *objective value*.

2.3. Gestalt theory and phenomenology

In psychology, structuralism begins with *Gestalttheorie* where we encounter the same issues, the same problems, the same criticisms of reductionism and the same categoriality that we have already sketched. In his classic introduction (recently republished), Paul Guillaume [2] insists that Gestalt theory is a rationalist monism which introduces the category of structure simultaneously in the physical, the biological and the psychological realms. In psychology, it begins with a criticism of the atomistic view of sensations and of associationism, and maintains close relations with Husserlian

[1] For more details, see for instance, RuffiÃ©, 1982: Chapter XI.

[2] Guillaume, 1979.

phenomenology. The concept of pure sensation is just an experimental artifact, a hypothetical explanatory concept, because a sensation cannot exist without perceptual organization. Indeed peripheral excitations (retinal, for example) are produced by the external stimuli. But they are only local inputs for corresponding global percepts. They are not their determinant cause. The fundamental hypothesis of Gestalt theory is that it is

impossible to reduce perceptions to systems of atomic sensations, since such systems are the product of a construction which involves a *real* transformation of the state of consciousness. Neither the terms nor the relations have an atomic sensorial reality and that is why it is necessary to conceive of perceptions as â€œcomplexionsâ€ (to use Meinong's term), as Gestalten, i.e., as structures, as

> â€œorganic units which are individualized and delimited in the spatial and temporal field of perception or of representationâ€. [1]

These structures, morphologically organized and internally articulated, result from an original formative activity. Their difference with systems of components in interaction again lies in the existence of connections determining positional values. They are *non-compositional* totalities, whose moments do not possess the status of independent parts detachable from the whole.

Instead of attempting a purely phenomenological description of structures like Husserl, or a symbolic-combinatorial description like the formalists, the gestaltists theorized them dynamically as natural biophysical phenomena. To this end, they put forward the hypothesis (masterly confirmed later; see Sec. 3) that

> â€œthe principles of dynamics exceed, in their generality, their strictly physical applications.â€ [2]

As Guillaume emphasized, Gestalt theory views the organized entities, whether physical, biological, or psychological,

> â€œas satisfying very general laws of dynamics pertaining to organized wholes, laws which are neither specifically physical nor psychological, but common to both physics and psychology.â€ [3]

In this regard, KÃ¶hler spoke of *Eigenstruktur* governed by a principle of *functional proximity*.

Thus, even before the structuralist trends of the 50's and 60's, as much at the level of natural phenomena as at the level of phenomenology of perception, or of language that mediates between perception and the world, the concept of structure has been deeply

[1] Ibid. p. 23.

[2] Ibid. p. 36.

[3] Ibid., p. 153.

reflected upon, early in this century, in Austro-German philosophy where there existed close relations between:

1. the founders of structural psychology, Stumpf, Meinong and Ehrenfels (all of them students of Brentano; Karl Stumpf taught Husserl and the Gestaltists of the Berlin school, Wertheimer, KÃ¶hler and Koffka);
2. Husserlian phenomenology;
3. Hilbertian axiomatic;
4. linguistic reflections of Wittgenstein and the Vienna Circle;
5. via Jakobson, the linguistic works of the Prague Circle.

Therefore we cannot afford to forget that the roots of modern structuralism are situated at the meeting point of biological naturalism, phenomenology, and gestalt theory. We have to add a few more words in this regard. [1]

From Brentano on, the classical debate on parts/whole relations has been taken up in a new perspective. Many issues can now be considered as conceptually resolved (for instance, the physical content of causality or interaction, the set theoretic notions of membership or of inclusion of one class into another, the nature of spatial connections in a given space, the relations of syntactic dependence in a logical formula, etc.). But many other issues, crucial for phenomenologists and gestalt theorists, remain mostly unresolved.

Some of these are the following.

1. The problem of the *objective* correlates of the classificatory relation between a genus (higher type) and a species (lower type): what can be the objective validity of classifications, and a *realist* concept of abstraction?
2. That of the objective correlates of the relational â€œaccidentsâ€ù, either of static type (contractual relations, like kinship relations) or of dynamic type (actantial relations). This central problem (to which we will return in sec. 2.4) concerns the *states of affairs*, which without being objective in the strict (physical) sense, are nonetheless objective correlates of their linguistic descriptions.
3. That of organization, be it biological or perceptual.
4. That of *non-detachable* parts in a whole, i.e. that of dependent moments. For

example, in the perception of an object, a sensible quality like colour is non-detachable from its spatial extension, other than by abstraction. Similarly, the apparent contour of an object is non-detachable from its extension. It cannot exist independently.

This last problem, namely the relations of dependence between a moment and the whole from which it cannot be detached, has been deeply investigated by Stumpf,

[1] For elaborating these issues, we will refer to the important work of Barry Smith, Kevin Mulligan and their colleagues which throws a fresh light on this tradition. See, Smith, 1982.

Meinong, and Husserl. [1] We can approach it either as a problem of psychology and Gestalt theory, or as a general problem of ontology. This is what Husserl does in conceiving of the relation of dependence as a *formal* concept, and in attempting to â€œaxiomatizeâ€ù it in terms of formal ontology. This move is of considerable significance, since it presupposes the realist hypothesis that the relations of dependence (Husserl called them also â€œrelations of foundationâ€ù or â€œmetaphysical connectionsâ€ù) are not only psycho-linguistic but also â€œa prioriâ€ù valid for every field of objects, and therefore possess an objective content. Its consequences are far reaching.

1. It played a foundational role in Gestalt theory.
2. Applied to *syntactic* units, that is, to what Ehrenfels and Meinong called the higher order objects, it strongly influenced the Polish school of logic (particularly, Lesniewski and Ajdukiewicz) and the development of a â€œpure logical grammarâ€ù.
3. It became the theoretical cornerstone of Jakobsonian phonology; the distinctive features are dependent moments par excellence; the phonemes are neither equivalence classes of allophones nor descriptive abstractions, but formal and relational units constituted of dependence relations; they are real relations in the sense of an ontological autonomy of the phonological level (see Sec. 2.5 below).

2.4. The states of affairs (*Sachverhalte*)

Before taking up the relationship between structuralism and semiolinguistics, let us say a few words on the crucial notion of *Sachverhalt* which relates linguistic structuralism and Gestalt theory, and which relies upon the realist conception of relations of dependence proposed by Husserl. The descriptive relation between language and the external world cannot be reduced to a mere denotative one. To understand it, it is necessary to introduce a *third term*. If we take a sentence describing an external fact (for instance, an actantial interaction), we must suppose that its syntactico-semantic structure possesses an objective correlate, and that there is an â€œobjectiveâ€ structuration of the fact â€" a system of structural connections â€" which is linguistically expressed. The difficulty is that such a structuration is neither of a physical nor of a linguistic type. It does not have any material existence. It â€œsubsistsâ€ ideally as a morphological articulation of the physical world. It constitutes a third term between expression and reality, which is what is called a state of affairs. [2]

Now, we can consider the concept of state of affairs in two opposite ways:

[1] For more details, see, Smith, 1982.

[2] See again Smith, 1982.

1. Either, by equating it with the correlative fact, and ascribing to it only the role of a truth-maker: this is the dominant point of view in the philosophy of language. Whatever be its latter refinements (e.g., intensional logic explaining opaque contexts or the *de dicto/ de re* distinction in modal logic), the relation between language and reality still depends on a denotative conception analogous to the relation between syntax and semantics in model-theoretic logic.
2. Or, by trying to explain how it can emerge from the external fact as an â€œobjectiveâ€ structure, a *phenomenological invariant*, whose reality is neither physical nor symbolic.

This second position, much more restrictive than the first, is quite relevant because it shows how linguistic structures are determined by constraints imposed by the structure of reality and of perceptual Gestalts. RenÃ© Thom holds such a view when he asks:

> â€œCan't we accept ... that the factors of phenomenological invariance which create in the observer the sensation of signification, comes from the *real* properties of objects of the external world, that they demonstrate the *objective* presence of formal entities pertaining to these, and which can be called â€˜*bearers of signification*â€™.â€ù

Obviously, such a claim is acceptable only if we can integrate phenomenological appearance with objective reality and provide a mathematical definition of these â€œformal entitiesâ€ù as â€œfactors of phenomenological invarianceâ€ù.

As we will see, Catastrophe theory provided the first synthesis between phenomenology and physical objectivity. According to Thom,

> â€œstrictly geometrico-topological [morphological] analysis (â€¦) allows us to associate with every spatio-temporal process certain invariants of combinatorial nature [catastrophes] (â€¦) which, by virtue of their fundamental character, can reasonably be thought to play an essential role in the verbal description of the process. Such is the origin, I think, of the original schematism that underlies the linguistic organization of our vision of the world.â€ù[2]

> â€œSince the primordial function of language is to transcribe the phenomenological catastrophes of the external world in a form communicable by our organs, (â€¦) the message bearing an autonomous signification inherits the structure of the external catastrophe that it intends to signify.â€ù[3]

Lacking such a theoretical device, we might have to conclude with Husserl and Wittgenstein that physics, however perfect it may be, will not yield a description of the phenomenological states of affairs and that the latter are apprehendable only via their

[1] Thom, 1980a: 170.

[2] Thom, 1980c: 24.

[3] Thom, 1972a: 329.

linguistic expressions. But then, the two become indistinguishable and we are thus constrained to postulate that a linguistic statement refers to a non-linguistic state of affairs without being able of saying anything of it except in a tautological manner.

This vicious circle, well pointed out in Wittgenstein's *Tractatus*, pervades contemporary linguistics as well as analytical philosophy. Without a synthesis between phenomenology and physical objectivity we cannot escape the dilemma excellently formulated by Pierre Ouellet:

> â€œIs language something which gives entities their place, creating, in the world, the discontinuities that we call states of affairs (â€¦) and to which we refer while thinking and speaking; or on the contrary is it just that these states of affairs, which are already perfectly constituted as phenomena, become the subject of discourse?â€ [1]

In Wittgenstein's *Tractatus* there is a double **meaning** of the *logical image* (the proposition as â€œpictureâ€): on the one hand, it concerns the structural unity of the proposition and on the other, the homology between this structure and the correlated state of affairs. This homology matches the syntactic-semantic connections that constitute the proposition with the real connections that constitute the state of affairs. In this sense, the logical image (*Form der Abildung*), becomes the very form of the appearance of the state of affairs (*Form der Darstellung*). That is why the logical form (*logische Form*) tends to be identified with the form of reality (*Form der Wirklichkeit*). [2] We emphasize the fact, that for Wittgenstein, it is the relation of pictorial similarity between a proposition and the correlated state of affairs which allows us to identify the **meaning** of the proposition with the evaluation of its truth-conditions.

> â€œThe possibility of an object to occur in a state of affairs (its logical form) and that of a proposition to have a truth-value (its form of representation) is part of the possibility that the logical image can be structured parallel to the reality it represents (its form of reproduction).â€

In other words, contrary to what is the case in model theoretic logic (Tarskian semantics), understanding the relations between language and object depends on the elucidation of the manner in which the structure of a state of affairs can emerge from objective reality. For if it were not so, would the homology between a proposition and the corresponding state of affairs, have any **meaning**? For Wittgenstein, the structuration of reality into states of

affairs corresponds to the manner in which we *think* it. By thinking the reality according to a certain state of affairs, we apply to it the corresponding proposition, this projection

[1] Ouellet, 1982: 10.

[2] See, ibid., p. 47-48.

[3] Ibid., p. 52.

constituting the form of **meaning** (*Form der Sinn*). In other words, for Wittgenstein, there is an equivalence between the way in which a state of affairs (conceived as a system of real connections) is manifested and the manner of thinking the **meaning** of the proposition which supplies its logical image. In this equivalence, we must proceed from manifestation to **meaning** and not from **meaning** to manifestation. We must explain these objective â€œformal entitiesâ€ù which govern the Thomian â€œfactors of phenomenological invarianceâ€ù of the states of affairs. In other words, the thought of the **meaning** of a proposition must be rooted in the *phenomenological structuration* of reality.

2.5. Structuralism in Phonology (generalities)

In Chapters II and III we will take up the three â€œpilarsâ€ù of linguistic structuralism, namely phonology, structural syntax, and semiotic theory of narratives. But, even at the risk of being repetititve, we will present here their general outlines.

In linguistics, the structuralist perspective goes back to Saussure, especially to the basic concept of *paradigm*. Saussureâ€™s main contribution lies in substituting the classical *substantial* criteria of identity with *relational* ones. In a paradigmatic system, the identity of a linguistic unit is referred to as its *value*. It is purely positional. Using a â€œgeographicalâ€ù metaphor, we can say that a paradigm is a *categorized* domain D, that is, a domain divided into sub-domains D_i by a system of *boundaries*, K. Each sub-domain D_i is defined by its extension, in other words, by the categorization K. Structure is

identified with the *global* organization *K*, which determines simultaneously the *local* units D_i. Thus, a paradigm is not a system of relations between predefined terms. As regarding their value, the terms of a paradigm do not have any autonomous existence. They can be defined only by their *reciprocal determination*. The category of reciprocal determination is fundamental to structuralism. [1] We recognize here the well known structuralist â€œaxiomâ€ as per which difference is prior to identity. Saussure is quite explicit on this point. [2] For him, there are no natural boundaries delimiting the phonetic and the semantic zones corresponding to the signifiers and the signified units of a language. [#] Each term of a paradigm tends to â€œoccupyâ€ the whole of it, its domain (its value) being limited only by its conflict with the other domains. The definition of a positional value is purely negative, characterized by limiting boundaries. The relations between the terms of a paradigm are

[1] Of course, we should not confuse â€œcategoryâ€ in the philosophical sense with â€œcategoryâ€ in the sense of a sub-domain of a categorized domain. Similarly, we should not confuse â€œparadigmâ€ in the sense of Saussure with â€œparadigmâ€ in the sense of Kuhn.

[2] See Ducrot, 1968.

[#] â€œSignifier/signifiedâ€ translates the key Saussurian opposition â€œsignifiant/signifiÃ©â€.

relations of dependence in the sense of Sec. 2.3. For Saussure and for semiotics in general, language is a form and not a substance. [1]

Saussureâ€™s concept of paradigm was used by Roman Jakobson as the founding concept of phonology. While allophones of a phoneme are substantial units of an auditory-acoustic nature (the units of the substance of expression in the sense of Hjelmslev), phonemes are on the contrary, abstract distinctive units, of a linguistic and functional nature. They can be described as bundles of distinctive features and are governed by phonological rules. Thus, the main theoretical problem is to understand the link between phonetics and phonology, between the organization of the substance of expression and the articulation of the form of expression. It is to understand how

phonological categorizations whose description is the goal of phonology, can emerge as structures, from the phonetic substrata, i.e., from the auditory-acoustic flow.

This problem has been seen as a kind of antinomy within general phonetics, and led to a conflict between, on the one hand, *substance-based* reductionist conceptions which regard phonological descriptions as mere artefactual epiphenomena without objective value, and, on the other hand, *form-based* structuralist conceptions emphasizing the ontological autonomy of the form of expression. In the latter perspective, a phoneme is conceived of as

> â€œa differentiating unit having no concrete qualities, but manifested in speech, by an allophone having physical (physiological, acoustic, perceptual) qualities which translate into the world of physical realities their differential qualities.â€ [1]

In other words, the form of expression is an *abstract* system which, like the Aristotelian *morphe*, is realized in the substance of expression, i.e., in the concrete event of speech. Now, if we accept that it determines phonetic perception, then we will have to proceed from the abstract to the concrete:

> â€œThe description proceeds (...) from the abstract and the functional to the concrete and the material, from form to substance.â€ [2] [3]

But the substance of expression is not an undifferentiated *hyle* which would be â€œin-formedâ€ by an ideal form, an essence, an eidos. It is an organized substance. Phonological structuralism should therefore explain how the phonological form can emerge from the organization of the substance. But there is a serious problem here. As Didier Pisoni observed,

[1] See, Coquet, 1982.

[2] Malmberg, 1974: 220.

[3] Ibid., p. 30.

> â€œ[The] lack of correspondence between attributes of the acoustic signal and the units of linguistic analysis has been and still currently is, one of the most important and controversial issues in speech perception.â€ [1]

The key for the resolution of this difficulty is to be found in the structure of phonological perception whose essential property is to be what is called *categorical*. This means the following. [2] Studies on the structure of speech sounds have shown that it depends on a small number of parameters, called *acoustic cues*, that can be varied continuously in speech synthesis. Tests of identification and discrimination reveal that discrimination is subordinate to identification. In other words:

(i) identification categorizes (discretizes) the continuous space of acoustic cues, and divides it into domains corresponding to stable perceptions, and

(ii) there is no intracategorial discrimination.

It is this second feature that defines phonetic perception as categorical and distinguishes it from continuous perception where the discriminating capacity is essentially independent of categorization. It allows us to understand how perception can spontaneously *discretize* the auditory-acoustic flow, or in other words, how discontinuity can emerge from continuity. In this sense, it establishes a link between the audio-acoustic level of phonetics (organization of the substance of expression) and the linguistic level of phonology (abstract relational nature of the form of expression): the phonemes encoded in the auditory-acoustic flow are categorical as a consequence of the perceptual process itself; they have a psychological reality as discrete units.

2.6. Actantial structures and case-grammars (generalities) [3]

In syntax, the structuralist approach goes back to Lucien TesniÃ¨re. [4] For TesniÃ¨re, a sentence is essentially a system of *connections* which, being â€œnon-corporealâ€ (non-sensible), exists only in the â€œmindâ€. The structural connections are not of a symbolic essence, but are part of a â€œvital and organicâ€ principle of organization (TesniÃ¨re refers to Humboldtâ€™s celebrated *innere Sprachform*). TesniÃ¨re schematized them by means of graphs called â€œ*stemmas*â€, which can be considered as the precursors of the syntactic trees used in most formal linguistic descriptions since Chomsky. As the visual manifestation of abstract dependence relations (see Sec.2.3) a stemma is nothing but the structural schema of a sentence.

[1] Pisoni, 1979: 334.

[2] See, **Petitot**, 1982b; 1983b.

[3] For more details, see, **Petitot**, 1982c, and Chapter II.

[4] See, TesniÃ¨re, 1959.

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For TesniÃ¨re, the structural connections define the *functions*, that is, the *roles* assigned to words in the expression of thought. They are projected on the linear order of syntactic concatenations, and structural syntax is therefore dependent on â€œthe relations between the structural and the linear ordersâ€ù.

Recent developments in transformational-generative grammar and generative semantics might suggest that TesniÃ¨re's original structuralist position has been satisfactorily formalized and is now obsolete. But, that is not the case. Actually, these trends represent a static, taxonomic, formalist, and logico-combinatorial conception of syntactic structures, rather algebraic, and very different from TesniÃ¨reâ€™s dynamical, â€œvitalistâ€ù and Gestaltist viewpoint. Indeed, TesniÃ¨re has always emphasized that syntactic structures are self-regulated organizations akin to biological organisms, that structural syntax is neither a logically nor a psychologically based grammar, and that it is functional and dynamic and not categorial (in the sense of the grammatical categories) and static. In fact, his conception is an *actantial* â€œscenicâ€ù one based on the notion of *verbal valence*.

It was only with the *case grammars* of Fillmore, Chafe and Anderson, and later the *relational grammars* of Keenan, Comrie and Johnson based on the works of Perlmutter and Postal, and still more recently the *cognitive grammars* of Talmy, Langacker and Lakoff, that this conception of syntax received renewed attention. In â€œThe Case for case reopenedâ€ù¦ Charles Fillmore reintroduced a scenic conception of syntactic structures for the following reasons. Classical case grammars, in spite of their early success, ran into serious difficulties, particularly on the question of defining the case universals, because they are based on a *semantic interpretation* of deep syntactic relations. Their basic hypothesis is that there exist a finite set of deep case-universals which are also functional categories (e.g., Agent, Dative, Instrumental, Locative,

Objective and Beneficiary), whose *notional* content can be determined, which select the semantic (actantial) roles, and which, though of a semantic nature, can be discovered applying purely *syntactic* criteria. But from a cross-linguistic comparison, one can conclude that there exists a conflict between the proliferation of cases entailed by their conception as classifiers of sentences, and their limitation entailed by their conception as universals. If case universals are assigned a distinctive notional content, then they will have to share the lexical content of the verbs, and thus they will proliferate. Instead, if they are given a sufficiently broad notional content so as to form a restricted set (a closed class in Talmyâ€™s sense), then their content becomes too broad.

A first solution to this difficulty was proposed by John Anderson [2] on the model of the distinctive features analysis of phonemes. It consists in:

[1] Fillmore, 1977.

[2] See Anderson, 1971; 1975a, b.

(i) treating case-meanings as complex contents analyzable into case features (â€œmulti-caseâ€ù analysis of the actantial roles);

(ii) classifying case features into a limited number of universals, on the basis of the *localist hypothesis*, according to which the *positional relations between spatio-temporal actants operate as schemas for the actantial relations*;

(iii) positing that verbs select case-features;

(iv) elaborating a â€œgenerative grammarâ€ù of such selections.

Fillmoreâ€™s solution is different. It is based on the observation that several different semantic fields can form the substrata for a single abstract schema of actantial connections. Fillmore introduces within case semantics a distinction between the specific semantic field under consideration and the purely positional meanings defined by the actantial stemma. He calls these semantic fields, â€œscenesâ€ù. Each â€œsceneâ€ù is lexico-syntactically organized by a restricted number of specific constructions which select the

corresponding cases with appropriate syntactic and lexical features. Hence the slogan:

â€œMeanings are relativized to scenes.â€ù

In developing this scenic conception, Fillmore employs the notion of *case-frame* which serves as an intermediary between the description of situations and the underlying syntactic representations. A case-frame assigns semantico-syntactic roles to the actants of the process represented by the sentence and thus constrains the choice of a perspective that selects one of the actants as the grammatical subject in relation to a case-hierarchy. Fillmore is arguing for a *conceptual* definition of cases in placing them at the interface of language and thought: we produce and understand linguistic expressions by â€œactivatingâ€ù in our mind prototypical scenes. In other words, when perspectivized, an expression evokes the global background on which it is profiled.

Thus in structural syntax, we again encounter all the problems of Gestalt theory and phenomenology that we have already referred to (Sec 2.3 and 2.4): linguistic universals should be rooted in the perceptual organization of the state of affairs.

The most delicate issue is however to arrive at what we will call *a configurational definition of case meanings*. Indeed, even if case meanings are relativized to scenes, they still continue to have a purely positional value. Now, their notional (actantial) content cannot be defined as autonomous, but only in terms of *relative positions* in actantial schemas. These positions are reciprocally determined as paradigmatic values. Structural syntax thus has to tackle a double problematic:

(i) how can actantial schemas emerge as self-regulated structures, dynamic morphologies, and syntactic Gestalten, from the phenomenological organization of reality into states of affairs?

[1] Fillmore, 1977: 59.

(ii) how do these schemas allow for the description of case meanings in terms of positional values.

To solve these problems, it seems necessary to resort to the *localist hypothesis*, [1] and assume that structural connections between spatio-temporal actants can serve as model for syntactic schemas in general. Such a hypothesis has been thoroughly confirmed by RenÃ© Thom's interpretation of case universals in terms of elementary catastrophes. Most of the theoretical difficulties that we have indicated above can be solved from this perspective. [2]

2.7. Semio-narrative structures (generalities) [3]

Actantial structures exist not just at the sentence level. They are also present at the level of *narratives*, as demonstrated in the structural analysis of folktales. At the surface (manifest) level, myths, fairy-tales, drama, novels, etc., relate intrigues involving *dramatis personae* (the actors) who are situated spatio-temporally, defined by thematic roles, linked by kin relations, and interacting through conflicts, gifts, contracts, separations, unions, passions, etc. In spite of the proliferation of the superficial discursive structures, we can identify certain deep structures, which A.J. Greimas called *semio-narrative*. This method of analysis is able to show that:

(i) the abstract (non-figurative) discourses, be they philosophical, political, or scientific are also partly organized on similar bases;

(ii) the deep semio-narrative structures reflect also *lived* experiences of passions, ideologies, actions, dreams, etc.

This suggests that *the semio-narrative structures are anthropological structures of mind.*

Greimasâ€™s semio-narrative grammar is mainly concerned by a truly original relationship between syntax and semantics, namely the projection (or conversion) of the paradigmatic axis onto the syntagmatic axis which constitutes one of the central thesis of structuralism.

The recognition of a syntactic component of deep semio-narrative grammar [4] goes back to Propp's analysis of Russian folktales in his celebrated work *Morphology of the Folktale*. Underlying the actions of the characters in a tale, Propp identified a set of *functions* (that is to say, typical actantial relations) *canonically* ordered, appearing in a

[1] For an historical account of the localist hypothesis, see Chapter II and Hjelmslev, 1935.

[2] See, **Petitot**, 1979c, 1982c; Wildgen, 1981, 1982; see also Chapter II.

[3] For more details, see Chapter III.

[4] Semio-narrative grammar has at least two levels: deep and surface levels. Each level has two components: the syntactic and semantic ones.

rule-governed manner as if in a process of **morphogenesis**, and expressed by typical sequences: establishment of an initial lack (e.g. by transgression of social rules, deception, etc.); contract between a Sender (e.g., a king, a dominant social group, etc.) and a Hero; a series of tests, first a qualifying test by which the Hero acquires the modalities of wanting, knowing and/or being able to (e.g., obtaining a magical instrument from a Helper), followed by a decisive test (main test) wherein the Hero accomplishes a feat that liquidates the initial lack (e.g., killing a dragon), and finally a glorifying test in which the Heroâ€™s performance is approved by the Sender. In other words, Propp identified invariant, stable, and universal actantial structures governed by an actantial syntax which syntagmatizes an actantial *paradigm* consisting of typical actants such as Sender / Receiver, Subject / Object of value, Subject / Anti-subject, Helper / Opponent.

After Proppâ€™s syntactic achievement, it was LÃ©vi-Strauss who introduced a *semantic* component in deep semio-narrative grammar. [1] It is indeed the most challenging part of structural narratology. This deep semantic component is very different from the discursive and figurative surface grammar which distributes lexical meanings along the surface syntactic structures. Of course, one can analyze narratives like myths by focusing only on the discursive-figurative â€œclothingâ€ of deep actantial syntax, but then one will not understand their anthropological function, except, as is often done, by interpreting the surface contents symbolically. It is precisely this anthropological function that LÃ©vi-Strauss sought to define. For demonstrating the logical coherence of myths, he was committed to a semantic approach. This was the basis of his criticism of Propp. Lacking a correct understanding of the relationship between the paradigmatic and the syntagmatic dimensions, Propp was only able to identify the syntagmatic invariants of an actantial syntax. [2]

Inspired by the Prague school (Jakobsonian) phonology and Hjelmslevâ€™s principle of the parallelism between the expression plane and the content plane, LÃ©vi-Strauss

introduced in the theory of deep semio-narrative structures, the most important aspect of the paradigmatic dimension, namely *categorization* (see, Sec. 2.5). The idea is that tales, and particularly myths, share a level of deep semantic categorizations expressing values which belong to unconscious codes (familial, natural, cosmological, economic, culinary, etc.) and which are projected on the syntagmatic dimension. This deep semantics does not correspond to the surface lexical meanings. It has a contextual and global function. It selects from the surface lexical figures (â€œsememesâ€ù) certain specific semantic features (â€œsemesâ€ù). But the contents it articulates (Life / Death, Nature / Culture, Man / Woman, Divine / Human, etc.) do not have a reference in the objective world. They are some sort of psychical drives or ideals that â€œgive **meaning** to lifeâ€ù, *a **meaning** that cannot be*

[1] See, LÃ©vi-Strauss, 1958 and 1964-1971.

[2] See, Coquet, 1982.

grasped as such but only experienced via its conversion into actantial structures.
More precisely,

(i) the deep semantic categories are anthropological universals of the imaginary order; [#]

(i) they act only when axiologized and ideologically invested in the objects of value, the quest for which motivates the actions (the â€œnarrative programmesâ€ù) of the subjects;

(iii) only the circulation of such objects of value can allow them to be subjectivized; in other words, they can become part of the subjects only through experiences and actions .

(iv) thus, actantial syntax *converts* the deep semantics of the tale into a narrative â€œdoingâ€ù which determines its anthropological function. It allows to grasp the unconscious structures of subjectivity, by simulating a â€œtheatreâ€ù that presents them in a scene.

From this point of view, we can see that a correct semio-narrative grammar would involve the resolution of three problems:

(i) what is an elementary narrative structure? (we already know that it is of an actantial nature);

(ii) what is meant by semantic categorization? (we already know that it is similar to categorization in phonology);

(iii) what is the nature of the conversion of deep semantics into syntax? (we already know that it is a projection of the paradigmatic axis onto the syntagmatic one).

These are, among others, three questions that Greimasian theory is mainly concerned with.

As regards deep semantics, we must first of all *formally* define the morphologies of categorization which constitute the *form* of content (in the sense of Hjelmslev). This is the function of the *semiotic square*. [1] According to Greimas, the semiotic square is a universal schema for the articulation of **meaning**, for the apprehension of which it ensures the minimal conditions. As an elementary morphology prior to any sememic investment, it unfolds a *semic category* connecting two contrary semes into a relation of *junction* (conjunction / disjunction as reciprocal presupposition).

Taken simply as a logical form in the framework of elementary Boolean logic, the semiotic square is completely trivial. It is only the reformulation of the â€œlogical squaresâ€ whose tradition goes back to Aristotle. But everything changes if we observe that it is a structure in the strong sense, that is, an â€œorganicâ€ and â€œself-regulatedâ€ system of dependence relations (see Sec. 2.3) defining positional values. The relations of contrariness and contradiction which are constitutive of it are not logical. As shown by

[#] In French, it is very easy to substantivize adjectives or verbs for constructing abstract nouns: *lâ€™imaginaire*, *le symbolique*, *lâ€™Ãªtre*, *le faire*, etc. As it is not the same in English, we will use expressions such as â€œimaginary orderâ€, â€œimaginary stanceâ€, or â€œimaginary functionâ€.

[1] For some general reflections on the semiotic square, see, SES, 1976; and BGRS, 1981.

Arild Utaker, [1] they are respectively equivalent to *qualitative* and *privative* oppositions in Jakobsonâ€™s sense. They have to be treated as such.

Now, the notions of opposition and reciprocal presupposition rely on a primitive notion of position which is primarily *topological* and not logical. Similarly, oppositions

are based on conjunctions and disjunctions and these notions rely on a primitive notion of junction which is also primarily topological, and not logical. Thus the formal essence of the semiotic square, depends ultimately on a dynamical topology of places and connections and not on a static logic of terms and relations. We have shown that such a framework is provided by the elementary catastrophes. [2]

As for the narrative syntax, Greimasian theory regards elementary actantial structures as the syntagmatization of the paradigmatic relations constituting the actantial model (narrative programmes). These relations are basically reduced to relations of reciprocal presupposition between Sender and Receiver (contract), Subject and Object (acquisition of modal competence and/or performance), Subject and Anti-subject (performance). As regards the subject/object relation, Greimas views the subject as an *intentional* subject (a subject of lack, of quest, of desire) persuing a semantic value invested in an object. This means that the basic narrative programme is to realize a conjunction between a subject and an object of value.

There are, however, some difficulties. For instance, Paul Ricoeur has pointed out that the phenomenology of action unfolded in narratives cannot be reduced to a mere syntactic â€œdoingâ€ consisting of simple operations of conjunction and disjunction between subjects and objects of value. [3] Further, the conception of semiotic subjects as intentional subjects, evidently raises the question of the nature of their intentionality. A closely related issue concerns the problematics of belief, seduction, manipulation, and selection of objects of value.

But the main difficulty is still the conversion of deep semantics into actantial syntax, i.e., the projection of deep semantic categories onto narrative programmes. [4] In Greimasâ€™s theory, it is tackled by the introduction of an intermediate level, the â€œsyntax of operationsâ€, *akin to both the semiotic square and the actantial structures*. The guiding principle is that the constitutive relations of position and junction can be converted into logical operations on the terms they define, and that these operations can themselves be accounted for by actantial interactions, i.e. by a â€œsyntaxâ€ of action.

Though partially acceptable, this response to the problem of conversion remains incomplete and has to be further interrogated. It clarifies neither the nature of

[1] Utaker, 1974. See also, Section III.3.3.

[2] See, **Petitot**, 1977b; 1982a.

[3] See, Ricoeur, 1980; and Chapter III. 4.

[4] For a description of certain aspects of this conversion, see, BGRS, 1982.

intentionality, nor the mechanisms by which an unconscious drive can be invested in an object and confer on it the â€œauraâ€ù of an object of value. But these phenomena go far beyond pure structural semiotics. Their comprehension would require a â€œmetapsychologyâ€ù, either in the Freudian sense, or in the sense of an anthropology of the imaginary stance. [1]

3 . THE PROBLEM OF FORMALIZING STRUCTURES

3.1. The intrinsic limits of the formalist perspective

This overview of some key aspects of structuralism shows that, as a conceptual and methodological perspective, it is intrinsically transdisciplinary (touching upon biology, anthropology, gestalt theory, cognitive psychology, phonology, linguistics, semiology) and that in each of its domain of empirical validity, it reveals, as emphasized by Piaget

> â€œa common positive ideal of intelligibility.â€ù

As an epigenetic and relational doctrine of organization, structuralism represents, along with physics, practically the only area where several different domains are brought to a rational synthesis. The question of its *formalization* is therefore especially crucial.

Now, it can be observed that structuralism, owing to the lack of suitable formal tools, never reached its intended objectives. Until now, it only succeeded in developing a symbolic (logico-combinatorial) conception, a conception we are going to criticize, and to which we shall propose an alternative.

The symbolic perspective in structuralism is twofold. It is concerned with formalization of either structuralist conceptual theories or structures conceived as phenomena.

As regards the formalization of structures viewed as a particular class of

phenomena, the situation may appear quite satisfactory. Indeed, the structural methodology has resulted in a plethora of *models*. In fields such as system theory, cybernetics, artificial intelligence, language automata theory, formal grammar, categorial grammar, intensional logic, etc., it has been quite successful. We must, however, note that these achievements were made possible by a general â€œreificationâ€ of structures, enabling them to be algebraized. Dynamical structuralism, which, for us is the genuine

[1] See, for instance, Brandt, 1982a; Thom, 1981, 1983; **Petitot**, 1982g.

[2] Piaget, 1968.

structuralism, has meanwhile remained in the dark. In biology, for instance, whatever be the usefullness of formal cybernetic schemas, their application encounters, as Thom notes,

> â€œvery serious difficulties as soon as we move from an abstract schematism to a material realization in space-time.â€[1]

That is, from a formalist perspective, one cannot always understand how the structures represented by such schemas can emerge from the physico-chemical properties of the substrata. This perspective is valid

> â€œonly for partial mechanisms, ready-made, and in full functional activity.â€

> â€œIn no case it can be applied to the global structure of living beings, to their epigenesis, or to their physiological maturation.â€ [2]

That is why, in biology, it is pertinent to partially resort to a morphodynamical approach which allows us to understand the emergence of structures out from their physico-chemical substrates.

In linguistics and in semiotics, formalism has similar intrinsic limitations. The

widely accepted belief

> â€œthat the only generative virtue of a structure, coming from its pure form, should be admitted *a priori*, and needs no explanation,â€ [3]

should be questioned, for, in the case of natural language,

> â€œit is the self-limitation of generative capacities of syntax that requires explanation.â€ [4]

In order to understand this self-limitation, we have to consider the *dynamics* underlying the formal cinematics described by formal languages and no longer base structures

> â€œon the automatic iteration of certain operations, but on the contrary, on an intrinsic combinatorics provided by the dynamical interpretation.â€ [5]

As regards now the formalization of structuralist theories, there is a lot of confusion, due to the strong influence exerted by mathematical structuralism. The idea goes back to Husserl who attempted to â€œaxiomatizeâ€ in a quasi-Hilbertian way a formal

[1] Thom, 1980a: 154.

[2] Thom, 1972a: 207.

[3] Thom, 1980a: 164.

[4] Ibid.

[5] Ibid., p. 106.

ontology of dependence relations. Later, it was adopted by Hjelmslev in semio-linguistics and became the basis of Greimasian epistemology. From this perspective, a theory is considered as a conceptual system, a descriptive metalanguage, defining hierarchically concepts from primitives. Being undefinable, the primitive concepts behave like *regional categories*. In Greimasian theory, the primitives are notions such as continuous / discontinuous / discrete, relation, difference, opposition, junction (conjunction / disjunction), transformation, operation, etc. It is assumed that by providing them with a

formal expression, it will become possible to â€œaxiomatizeâ€ù the descriptive metalanguage and convert it into a formal language, a â€œpure algebra.â€ù

The main difficulty with this perspective is that it can, at best, only elucidate the logical architecture of the theory and cannot obtain an effective *mathematization of its content*. It relies upon a formal logic concerning the linguistic form of knowledge and not a transcendental logic concerning the *objective* content of knowledge. It misunderstands the critical fact that, in science, mathematical schematization of regional categories is the key to any constitution of objectivity and consists not in an â€œaxiomatizationâ€ù, but in a mathematical *interpretation* of the categorial content. In this way, *there exists a conflict between formalization and mathematization in the structural field*. This point is for us of utmost importance. We will see that it is the topological and dynamical interpretation of the structuralist categories which constitute the basis of their objective significance.

3.2. The topological a priori as the central theoretical problem of structuralism

In all the domains we have considered, structural categoriality is always the same and possesses a content which ultimately refers to topological intuitions (position, junction, paradigmatic categorization, connection, etc.). As we have seen, every structure is primarily a structurally stable and (self-)regulated system of connections between positional values. This basic fact should guide any attempt of theorization in this field. Let us therefore further clarify the nature and the significance of some of the issues we have already mentioned.

One of the main hypotheses of structuralism is that the paradigmatic dimension of systems constrains the syntagmatic one. Now, logical formalisms (elementary formal logic, modal logic, intensional logic, combinatorial logic, algebras of relations, automata, category theory, topoÃ¯, etc.) which are used generally to formalize the semantic and/or syntactic descriptions, involve an elimination of the paradigmatic axis in favour of the syntagmatic one. They are therefore unsuitable for structural formalization. Whence a first

[1] Greimas-CourtÃ¨s, 1979: 225.

formulation of the central theoretical problem: *what kind of formal essence should be attributed to the paradigmatic dimension of semiotic systems in general* ?

The structuralist axiom postulates that the paradigmatic organization is purely relational and determines abstract units which possess no independent identity, and exist only as pure positional values. It asserts the primacy of difference over identity in the semiotic realm. Whence a second formulation of the central theoretical problem: *what kind of mathematical content should be assigned to the category of relation in such a manner that it could schematize the structural primitives of difference and positional value* ?

There is actually an irreducible gap between structuralist eidetics and symbolic formalisms. In its pursuit for a symbolic calculus and a control of the recursive complexification obtained by iterating rules, the latter ignores the evident fact that, in the case of natural language, the relations are *meaningful* relations belonging to the *form of content*. As Greimas emphasized, this is one of the â€œfundamental optionsâ€ù for structuralism:

> â€œwhile the symbol-units of a formal syntax constitute an alphabet (i.e., some sort of an inventory, often wrongly referred to as â€˜structureâ€™) governed by a set of operational rules, the units of conceptual syntax are arranged in a taxonomy (a sort of elementary morphology) upon which the syntactic operations are performed.â€ù [1]

The distinction between formalist theories of syntax, which develop a symbolic calculus of recursive linguistic properties, and conceptual theories of syntax, which model the paradigmatic relations of the form of content now appears as a true antinomy.

The paradigmatic organization of semiotic systems involves a taxonomic dimension. But in its structuralist reworking the classical concept of taxonomy undergoes a mutation. Traditionally, [2] taxonomy is concerned with the classification of already defined, individuated, and autonomous objects. In structuralism, on the contrary, the abstract units are defined and determined by the classification itself. Taxonomy concerns therefore the emergence of discrete units from a continuous substratum by a process of categorization. That is why the primitive notion of discontinuity â€” of difference â€”, is in some ways the â€œpure intuitionâ€ù of the structural order. A structural â€œspaceâ€ù, we have seen, is a continuous space categorized by a system of discontinuities and thus

discretized.

The paradigmatic is then the new apellation for the taxonomic when we no longer assume that a multiplicity of discrete units, already individualized, are distributed in an abstract system of equivalence classes, but on the contrary, that a categorizing

[1] Greimas-CourtÃ¨s, 1979: 378. We will come back to this quotation in sec. II.2.4.

[2] See, for instance, Gil, 1981.

classification discretizes a substance and defines discrete units by reciprocal determination. [1] In a paradigm, the positional values of the units result from a process of ***morphogenesis***.

In this new perspective on paradigms, the central theoretical problem *is to work out an adequate concept of space*. A â€œstructuralâ€ù space would evidently not be a physical one. It is a generalized space of deformable entities (for instance, semantic units or acoustic images), a functional space of internal states of a â€œblack-boxâ€ù.

The hypothesis of a spatiality immanent to the paradigmatic dimension explains the mutation undergone by the taxonomic one within structuralist practices. It involves a conception where the taxonomic becomes *a synthesis between the concept of classification and the concept of generalized space*. Paraphrasing Riemannâ€™s well-known statement on the concept of manifold [2] we can say that: within a discrete manifold the principle of the relations between units is already present in the concept of this manifold while, in a continuous manifold, this principle should come from outside. It is therefore the case that either the reality on which the classification is founded forms a discrete manifold, or the basis of the relations are to be sought outside of it, i.e., in the form which categorizes it.

The theoretical challenge is then to *geometrize* the paradigmatic categorizations. We can reformulate the central theoretical problem as follows: how can a geometrization of the paradigmatic synthesis between the concepts of classification and generalized space be used

(i) to assign a mathematical content to the structural primitives of difference and positional value;

(ii) explain the differentiating action of discontinuities, which results in the formation of discrete units, and

(iii) deduce, at the syntagmatic level, the conceptual syntactic relations manifesting the form of content?

It is the resolution of these difficult questions, which go far beyond a simple descriptive-conceptual theory, that is the original task of a mathematical schematization of structures. Such an imperative is so alien to the social sciences that it is remarkable it could have been philosophically formulated very early: we have in mind a major work of Gilles Deleuze.

[1] See Gil, **Petitot**, 1981.

[2] Riemann, 1854. â€œIn a discrete manifold, the principle of metric relations is already contained in the concept of this variety, while in a continuous manifold, this principle should come from outside. It must then be the case that either the reality on which the space is founded forms a discrete manifold, or the foundation of metric relations be sought outside of it, in the binding forces which work within it.â€ (Our translation).

3.3. Deleuzeâ€™s proposal for a schematism of structure

Deleuzeâ€™s reflections on structuralism should be understood from a philosophical standpoint. His project is to evaluate structuralism in showing how it modifies the transcendental tradition. In his article â€œA quoi reconnaÃ®t-on le structuralisme ?â€ that we summarize below, he analyzes the different structuralist approaches according to seven criteria.

3.3.1. The symbolic realm

> â€œThe first criterion of structuralism is the discovery and the recognition [along with the imaginary and the real orders, but deeper than both] of a third order, a third realm, that of the symbolic.â€ (p. 301) [2]

The symbolic stance (recognized for the first time by structural linguistics) is the â€œelementâ€ of structures. It is very difficult to be decerned as such, because it is always hidden by the concrete properties of the substrata where the structures are implemented in. A structure is neither a Gestalt, nor a figure of the imagination, nor an intelligible essence.

> â€œIt is a combinatorics of formal elements which possess in themselves neither form, nor signification, nor representation, nor content, nor empirical reality, nor hypothetical functional model, nor intelligibility behind the appearances.â€ (p. 303)

3.3.2. The criterion of locality or of position

If the symbolic stance refers to no pre-existing reality, if no imaginary or conceptual content provides it with a signification, if

> â€œthe elements of a structure have neither extrinsic designation nor intrinsic signification,â€

it is because

> â€œas LÃ©vi-Strauss had clearly pointed out, [these elements] have nothing but a *content*: *a content that is uniquely and necessarily â€˜positionalâ€™* â€(p. 304).

[1] Deleuze, 1973. The page numbers will be referred to in the text.

[2] The triad â€œreal, imaginary, symbolicâ€ was one of the main themes in the sixties (see e.g. Lacanian psychoanalysis). In this context, the term "symbolic" has nothing to do with "symbolic" in the logical sense.

This is indeed the most crucial fact. We shall do well to meditate on Deleuzeâ€™s assertion that

> â€œthe scientific ambition of structuralism is not quantitative but topological and relationalâ€ (p. 305).

We must emphasize here the term â€œtopologicalâ€. As Deleuze insists:

> â€œwhat is structural, is space, but a non-extended and pre-extensive space, pure spatiumâ€ (p.305).

To give a scientific status to the â€œandâ€ in â€œtopological and relationalâ€ constitutes the main challenge. That is why

> â€œstructuralism is inseparable from a new transcendental philosophy wherein the places are more important than the things that fill themâ€ (p. 306).

The consequences of the locality criterion are far reaching. The content resulting from the combination of purely positional identities is always an effect

> â€œproduced as an excess by the combination of places in the structure,â€

it is always overdetermined (p. 306). That is why the symbolic order transcends both the real and the imaginary ones:

> â€œPlaces in a purely structural space are prior to the things and the real beings which occupy them, prior also to the imaginary roles and events which necessarily appear when the places are occupied.â€ (p.305)

3.3.3. The differential and the singular dimensions

The â€œpure intuitionâ€ of structuralism can thus be easily formulated. It is the intuition of dividing a â€œsubstratum spaceâ€ by means of a system of thresholds. The problem is to make such systems autonomous relative to the real and/or semantic identities which they are invested with. It is to conceive articulations of differences that are *independent* of substrata though existing only if implemented in them. In that sense, structuralism relies upon a very typical *functionalism*. It can even be considered as the true source of functionalism.

Such a conception of the symbolic stance requires a â€œgeometrizationâ€ of the primitive notions of position and difference. This is required firstly, for freeing the

positional values from any purely logical principle of identity (the symbolic effects are due to an opposition between positional identities of and real or semantic identities), and secondly, for viewing differences as resulting from a *genetic* process of differentiation.

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Structural objectivity thus hinges on a â€œgeometry of positionâ€ù whose mathematical essence must be understood. Deleuze remarkably anticipated its general idea while taking recourse to the mathematical notion of *singularities* of differential equations:

> â€œThe important notion of singularitiy seems to be relevant in all domains where one speaks of structure.â€ù

A structural â€œspaceâ€ù is a space divided into regions (places) by a system of differences. It is a space of coexistence, of colocalisation. For the symbolic elements that it is invested with, the differences are not external relations between pre-existing identities but constitutive relations of â€œreciprocal determinationâ€ù. Genetically, they are obtained from the *unfolding of singularities*. When singularities unfold in â€œspaceâ€ù they differentiate and organize it into a â€œstructural spaceâ€ù.

> â€œThe *reciprocal determination* of symbolic elements extends to the *complete determination* of the singular points which constitute a space corresponding to these elementsâ€ù (p.309).

> â€œEvery structure reveals two aspects: a system of differential relations on the basis of which the symbolic elements are reciprocally determined, and a system of singularities corresponding to these relations and tracing the space of the structureâ€ù (pp. 309-10).

A domain can be defined in structural terms if:

(i) symbolic elements are â€œembodiedâ€ù in its objects;

(ii) differential â€” i.e. categorical â€” relations are â€œactualizedâ€ù in the real relations

linking these objects;

(iii) singularities â€" i.e. â€œeventsâ€ â€" â€œdistributeâ€ roles and functions to the objects which occupy them (p. 310).

In this sense

> â€œevery structure (â€¦) represents a complex category-function.â€ (p.311)

3.3.4. Differentiating and Differentiation

The main difficulty encountered by the structuralist *Ã©pistÃ©mÃ©* is that structures are

> â€œmasked by their products or effectsâ€ (p. 316).

The expression of a structure is always a fading of its symbolic nature. For a structure is never actualized as such. Being

> â€œreal without being actual, ideal without being abstractâ€,
>
> â€œvirtuality of coexistence pre-existing to the entitiesâ€ (p.313),

a structure is â€œembodied.â€ It is actualized in the production of spatio-temporal and/or semantic differences but, on being actualized, it vanishes as such (see, Sec. 1).

To underline this specific manner in which the metaphysical opposition virtual / actual acts on the concept of structure, Deleuze plays with the terms *differentiation / differenciation* (p.314). In so far as it is virtual, a structure is differentiatal. On actualizing itself it becomes a principle of differenciation. A structure

> â€œis differential in itself, and differenciating in its effectâ€ (p. 315).

3.3.5. The serial function

After having identified the non-trivial theoretical content of structuralism, Deleuze

goes on to show that structuralism is also non-trivial in practice. Since LÃ©vi-Strauss's account of totemism, we know that a symbolic system of differences (e.g., a zoological taxonomy) can be used for encoding another symbolic system (e.g., social relations). The practical content of structuralism lies in showing how, by projecting the paradigmatic axis on the syntagmatic one, the symbolic elements of a structure â€œare serially orderedâ€ and how a series always refers homologically to another series (p.318). According to Deleuze, LÃ©vi-Strauss's main contribution is in showing that this type of homology between two series is not a trivial encoding, that is, a mere term-to-term correspondence. In fact, the places (positional identities) in the first series are inseparable from *displacements* induced by the second series (p.320). The problem is of explaining how the relative displacements in the series

> â€œare absolutely a part of the places in the structureâ€ (p.321).

It is concerned of solving the paradox of a *metonymic* principle of identity for positions. The identity of a symbolic place is not what ensures its stability, but what ensures the possibility of its displacement. Metonymy violates common sense logic.

> â€œThis relative displacement of the two series is not at all secondary; it does not affect their terms from outside and secondarily as if to give them an imaginary disguise. On the contrary, displacement is strictly structural or symbolic: it belongs essentially to the places in the space of the structure, and thus governs all the imaginary disguises of the beings and objects which happen to secondarily occupy these places.â€ (p.321)

3.3.6. The empty place

If the relative displacement (metonymy) can be an intrinsic part of the identity of position, it is because every structure

> â€œcontains an object or an element which is quite paradoxicalâ€ (p. 321).

This paradoxical element is of a kind different than the symbolic elements, the differential relations, and the singularities It circulates within the series as if it was

> â€œits own metaphor and its own metonymyâ€ (p. 322).

It lacks any ontological function (it is not an object), any self-likeness (it is not an image), any logical identity (it is not a concept) (p. 323). And if the relative displacements is an intrinsic part of positional identities, it is because the relative place of the terms in the structure depends on their absolute place in relation to this element.

> â€œIt is in this sense that displacement, and more generally any form of exchange, is not something coming from the outside, but the fundamental property which allows one to define structure as an order of places under the variation of relationsâ€ (p. 324).

3.3.7. From the subject to practice

When a structure is actualized, real and/or semantic entities occupy its places. But the places are already virtually occupied by symbolic elements which determine their colocalisation. But the â€œempty placeâ€ always escapes this â€œprimary symbolic filling-inâ€ (p.330). Being of a nature different from the symbolic elements, the differential relations and the singularities, the â€œempty placeâ€ remains empty.

> â€œBeing its own symbol, it does not have to be filled-in.â€ (p.330)

And precisely because it remains empty, it is the â€œmetonymicâ€ principle of identity of the symbolic elements, and is correlated with the â€œeminently symbolicâ€ instance which the *subject* is (p. 330). This subject is â€œsymbolically affectedâ€ by the

> â€œideal events which form part of the structure itselfâ€,

that is, by *immanent* events in the structure (p. 332). It is in this sense that structuralism is also a praxis (p.333).

This brief account of Deleuzeâ€™s criteria of the structuralist *Ã©pistÃ©mÃ©* is in accordance with our own view. Tending towards a positional schematism of the category of relation, it asserts the necessity of deducing the â€œlogicâ€ of **meaning** from a primarily spatial conception. In other words, it helps us to understand that a â€œlogicâ€ of **meaning** must be in fact, a â€œphysicsâ€ of **meaning**. *The symbolic order is to the semantic substance what* ***morphogenesis*** *is to matter*.

4. THE NECESSITY FOR A MORPHOLOGICAL GEOMETRY

The structuralist problematic has a philosophical genealogy. If, as Jacques Derrida once claimed:

> â€œ*stricto sensu*, the notion of structure refers only to space, a morphological or geometrical space, i.e., an order of forms and placesâ€ù

and if Deleuze's characterization of structuralism is valid, then the schematization of structural categories depends entirely on the possibility of mathematically determining the â€œpositional intuitionâ€ù which operates as the â€œform of intuitionâ€ù for structural phenomena. It depends *hic et nunc* on the elaboration of a *geometry of position*. Now, as Buffon emphasized long ago, regarding embryogenesis, such a geometry of position has always been radically missing:

> â€œWhatever is directly connected with position is totally lacking in our mathematics. This art which Leibniz called *Analysis situs* is yet to be born, and still, this art which would let us know the relations of position between things would be as useful and perhaps more necessary to the natural sciences than the art which only account for the quantitative aspects of things; for, often it is more important to know about form than about matter.â€ù

Leibniz himself wrote on February 2, 1706, in a letter to Rev. Fr. des Bosses:

> â€œIf we assume the fullness of things (as the Cartesians do) and the uniformity of matter, and if we introduce just movement, then we always get a sequence of equivalent things; (â€¦) and thus, nobody can distinguish the state at one moment from that at another, not even an angel; in this way, one would never find any variety in phenomena:

> hence in addition to figure, magnitude, and movement, one must admit forms by means of which the difference of appearances emerge within matter, forms that one can grasp intelligibly, it seems to me, only from Entelechies.â€ù

Concerning the possibility of constituting a *descriptive eidetics*, that is, a geometry of morphological types adequately described by the concepts of natural language, Husserl in his turn declared in *Ideen I* (Sec. 71-75):

> â€œThe geometer is not interested in the forms given in sensible intuition, as does a scientist in a descriptive study of nature. He does not construct, like the latter, *morphological concepts* bearing upon vague types of forms which, being founded on sensible intuition, could be

[1] Derrida, 1967: 28.

[2] Buffon, 1744, t. IV, Chap. IX, p. 73.

[3] Leibniz, 1706.

> directly grasped and whose concepts and terminology would be as vague as these types themselves.â€ù[1]

> â€œThe most perfect geometry and its most perfect practical mastery can hardly be of help to the philosopher who wants to describe nature for expressing with exact geometrical concepts the things he actually expresses in an extremely simple, comprehensible, and fully appropriate manner, by using words like serrated, notched, lens-shaped, umbellate, etc.; these simple concepts are *inexact in essence, and not by chance; for the same reason, they are also non-mathematical*.â€ù

> â€œWhatever be the achievements of an exact science, that is a science operating with ideal understructures, it cannot solve the originary and entitled tasks of a pure description.â€ù[3]

Thus structuralism, as far as its mathematization is concerned, requires the

elaboration of a general mathematical theory of morphologies and **morphogenesis**. Catastrophe theory is the first effective proposal in this direction, and that is why it is crucial in this endeavour.

5 . T HE PRINCIPLES OF C ATASTROPHE THEORY

At the beginning of his pioneering work *Biology and Structuralism*, RenÃ© Thom asked:

> â€œCan the recent structuralist trends in social sciences such as linguistics and anthropology provide new methods for the edification of an experimental science like Biology?â€ď

In other words, is it possible to reach a synthesis between the dynamical structuralism focusing on **morphogenesis** and the phonological or semiolinguistic structuralism focusing on the form of semiotic systems? I think we can now answer this question positively. For this, we have :

(i) to reduce every structure (paradigmatic categorization, actantial interaction, morphogenetic differentiation, etc.) to a morphology defined on a suitable substratum space;

[1] Husserl, 1913: Â§74 ("Contrast between geometry and descriptive science").

[2] Ibid.

[3] Ibid.

[4] Thom, 1968b.

(ii) to reduce every morphology to a system of qualitative discontinuities on its substratum space.

We could then seek to describe the observed morphologies in the chosen empirical corpus as gluings, combinations, or concatenations of a small number of structurally stable and recurrent sub-morphologies, what are called â€œmorphogenetic fieldsâ€ or â€œchreodesâ€. We could further seek to elaborate firstly *local* dynamical models that generate these chreodes, and secondly *global* dynamical models capable of explaining purely morphologically the stable associations of chreodes as well as the phenomena of order and hierarchy.

Before concluding this introductory chapter, we will then briefly outline the basic principles of catastrophe theory (CT).

5.1. Phenomenology and objectivity

Early in *Structural Stability and* ***Morphogenesis***, RenÃ© Thom assigns to CT the task of explaining the stability, the transformation and the succession of forms.

> â€œOne of the central problems posed to the human mind is the problem of the succession of forms. Whatever be the ultimate nature of reality (assuming that this expression has any **meaning**), it is undeniable that our universe is not a chaos; we discern in it beings, objects and things that we denote by means of words. These beings or things are forms, or structures endowed with a certain stability; they occupy a certain portion of space and lasts a certain interval of time; further, though a given object can be perceived under very different aspects, we do not hesitate to recognize it as such; the recognition of the same entity under the infinite variety of its aspects poses a problem (the classical philosophical problem of the concept), that *Gestalt* psychologists were the first to tackle in a geometric perspective accessible to scientific interpretation. Let us suppose that this problem is solved on the basis of a naive intuition that grants to the external objects an existence independent of our perception. Nevertheless we have to admit that the spectacle of the universe is an incessant movement of birth, development, and destruction of forms. The purpose of science is to predict this evolution of forms, and if possible to explain it.â€ [1]

This problem cannot be dissociated from that of the linguistic description of phenomena. To understand the dynamics of forms in its material, efficient and formal causes, is also to understand the efficiency of the real-world descriptions in natural language, which is a central enigma whose clarification requires extremely sophisticated mathematical constructions. [2]

[1] Thom, 1972a: 17.

[2] See Thom, 1980d, Chapter II.

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We see that the catastrophist point of view is distinct from the classical scientific one. For the former, the description of perceptual experience is neither superfluous nor illusory. Its possibility is rooted in the very objectivity of phenomena. [1] To draw a parallel, one could say that just as quantum mechanics included the fact of measurement as an integral part of physical objectivity, CT seeks to include the fact of description as an integral part of objectivity, to introduce in the mathematization of reality a complementarity between world and language, and thus to constitute afresh the very concept of â€œobjectivityâ€ù.

5.2. Four guiding principles

RenÃ© Thom's arguments are often distinctly phenomenological in their style and content. We can discern in them four guiding principles.

5.2.1. Phenomenological abduction

The idea is the following. In classical physics, one proceeds first from general principles to dynamics, and then from dynamics to the observed phenomenology. Here, on the contrary, one begins with phenomenology and tries to go backwards to *constraints* on the generative dynamics.

> â€œThe method (â€¦) essentially consists in accepting *a priori* the existence of a differential model underlying the process investigated and, without explicitly knowing this model, to deduce only from the supposition of its existence, conclusions about the nature of the singularities of the process. From this fact, certain consequences of a local and qualitative sort could be obtained from the hypothetical existence of the model.â€ù [2]

This principle *reverses* the usual top-down order of physical deduction. But it is not an induction either. It is a sort of backward bottom-up deduction. What Peirce called an

abduction.

> â€œOur central idea is that the processes of **morphogenesis** are in fact determined by an underlying dynamics, which in general would be impossible to make explicit. (â€¦) One can, to some extent, classify and predict the singularities of the systemâ€™s **morphogenesis**, even without knowing, either the underlying dynamics, or the dynamics of macroscopic evolution. (â€¦) In fact, in most cases, one will have to proceed in the reverse direction: *from a macroscopic examination of the **morphogenesis** of a process, from the local or global*

[1] See, section 2.4.

[2] Thom, 1975: 23-24.

> *investigation of its singularities, one will try to go back to the dynamics that generates it.*â€ [1]

These models which aim at

> â€œan analogical classification of the dynamical situation supposed to generate the experimental morphologyâ€[2]

reintegrate appearances within objective reality. They interpret appearances as the â€œexternalizationâ€ of the â€œinteriorityâ€ of phenomenal â€œblack boxes.â€

5.2.2. Ontological neutrality and phenomenological reduction

According to Thom,

> â€œOne of the essential features of the local modeling method suggested here is that it assumes nothing regarding the ultimate nature of reality; even if this reality should be of a complexity beyond description, only some of its aspects finally enter in the macroscopic description, namely, those which determine the â€œobservableâ€ parameters of the system.â€

The idea was therefore to bracket the fine-grained physics underlying natural phenomena and to retain only their salient qualitative morphologies. It was quite similar to Husserlâ€™s epoche (phenomenological reduction). As far as I know, it was the first time that such a phenomenological principle was introduced in natural sciences. We will see later that it is the bridge linking the physical foundations of phenomena with their semiotic form.

5.2.3. The independence from the substratum

CT aspires to be

> â€œa theory of **morphogenesis** *in abstracto*, purely geometric, independent of the substratum of forms and of the nature of the forces which create them.â€ť

> â€œIn catastrophe theory, there is need for a synthetic method which, to some extent, is inherited from the old *Naturphilosophie*. In my opinion, if we observe phenomena from a distance, we notice that several morphological accidents seem to be independent of the nature of the entities they involve. The classification of these general and ubiquitous phenomena allows us to isolate â€œentitiesâ€ť which operate locally in these dynamics, and which I refer to as *logoÃ¯*, or archetypes. In principle, these archetypes can manifest themselves on any

[1] Thom, 1980a: 101.

[2] Thom, 1972a: 20.

[3] Ibid., p. 23.

[4] Ibid., p. 24.

> substratum whatsoever. (â€¦) The theory of elementary catastrophes is in some way a theory of the most general substratum, that is, of the undifferentiated substratum, and I would say, of the *materia prima* of the scholastics.â€ť

This principle is certainly most astonishing:

> â€œThe main idea of our theory, namely that a certain understanding of morphogenetic processes is possible without recourse to the special properties of the substratum of forms, or to the nature of the active forces, could seem difficult to accept, especially for the experimental scientists used to cutting the flesh and who are always confronted with a reality that resists them.â€ [1]

It asserts that for the morphological order, causality is structural and formal before being physical and material. It is justified by:

(i) the evidence that, at least locally, the morphology and the **morphogenesis** of phenomenological accidents are essentially *underdetermined* relative to the internal generative dynamics, and

(ii) the demonstration that they undergo drastic mathematical (geometrico-topological) constraints, so drastic as to permit, in the elementary cases, the reconstruction of a minimally complex generating dynamics.

It does not surprise anybody today, if we say, for example, that space-time geometry constrains the physics of elementary particles to the extent of largely determining it. Or that for purely topological reasons the movements of integrable Hamiltonian systems are quasi-periodic movements on invariant tori, or still that self-reproduction requires, according to Von Neumann's theorem, a structure of â€œgenetic codeâ€ type. Thus, we neednâ€™t be astonished by the fact that the morphological order can also be constrained by a geometric *eidos* that â€œnatureâ€ is â€œobligedâ€ to realize materially.

5.2.4. Hylemorphism

> â€œIn a being â€” or object â€” we distinguish, classically, its existence i.e., the fact that it fills a certain portion of space-time, and its essence, that is, the totality of its attributes and qualities. The materialist perspective, common in science, insists that existence precedes essence (in fact, existence implies essence); the CT model of **morphogenesis** counters this axiom, for it presupposes that, to a certain extent, existence is determined by the essence, the set of qualities of the being. What we have here is a return to the Aristotelian notion of hylemorphism: matter aspires to form.â€ [3]

[1] Thom, 1980d, Chapter III.

[2] Thom, 1966, and 1980a: 10.

[3] Thom, 1980a: 87.

The general silence on these questions is largely due to the Galilean-Newtonian tradition which imposed an ontological primacy of force over form.

> â€œThere is hardly any reason to think that force has, in principle, a deeper ontological status than form. (â€¦) I think that, in a very general sense, the concept of form is infinitely richer and more subtle than that of force.â€

The subtlety and the richness of the concept of form becomes particularly evident when we move from the local archetypes to their integration in stable global structures. [2] In such an integration the specific internal dynamics recovers their rights.

> â€œMatter often imposes additional constraints of rigidity, symmetry, and certain invariance of volumes, etc., and consequently, the theory of singularities has to be modified. This modification manifests itself empirically in the specific nature of the singularities: for example, the singularities of clouds are not the same as the singularities of an iceberg, or of a rock.â€

> â€œWhy is it that the form of clouds is not the same as that of mountains, why is the form of crystals not that of living beings? I would answer that our model aims only to classify the *local accidents* of **morphogenesis** that we call *elementary catastrophes*. But the macroscopic global appearance, or form in the ordinary sense of the term, comes from the aggregation of a large number of such local accidents; and the statistics of these local catastrophes, the correlations which govern their appearance in the course of a given process, are determined by the topological structure of their internal dynamics; the integration of all these accidents into a global structure will require â€” if we wish to pursue the application of our model â€” the consideration of catastrophes on spaces of dimensions much larger than the usual three. It is because of the topological richness of the internal dynamics, and their more or less integrated character, that one can ultimately explain the nearly infinite diversity of appearances in the external world, and perhaps also the fundamental distinction between life and non-life.â€ [4]

5.3. CT as a mathematical phenomenology

As soon as CT legitimizes the bracketing (phenomenological reduction) of the internal generating dynamics, as soon as it can provide a precise mathematical interpretation of appearances as the expression of being, it can be applied as well to physical substrata where one can, in principle if not in fact, make explicit the internal dynamics, as to non-physical substrata where such an explicitation is impossible. We see

[1] See, Thom, 1980d, Chapter III.

[2] For an examination of the Local / Global opposition, see **Petitot**, 1979b.

[3] Thom, 1980d, Chapter III.

[4] Thom, 1972a: 24-25.

that CT always aims at a mathematical description of the morphological manifestation, but, depending on the case, it opts for either a phenomenological bracketing or a physicalist explicitation regarding the generating dynamics. Whence its ontological neutrality. It is compatible *both* with physicalist reductionism which causally deduces form from matter and hylemorphic idealism which ascribes form to matter.

CT is thus a *mathematical phenomenology* that works out a synthesis of the physicalist and structuralist viewpoints; what Thom calls a *geometrization of concepts* establishing a mediation between natural phenomena and signification (hence between natural sciences and semiotics). It functions in opposite directions in natural sciences and social sciences. In natural sciences, it results in the integration of a morphological phenomenology to physical objectivity. But, in social sciences, it naturalizes semiotic structures.

Actually, I believe that the transcendental relevance of CT is that its â€œstep backâ€ù towards appearance and manifestation is at the same time a naturalization of **meaning**.

> â€œIn social sciences the use of natural language and of purely conceptual thinking leads to a way of reasoning which is often extremely intricate and subtle. (â€¦) If we are able to translate such reasoning into a purely geometric (topological) picture, then we may ensure to a large extent the objectivity of this thinking; by using the â€œdistanciationâ€ù effect of

> geometric representation, we can break the hermeneutic circle which has kept imprisoned so many of social science thinkers.â€ù [1]

> â€œOne of the biggest difficulties in Semantics is that, when we wish to analyze **meaning**, (â€¦) we are *in* **meaning**. (â€¦) That is why, to succeed in doing an objective and scientific analysis of **meaning**, we should be able to be distanced from it. (â€¦) In this lies the great interest of a geometrization of **meaning**. To the extent we can geometrize the processes bearing significations by rendering them inert, we can submit them to a combinatorics which falls outside the traditional semantic categories. It is precisely this type of analysis which is made possible by the geometrization associated with Catastrophe theory. (â€¦) Geometrization of the semiotic processes is extremely interesting because it is able to break the â€˜semiotic circularityâ€™.â€ù

Thus catastrophist hermeneutics, far from eliminating **meaning** in a formalist manner, attempts to reduce its subjectivity by substituting

> â€œsemantic intuition which is of a directly subjective nature, with geometric intuition which spatializes its object, and distanciates it from the thinking subject.â€ù

[1] Thom, 1980b.

[2] Thom, 1980d, Chapter IV.

[3] Thom, 1980a: 123.

Of course, this substitution is possible only by considerably extending geometric intuition. In this sense CT is a â€œlanguageâ€ù which is â€œformalâ€ù in an entirely new sense. It is not a symbolic, but a topologico-geometrical language, whose semantics is geometrized and whose syntax is constructed locally from the most simple and archetypal events and interactions. Just as for the morphological order the integration of local accidents into a global structure is a central problem, so for this language, contrary to the formal languages, integration of local syntactic structures, iteration and recursion, in short,

generativity, constitute a central problem, still completely unexplored and which should become the goal of a â€œdynamical topologyâ€ù.

5.4. Critique of logicism

It is then understandable that the catastrophist point of view levels constant objections against the purely symbolic points of view. Its critique is twofold.

5.4.1. Extensionality / Intensionality

Firstly, though highly relevant in mathematics, the logicist-formalist conception is fundamentally inappropriate to the study of natural languages because:

(i) linguistic concepts, as opposed to mathematical ones are vague and â€œnon-constructedâ€ù concepts;

(ii) grammatical recursivity is so poor that it is not a recursivity in the logical sense of the term.

> â€œFrege (â€¦) stands in opposition to Russell and Hilbert (â€¦). He always wanted the axioms to be *true*, and not empty postulates. His logic was basically intensional and not extensional. It is only by invoking the â€˜principle of extensionalityâ€™: â€˜the intension of a concept determines its extension and vice versaâ€™, that he was able to establish a logic of a combinatorial and formal type. Now, closer observation shows that the extension of a concept in natural language is a â€˜fuzzyâ€™ set whose limits can never be defined â€” supposing that they exist independently of the idiolect of any individual speaker. This means that every extensional logic is fundamentally inadequate to describe the mode of reasoning specific to natural language. Hence the basic impossibility of reducing a theory of natural language to a Boolean or Fregean type of logic. A logic that would account for natural reasoning is necessarily intensional and it is obtained necessarily via a theory of the concept seen as an intensional entity. How can we, faced with such massive evidence, still hold on to dogmatic anti-psychologism ?â€ù [1]

[1] Letter of R. Thom to G. Granger (July 28, 1979).

> â€œAny true logic has to be intensional and cannot be extensional unless it deals with concepts of an artificial kind, whose extension can be generated by a constructive procedure.â€ [1]

Whatever be the advances made by Kripke, Hintikka, and others in their interpretations of intensional logics in terms of possible worlds, the central question of a *qualitative* logic of the concept is still widely open.

5.4.2. Cinematics / Dynamics

The second criticism leveled against the formalist-logicist points of view no longer concerns their inadequacy to the structure of natural languages, but their ability to model phenomena adequately. When we model a real system by a formal system *P*, we assume that

> â€œevery state *A* of the phenomenological process under consideration can be parametrized by a system of propositions *a* of the formal system *P*â€

and that

> â€œif, in course of time, the state *A* is transformed into the state *B*, *B* can be parametrized by a set *b* of the system *P* such that *b* can be formally deduced from *a* in *P*.â€

In other words, we assume that we can interpret temporal succession in terms of logical implication. But,

> â€œevery model consists *a priori* of two components: a cinematic component whose role is to parametrize the forms or the states of the process, and a *dynamic* component whose role is to describe the temporal evolution between the forms.â€ [3]

The logicist conception implicitly postulates that *a formal cinematics can stand for a dynamics*. Such a dogma has evidently many advantages:

> â€œAn axiomatic or combinatorial type of description is very easy; deduction is formalized, and theoretically mechanizable.â€ [4]

But it remains nevertheless a fundamentally erroneous conception, for â€œ*no dynamics is possible*â€ in that context. Hence the necessity of introducing dynamical models for the

topological understructures: in order to overcome the triviality of their formal cinematics,

[1] Thom, 1980b.

[2] Thom, 1972a: 18.

[3] Ibid., p. 19.

[4] Ibid., p. 37.

structural formalizations should include underlying dynamics providing a morphological realization of their combinatorics and their surface axiomatic rules.

5.5. Centrifugal dynamics

At the beginning of Chapter 10 of *Structural Stability and* ***Morphogenesis****,* RenÃ© Thom comments on the following passage from UexkÃ¼ll's *The Theory of* ***Meaning*** which sums up the problem:

> â€œAny machine, for example, a pocket-watch, is always constructed centripetally, that is, all the parts of the watch â€" hands, spring, and wheels â€" must always be made first before being mounted on a common frame. On the contrary, the growth of an animal, such as the triton, always takes place in a centrifugal manner, starting from its germ; the *gastrula* appears first, followed by new buds which develop into differentiated organs. In both cases, there is a construction-plan (a design); the watch-plan proceeds centripetally, and the triton-plan centrifugally. Depending upon the plan, the parts are assembled according to completely opposite principles.â€ù

Thom says:

> â€œI do not think that there can be a better way than that description of the physiologist UexkÃ¼ll for characterizing the essential difference that separates the vital dynamics from anthropomorphic constructions with which it is often compared. It is not that the similarities between vital

> mechanics and certain aspects of human technical innovation (automata, electronic computers, etc.) are without any value: but these comparisons are valid only for mounted partial mechanisms which are in full functional activity: they can in no case be applied to the global structure of living beings, nor to their epigenesis and their physiological maturation.â€ù

The major difficulty with every organizational model is to be *compatible with the ontogenesis* of the phenomena they are modeling, that is to say, *to implement the formal cinematics in the underlying generating dynamics*. For structural models, the difficulty concerns the genesis of deep structures.

> â€œThe so-called â€˜deep structuresâ€™ (â€¦) are not really so deep! They are only equivalence classes of surface structures, obtained by means of relatively trivial transformations. Instead, for me, it would be far more interesting to reveal the generating dynamics of deep structures..., just as in biology it would be interesting to reveal the dynamical processes which generate the biochemical morphologies that the biologist studies. But, alas, it lacks an adequate conceptual equipment.â€ù [2]

[1] Ibid., p. 207.

[2] Thom, 1980d, chap. IV.

Due to this lack of any dynamical perspective on deep structures, formal linguistics tends to equate deep structures with their formal cinematics and to solve the question of their genesis using unverifiable innatist hypotheses.

The same can be said about the conception of structural paradigms. Every model of paradigmatic structures should formalize the dynamical processes of differentiation of the semantic substrata into positional values, i.e., *the genesis of the thresholds* which categorize and discretize them. The logico-combinatorial structuralism postulates that the thresholds are constitutive while at the same time treating them formally as already constituted.

> â€œIf we wish to understand how a threshold appears, we are obliged to adopt an ontogenetic as well as a diachronic perspective which explains the genesis of the threshold. But if we wish to explain the genesis of a threshold, we are quite automatically led to consider a situation of the catastrophe type. Evidently, we can also be not interested in the genesis of the threshold and simply wish to understand how an already constituted threshold functions.â€[1]

5.6. Phenomena as morphologies

Thus we see that the catastrophist strategy depends on a redefinition of the primitive â€œphenomenonâ€, which would be at the same time phenomenologically faithful, compatible with physics, and valid for non-physical domains.

This renewed definition view a phenomenon as a morphology, i.e., as a system of qualitative discontinuities on a substratum space. This is an *a priori* which, in RenÃ© Thom's ontology, plays the same role as the *a priori* of spatial extension in classical rationalism. Discontinuity is a pure intuition. Beyond its evident empirical realism, it possesses a transcendental ideality by which it conditions the appearances of phenomena. Discontinuities are inherent to objectivity. But their reality is also perceptual since

> â€œthe discontinuities of morphologies constitute the most (perceptually) salient and the most stable elements.â€[2]

In conceiving them as â€œsubjectiveâ€ in the transcendental sense, we are following Kantâ€™s practice where the invariants of perception are posited as pure intuitions.

If every phenomenon is, in its phenomenological appearance *and* its physical objectivity, a system of discontinuities, then the primary task of scientific explanation is, as we have seen, to mathematically model these systems so as to account not only for

[1] Ibid., chap. III.

[2] Ibid.

their physical origins but also for their describability in natural language. For this, we shall analyse the morphologies into aggregates of stable local accidents (chreodes), and we shall seek:

(i) local dynamical models for the chreodes, and

(ii) global dynamical models of integration and combination of chreodes into global structures.

If such a research program has been formulated only recently, # it is because every discontinuity is a *critical phenomenon* â€" a symmetry breaking of the substratum homogeneity â€" induced by a *singularity* of the underlying dynamics. It depended therefore on mathematical and physical breakthroughs in the conceptual and technical treatment of singularities, bifurcations, and structural stability of non-linear dynamical systems.

The relation between CT as a modeling procedure and CT as a morphological language is well summarized at the end of *Structural Stability and* ***Morphogenesis***.

> â€œ1. Every object, every physical form, can be represented by an *attractor C* of a dynamical system in a space *M* of internal variables.
> 2. Such an object is stable and can be perceived only if the corresponding attractor is *structurally stable*.
> 3. Every creation or destruction of forms, every **morphogenesis**, can be described as the disappearance of the attractors representing the initial forms and their replacement, through capture, by the attractors representing the final forms. This process, called *catastrophe*, can be described on a space *P* of *external variables*.
> 4. Every structurally stable morphological process is described as a (system of) catastrophe(s) on *P* that is (are) structurally stable.
> 5. Every natural process can be broken down into structurally stable parts, or *chreodes*. The set of chreodes and the multidimensional syntax which orders their respective positions constitute a *semantic model*.
> 6. If we consider a chreode *C* as a word in this multidimensional language, the signification of this word is nothing but the global topology of the associated attractors and the catastrophes that they undergo. Especially, for a given attractor, the signification is defined by the geometry of its domain of existence in *P* and the topology of the regulation catastrophes which bound this domain.â€ [1]

This interplay of physics, perception and semiotics, proceeding from the notion of discontinuity as pure intuition, its treatment within singularity theory, and the principle of structural stability, constitutes the phenomenological essence of CT as a synthesis of the physical and structural realms.

[#] i.e., in the seventies.

[1] Thom, 1972a: 321.

5.7. The locality principle

Though in part hermeneutic, CT is nevertheless properly scientific to the extent that it replaces the conceptual â€œmagicâ€ with a geometrization that satisfies the criteria of *locality*. The locality requirement is fundamental in physics where major breakthroughs have consisted in localizing classical theories (electromagnetism with Maxwell, gravitation with Einstein). With the project of geometrizing concepts, CT extends this scientific imperative to non-physical descriptive-conceptual theories, and in particular to biology and linguistics.

But if the locality principle happens to be one of the primary criteria of scientificity, the essence of objectivity will basically depend on the possible extensions from local to global. Now, Thom insisted that, in a very general way, physics relies on the specific extension from local to global which is called analytic continuation in complex analysis.

> â€œPragmatically efficient and predictive mathematical models imply the analyticity of the functions they involve, and of their solutions for temporal evolution. Consequently, this implies that the â€œsubstratumâ€ space on which one works must be provided with a natural analytical structure. Only the *analytic continuation* would allow for the extension from local to non-local that characterizes action.â€ [1]

In fundamental physics, the ground space-time is endowed (at least locally on the cosmological scale) with a natural analytic structure. Furthermore, *all the other spaces are explicitly derived from this ground space-time and inherit, in one way or the other, its analytic properties*.

> â€œIn fundamental physics, the internal spaces which must be introduced for describing the physical entities can be directly related to space-time or to its equivalence groups by well-defined mathematical constructions. *Nothing more is needed for explaining the main fundamental laws and their analytic character*.â€ [2]

The fundamental physical laws would express the analytic properties of

> â€œthe â€œregulationâ€ of space-time vis-a-vis the accidents it undergoes.â€ [3]

If Thom emphasizes this point so much, it is because it characterizes physical objectivity within an *extended* rational framework and therefore allows to define *alternative* types of objectivity. Actually, the notion of singularity represents another grand mathematical procedure â€" alternative to analytic continuation â€" for the extension

[1] Thom, 1980a: 116.

[2] Ibid., p. 118 (our emphasis).

[3] Ibid.

from local to global. Singularities can unfold in spaces endowed with a â€œweakâ€ geometrical structure. That is why,

> â€œinstead of the global regulation of space-time, we can envisage these local qualitative regulations which give birth to the typical forms (animate or inanimate) listed under recognizable (and identifiable) individuals.â€

Thus, structural â€œphysicsâ€ which conflates a phenomenological revival in natural sciences and a physicalist objectivization in structural semiotics is still a â€œphysicsâ€. But, it is a â€œphysicsâ€ founded on an altogether different procedure of extension from local to global and which, as a consequence, does not satisfy any one of the normative scientific criteria prevalent in fundamental physics. It is an alternative â€œphysicsâ€ which transforms the morphological order into a new order of objective legality.

5.8. Mathematics and reality

In attempting to geometrize concepts, CT seeks to overcome the positivist conception of rationality. It reintroduces the primacy of the theoretical dimension and reopens the question of the role of mathematics in the constitution of objectivity.

> â€œThe concordance, often observed in several disciplines relating to animate and inanimate world, between an empirical morphology and a mathematical structure brings up a classical problem of epistemology. We can address it with three types of responses:
> 1) The first attributes this agreement to a â€œpre-established harmonyâ€ù between mathematics and reality. This is the Platonic (more exactly, Pythagorean) response: God always employs geometry.
> 2) The second attributes the appearance of the mathematical structure to a phenomenon of local equilibrium, or as it is said in Mechanics, to the solution of a problem of extremality.
> 3) The third â€" which I advocate â€" attributes the appearance of the structure (and the morphological repetitions that it gives rise to) to a hypothesis of *genericity*: in all circumstances, nature realizes *the least complex* local morphology compatible with initial local data.
> The first response is pure metaphysics. Only the second can be considered strictly scientific, because it can be sometimes submitted to quantitative testing. (â€¦) The third response is mid-way between science and metaphysics. (â€¦) The second and third viewpoints are moreover not incompatible. (â€¦) The advantage of the third point of view lies in not taking sides at once on the question of determinism in the evolution of structures. In the third perspective, determinism is less *a priori* given than a conquest.â€ù[1]

[1] Ibid.

[1] Ibid. pp. 143-144.

CHAPTER II

CATEGORICAL PERCEPTION AND TOPOLOGICAL SYNTAX

A DOUBLE APPLICATION OF MORPHODYNAMICAL MODELS TO THE DOUBLE ARTICULATION OF LANGUAGE

In this chapter we will see how and why the catastrophist point of view is required in two key domains of structuralism, namely, phonology and structural syntax, corresponding respectively to the second and first articulations of language. We begin with phonology (Sec. 1) since it is, we recall, at the foundation of modern structuralism. The analysis of the fundamental phenomenon of categorical perception (Sec. 1.1 and 1.2) â€" already referred to in I.2.5 â€" will further provide a natural opportunity to sketch the principles of catastrophist models (Sec. 1.3) [1] We will then present some reflections on structural syntax. After describing the actantial schematization for different conceptions of grammar (Sec. 2, 3, 4) and criticizing the formalist point of view of transformational-generative grammars (Sec. 2.2, 4.1), we will show the close relationship that exists between catastrophist schematization and case grammars (Sec. 5). Then we will go on to identify the topologico-dynamical conception of deep cases with a renewed version of the localist hypothesis (Sec. 6).

1. PHONOLOGICAL CATEGORIZATIONS AS CRITICAL PHENOMENA

Let us elaborate on the generalities already presented in Sec. I.2.5.

1.1. Categorical perception

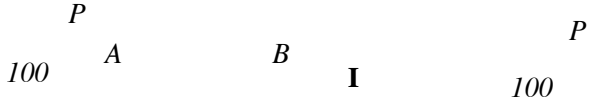
1.1.1. Definition

Discovered by A. Liberman in 1957, categorical perception is contrasted with continuous perception. Let us consider a â€œcontinuumâ€ù of stimuli ranging from an initial syllable $S_1 = C_1V$ to a final syllable $S_2 = C_2V$ with the same vowel V, the consonants C_1 [1]

[1] We will be rather concise concerning this theme, for we have treated it extensively in our book on phonology: **Petitot**, 1985.

and C_2 (in general stops) differing only by a single acoustic cue (e.g. voicing as in [ba]/[pa], [du]/[tu], etc., or place of articulation as in [bo]/[go], [pi]/[ti], etc.) This ideal â€œcontinuumâ€ù is in fact concretely a discrete series of N stimuli (where N is in general between 10 and 20) of which the first and the last are natural (i.e. articulatorily producible) and the others synthetic. With respect to this experimental material, a group of subjects are submitted to tests of identification and discrimination.

The results show that there is *no intra-categorical discrimination*: subjects discriminate two neighboring stimuli n and n+1 only if they are on either side of an interface separating two adjacent categories. In other words, and contrary to what happens in cases of continuous perception such as color perception, discrimination is subordinated to identification, that is, it takes place on an absolute and not a relative basis (see fig. 1).



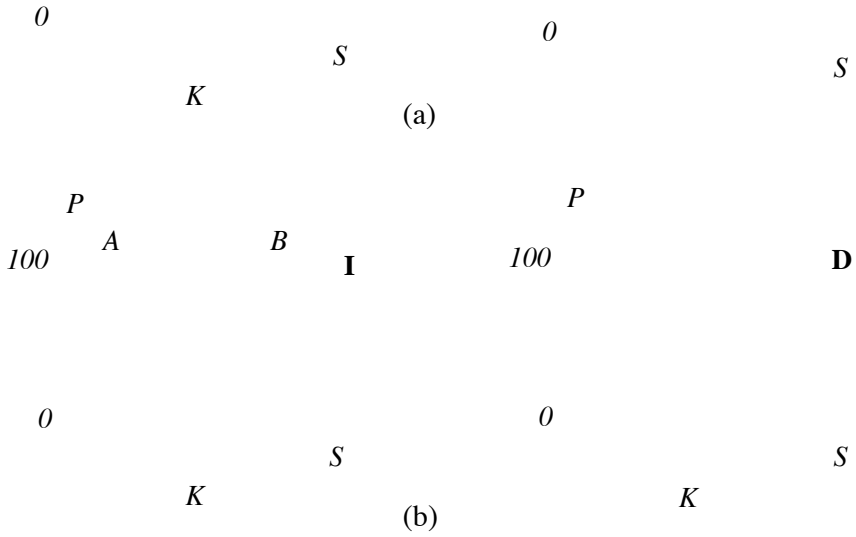


Fig. 1. (*P* = %, *S* = Stimuli, **I** = Identification, **D** = Discrimination, *K* = Boundary).
(a) Continuous perception.
(b) Categorical perception.

As M. Studdert-Kennedy and A. Liberman pointed out,

> â€œcategorical perception refers to a mode by which stimuli are responded to, and can only be responded to, in absolute terms.â€ [1]

[1] Studdert-Kennedy *et al*., 1970.

1.1.2. Function

The functional importance of categorical perception is evident. It is the absence of intra-categorical discrimination which ensures perceptual discretization, and thus enables the audio-acoustic flow to be the base for the phonological code. This discretization

essentially concerns the consonants (and especially the stops), that is, the phonemes which are strongly encoded in the flow (the perception of vowels and fricatives is more continuous than categorical). The encoded phonemes are categorical as immediately given to perception and probably there exists a specific mode (a â€œspeech modeâ€ù) for their processing and decoding.

1.1.3. General abstract situation

The phonetic phenomena of categorical perception result from the manner in which the acoustic cues control the percepts. [1] They correspond to the following abstract situation. Let u_1,â€¦, u_n be parameters (acoustic cues) varying over a space W and controling the internal states of a â€œblack boxâ€ù S (perceptual system). What is to be understood is how a controlled system can categorize its control space. This is a situation quite different from those described in automata theory. In fact, instead of sets of discrete inputs and outputs, the outputs being produced from the inputs via transitions between discrete internal states, what we are concerned with here is a continuous set W of inputs acting as control values, the transitions between the internal states having to generate not outputs, but a system of boundaries K (thresholds, discontinuities) in the external space W. There are typical physical cases of this general situation, namely the phase-transition phenomena. In this sense, it is legitimate to treat categorical perception as an induction of â€œphase diagramsâ€ù in the spaces of acoustic cues controlling the percepts.

1.1.4. Examples

In the late sixties and the early seventies, a number of crucial experiments were conducted on categorical perception. The boundaries K induced on the VOT axis [2] by the identification of basic pairs of stops [b] / [p], [d] / [t] and [g] / [k] were studied intensively. Pioneering experiments were conducted in 1970 by Lisker and Abramson who analyzed the variation of K as a function of the place of articulation (see fig. 2). [3]

[1] See Liberman *et al.*, 1967.

[2] The VOT (voice onset time) is the acoustic cue for voicing.

[3] See Lisker, Abramson, 1970.

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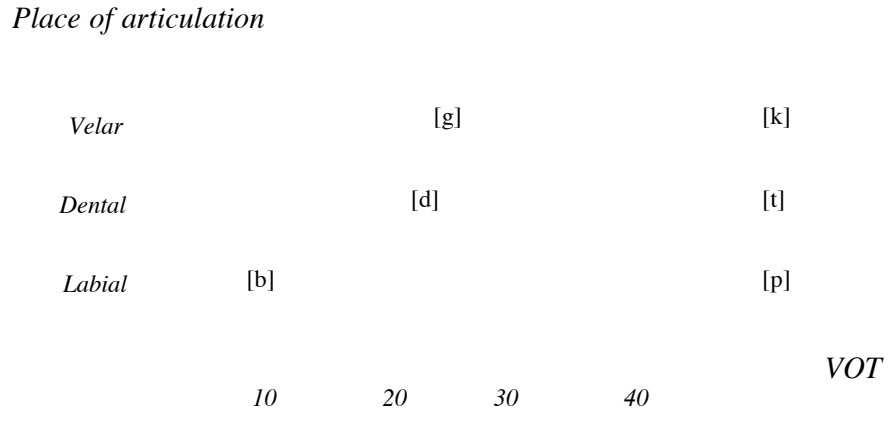

Fig. 2. Liskerâ€™s and Abramsonâ€™s experiments are insufficient: 3 points donâ€™t permit to reconstruct a 2-dimensional categorization.

But these experiments are still quite insufficient. In fact, since place of articulation (as well as voicing) depends on *several* continuous acoustic cues (e.g. the frequency of the plosive burst and the transition of the second formant, cf. P. Delattre's locus theory), the boundary system K induced by categorical perception categorizes a *multidimensional* external space W of dimension r. Now, for classifying and discriminating the percepts controlled by W, it is necessary to decompose W into domains (categories). This requires boundaries K of codimension 1 (i.e. of dimension râ€“1). Further, the fundamental information is the geometric one provided by the morphology of K. Now, as is clear from figure 2, Liskerâ€™s and Abramsonâ€™s results do not permit to reconstruct a morphology of codimension 1 (i.e., of dimension 2â€“1 = 1) in the external space of the VOT and the place of articulation.

However there have been successful attempts at an explicit reconstruction of a phase-diagram in an acoustic control space. One example is B. Reppâ€™s experiment on English fricatives. [1] Repp takes two control parameters, a period of silence â^†S and a period of fricative noise â^†B, and analyzes their cooperation in the discrimination of fricatives and affricates. In the case of an utterance like â€œDid anybody see the gray shipâ€ù,

the external space (âˆ†*S*, âˆ†*B*) is categorized into 4 domains corresponding respectively to the perceptions: [gray ship], [gray chip], [great ship], and [great chip] (see fig. 3).

[1] Repp *et al*., 1978.