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Archetypal Dynamics in Word Semantics: An Application of Catastrophe Theory

In this essay we shall use topological and dynamical concepts, especially those developed by René Thom and others in catastrophe theory, for the study of word meaning. Many semanticists believe that logics and algebra are the only formal means adequate for the construction of a semantic theory. They point to a strong tradition reaching from Aristotle to medieval philosophy and to modern philosophers as Carnap, Montague, Cresswell and others. There exists, however, another tradition starting with Heraclitus (544 to 483 B. C.) which considers the world essentially as something changing and governed by dynamic principles. The basic invariant forms are called *logos*. In modern times gestalt-psychology and, parallel to it, field-linguistics have taken up this tradition, seeking dynamic principles in the organization of cognition and language. We shall not pursue the issue of historical continuity or the question of the merits of the static-logical paradigm against the dynamic-geometrical paradigm.

The most far-reaching and mathematically richest dynamic theory of semantics has been proposed by René Thom (1968: *Topologie et Linguistique*, 1973: *Langage et Catastrophes*), who is the founder of catastrophe theory. Its application to word semantics is based on a larger research work (Wildgen, 1979a) which integrated the short and sketchy proposals of René Thom into the modern framework of interdisciplinary research in semantics.

We shall first present some results of research on human perception of processes, objects and qualities which allow the formulation of some crucial problems of a semantic model which has a cognitive foundation (in chapter one). In chapter two we discuss the semiotic basis of semantics, chapter three introduces the techniques of catastrophe-theoretical modelling and chapter four contains dynamic models related to the problems raised in chapter one. As this is the first essay on catastrophe-theoretical models in word semantics, we have not touched the problem of vagueness and the description of nominal compounding for which solutions have been proposed in Wildgen, 1980b and 1979a.

1. Foundations for a Theory of Word Semantics

1.1 Is the Word a Significant Unit?

The title of this reader presupposes that there is a significant unit called "word", and that a semantic theory must describe it more or less separately. But this presupposition is not obvious as the recent history of linguistics has rather negated the existence of a universal category "word". The relevant positions are summarized in Barri, 1977:

"To me the results of these early discussions seem final: the *word* as we use it is not a linguistic unit but an inexact everyday term, differing in each language and inconsistent within each language in accordance with local conventions of word-separation. . . . In linguistically pertinent descriptions the word has no status or "level of analysis" of its own. It is an accidental agglutination of elements, each word-type happening to cover different morpheme-paradigms, as luck would have it."

This position is perhaps extreme, but it points to some fundamental problems. The separation of levels of linguistic description is, however, less crucial for a dynamic theory which is not hierarchic in the same way as structuralist models. The mechanisms which will be exposed in chapters 3 and 4 can be applied to word semantics as well as to sentence semantics (perhaps even to text semantics, cf. Petitot, 1977). In this essay, we shall, however, primarily deal with phenomena which are traditionally considered as belonging to word semantics (lexicology). It is irrelevant for our treatment to ask whether the distinction of the linguistic level of "words" is appropriate or even universally applicable.

We assume that the dynamic principles governing the semantics of words are intricately connected with basic propositional structures. This is especially true for verbs. Our dynamic treatment of verbs starts with a consideration of the dynamic principles underlying the perception of space and time and of changes, motion, locomotion and action in space and time. The basic assumption underlying our dynamic theory is that semantic phenomena can be explained:

- (a) by the structure of our perception,
- (b) by the structure of the organization of human memory and of human memory retrieval.

The organization of memory is conceived as a selective mechanism which retains the most stable and the most characteristic features which have been perceptually registered. This assumption is plausible in the domain of micro-semantics where the syntactic organisation and the pragmatic and inferential mechanisms are rather poor. In a general semantic theory our archetypal and dynamic component would be a basic stratum whose influence becomes weaker as we progress to the levels of syntax and text (conversation).

In the following sections we shall primarily consider the perceptual mechanism underlying the use of words.

1.2 Perception of Space and Time as a Basis for the Semantics of Nominals and Verbs

In the first months of child development (up to 20 weeks) the child is not able to perceive the identity of objects under the impact of local or temporal changes, i. e. it has not yet acquired the ability to form a complete cognitive image of an object. This ability is, however, acquired in a predictable manner, so that one can speak of a perceptually based concept. The development is independent of the specific social context and of the language to which the child is exposed. The child abstracts from perspectives, contextual and temporal frames in its first concept (for an attempt to integrate such ideas in the framework of intensional semantics cf. Lieb, 1979; psycholinguistic research in this domain was done by Piaget, 1955, Harris, 1973, Butterworth, 1975 and Bamberg, 1979). Later on, this concept will be enriched by various social evaluations, functional embeddings etc. We call this second stage in the development: *attribution stage* (cf. Heider, 1958 and Jones et alii, 1971). On the level of dynamic semantics, we concentrate on the first stage, the biologically controlled development of semantics (the second stage appeals to socio-psychological mechanisms).

We can state the fact mentioned above in more formal terms. Initially an object, *O*, is a domain of existence in space-time. As solid objects cannot overlap spatially (and this kind of objects is primary for our perception), the domain of an object is a first definition of the object. As the child moves (or is moved) and as the object moves or is moved, the domain changes, so that the child perceives many different object-forms. The cognitive development of the child consists then in finding the invariant of "object-forms" under different movements or deformations of the object; this is a necessary achievement prior to naming and labelling.

The perception of processes and their classification is even more difficult because of their transient nature. The recognition of fundamental processes is, however, of paramount importance for the newborn. Our hypothesis states that the newborn is already able to control a limited set of processes (a first learning stage can have occurred already in the womb). Examples of these would be sucking, i. e. taking in fluid material through the mouth and primitive grasping. Even fundamental movements, like primitive walking, seem to be pre-programmed. The first processes controlled by the child are at the same time evolutionarily old processes which are fundamental for the control of primitive animal behavior.

- (a) *Eating, drinking*: more generally absorbing an external object or material. Biologically this process is already present in unicellulars.

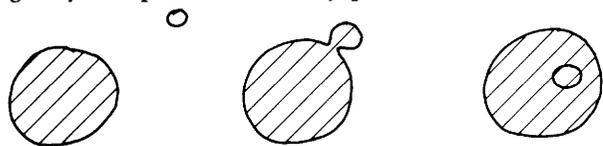


Fig. 1

- (b) *Secrete, expell*: this is the reverse process of (a)

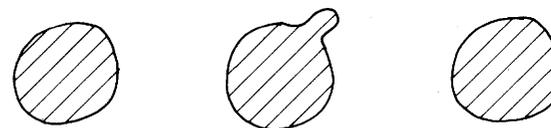


Fig. 2

- (c) *Grasp, take*: this activity is one stage higher in the evolution of the control of one's behavior as it presupposes the existence and the use of limbs, i. e. it is performed by a specialized part of the body. Schematically we have:

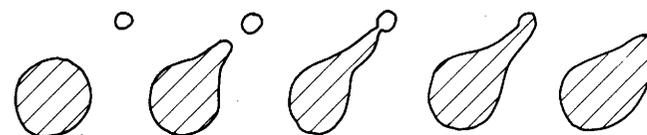


Fig. 3

- (d) The reverse process of (c) is that of *pushing, throwing*

The deeper hypothesis underlying archetypal dynamics says that those process types naturally emergent in living organisms are correlated with dynamic systems and their evolution under deformation. The reason why the formal mechanism of catastrophe theory should model natural processes has to do with the concepts of structural stability and deformation explicated by this theory. These concepts correlate to fundamental self-regulatory mechanisms in living beings.

This hypothesis can be reduced to a simpler assumption (loosing, however, the neurolinguistic and evolutionary dimension) which states that catastrophe theory offers a *language* for the description of events preserving their dynamic character. Events can now be described in a language adapted to the object under consideration.

Events (processes, changes, motions, actions) can be different in multiple ways. First the objects supporting an event typically change their location and their aspect (showing different sides). The constancy of object perception is therefore a precondition of event perception. Second the event itself can be timed differently and be partially obscured (i. e. the object can, for a short stretch of time, be occluded). Finally, the event can be embedded in a complex series of events with repetitions and a change in the objects.

The hypothesis underlying our semantic treatment of events states that they are perceived rather locally and expanded by generalization. This means that there are specific points (dramatic centers) in an event, such that the characteristics of the event can be derived from the process going on in the immediate environment of these points.

To illustrate this crucial point we schematize the event of a cat chasing a mouse. The lines in Fig. 4 symbolize the free movement of the animals. Both come into the (experimental) scene at the left, the cat catches the mouse, holds it for a stretch of time, lets it go and finally catches and devours the mouse.

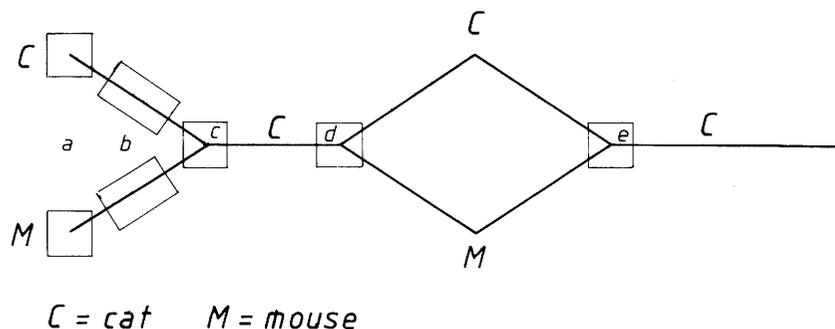


Fig. 4

We can distinguish four different types of local events: (C = cat, M = mouse)

- (a) The objects C and M enter the scene,
- (b) the objects C and M are in the scene,
- (c) the object C catches the object M,
- (d) the object C lets go off the object M, the object M gets away from the object C,
- (e) the same as (c).

(a), (c) and (d) are singular points (isolated) where a change takes place. On the other hand (b) has no singular points and nothing dramatic happens in the environment of (b): (b) is not an event. This rather intuitive view of events is the basis for our dynamic treatment in chapter four, where the points (a), (c) and (d) are derived from different types of catastrophes (= types of fast dynamic changes). We shall introduce the mathematical tools for an exact treatment of basic processes in chapter three.

The perception of objects and processes gets more complicated as the child is exposed to social experience. In rather simple tests of the permanence of objects Bower (1966) showed that whereas very young children (20 days old) reacted strongly to the disappearance of an object hidden for a short time, they did not react to qualitative changes of these objects (color and shape differences). The children of the middle group (40, 60 days old) also reacted to shape/color and to shape differences, whereas the children of the last group (80 days old) also reacted to simple color differences. A consequence of this and of other results is that the child successively acquires a "component structure" of events and processes (cf. also Gibson, 1969: 386). We shall not discuss the theories concerned with the elaboration of this component structure (cf. the "semantic feature theory" of Clark, 1973 and for a critique Bamberg,

1979). On a more fundamental level one can ask how specific qualities are differentiated on the basis of universal perceptual mechanisms. That is to say, we shall consider the first stage where the child passes from quality perception to a semantic classification which is the basis for the linguistic component-structure of words.

1.3 The Perception and Classification of Colors

The controversy about human perception of brightness and colors is very old. An important theory was put forward by Young in the 18th century and was developed by Helmholtz to give the trichromatic scheme which states that there are three fundamental colors: red, green and blue (violet). The values white and black should be the result of an equal distribution of these fundamental colors (for white) or of zero excitation (for black). The modern form of the trichromatic scheme is much more elaborate, it points to the (inferred) existence of three different cone photoreceptors with differently selective photochemical substances (cf. Hurwich, 1960: 200). One of the proponents of this theory is W. S. Stiles who says:

"The crux of the trichromatic scheme is that at some stage in the visual process, all light stimuli, whatever their spectral energy compositions, are converted into an activity specifiable by three variables, and whatever the subsequent elaborations of the response system, stimuli leading to the same values of these variables produce the same visual effects. The further condition must be added that a specification by two variables is not possible. In human colour vision the number of variables (dimension number) is arrived at by experiments on the colour matching of mixtures of stimuli." (Stiles, 1960: 187)

This theory was already challenged in the nineteenth century by Heringer (1874) who proposed a four-color-scheme with oppositions between *red* – *green* and *yellow* – *blue* (and a third pair *black* – *white*). Von Kries (1878) tried to reconcile the two theories in his theory of zones which admitted a three-variable scheme at the level of photo-receptors in the retina and its transformation into a four-color opponent scheme in the later stages of neural connections. Today the two positions are still controversial (cf. Stiles, 1960 and Hurwich, 1960 and for a comparison of the two Krantz, 1975).

Physiological research has corroborated the opponent-cell hypothesis of Hering, since Svaetichin and MacNichol (1958) found opponent schemes in electroretinograms of fish eyes and since the physiological studies by De Valois and Jacobs (1968) confirmed this scheme in monkeys. We can therefore take as given that at a certain stage of retinal color perception the opponent-color scheme is a reality.

These findings acquire dramatic significance when compared to linguistic and anthropological studies of color-naming. Since the classical investigation by Berlin & Kay (1969) which was based on a sample of 98 languages, the field has been very thoroughly investigated (cf. Wattenwyhl & Zollinger, 1979 for a rather short review). As Kay & McDaniel (1978) and Wattenwyl & Zollinger

(1979) show, the linguistic results are in correspondence with the opponent-color scheme which seems to be a universal psychological precondition for cultural color encoding. The existence of such prelinguistic schemes had already been confirmed by anthropological research. Rosch Heider and Olivier summarized their comparison of English and Dani (New Guinea) color naming, saying:

“In conclusion, we wish to argue that, although there are linguistic variables which correlate with color memory accuracy under certain conditions, the nature of color memory images themselves and the way in which they structure the color space in memory appear little influenced by language.” (Rosch Heider & Olivier, 1972: 352)

On the basis of these preliminary statements we can formulate our own position.

Assumption

The semantics of color-words is partially governed by underlying perceptual mechanisms (the opponent-cells scheme) and partially by cultural conventions.

Our dynamic reconstruction of this part of the lexicon will be built on these prerequisites. We shall therefore briefly summarize the basic physiological and anthropological findings.

Fig 5 is a simplified version of Fig 5 in De Valois & Jacobs (1958: 539), where the discharge patterns of the six principal types of macaque (primate) lateral geniculate-nucleus cells in response to various light flashes were measured. The thickness of the bars indicates the intensity of firing.

	Inhibitor	Excitator
+ white		
- white		

Fig. 5 a

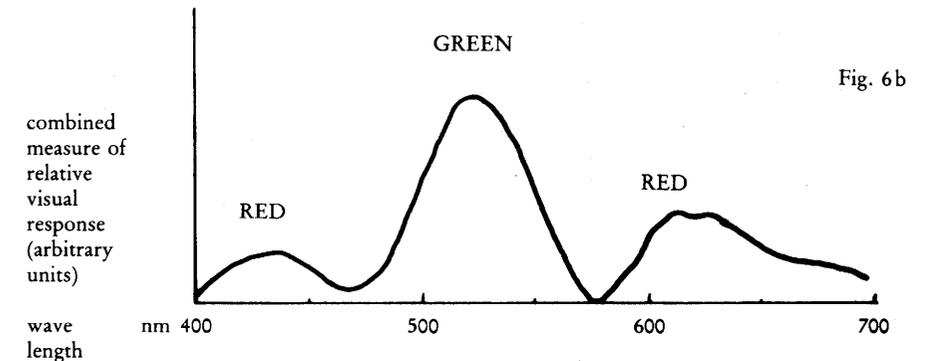
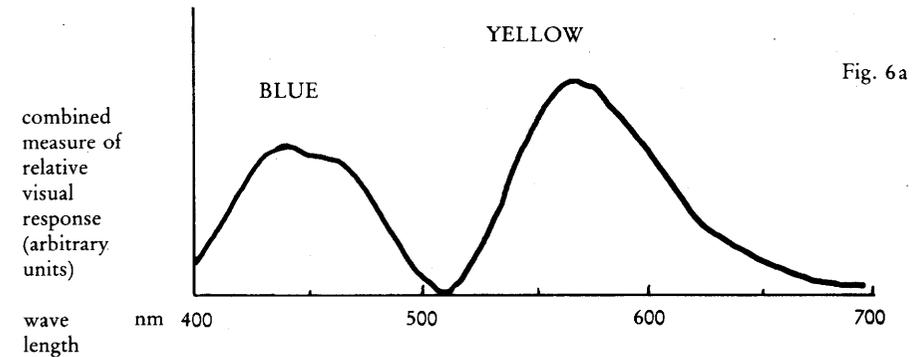
The relative intensity of reaction of the four cell types show maxima and minima, which correspond to the opposition referred to in the labelling of these cells. The (+ B - Y) cells have a reaction maximum with blue light (450 nm) and a minimum with yellow light (500 nm) and so on.

As Figure 5b does not directly consider the fact that the opponent cells operate together, we can estimate a combined measure for the two opposition pair ($\pm B Y$) and ($\pm G, \pm R$). We get functions with two main maxima. Fig 6a

nm	cell type	(+B -Y)	(+G -R)	(+Y -B)	(+R -G)
Blue (450 nm)					
Green (510 nm)					
Yellow (580 nm)					
Red (660 nm)					

Fig. 5 b

and 6b show the results (compare Hurvich & Jameson, 1957: 396, Krantz, 1975: 307 and Kay & Mc Daniel, 1978: 619, where the same facts are displayed with the help of opponent scales).



For the opposition "white-black" the curve with two maxima is even sharper as Fig 5a has already suggested. The linguistic-anthropological research on color terms is largely congruent with these results. Kay & Mc Daniel (1978: 629–636) distinguish:

- six *primary* color categories (white, black, red, yellow, green, blue)
- composite* categories: these occur in all stages that have not yet developed terms for all six primary color categories, e.g. *rax = grue* in Quechi
- derived* categories: they are intersections of the primary category terms, e.g. orange.

Moreover, the cultural evolution of color-terminology follows laws predictable by the opponent-color scheme. Kay & Mc Daniel (1978) have formulated an evolutionary sequencing rule, which summarized the results of a large amount of intercultural research on color terms. The primary colors are only encoded after stage V (see below).

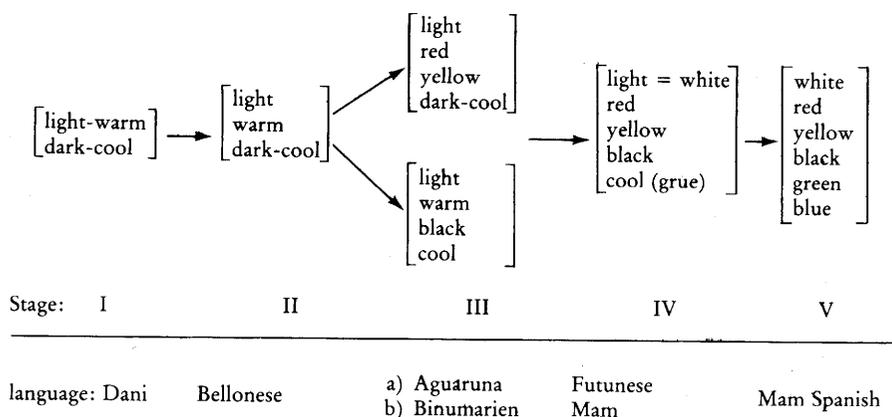


Fig. 7 (cf. Kay & McDaniel (1978: 639 (Fig. 13) and 640f))

The development at stages VI and beyond encodes intersections of primaries and produces the color terms: brown, pink, orange, purple, grey etc. The development is still going on and one can observe how several presently non-basic color terms become basic in parts of the linguistic community (aqua/turquoise (green + blue), marron/burgundy (black + red), chartreuse/lime (yellow + green) (cf. Kay & Mc Daniel, 1978: 641).

In chapter four we shall reconstruct both the field character of color perception and labellings as well as the dynamics of color naming evolution in the framework of archetypal dynamics. Fig 6a and 6b as well as the patterns of successive differentiation of a lexical field in Fig 7 strongly suggest a dynamic modelling, which is more natural than traditional classificatory schemes or the fuzzinezz-model of Kay & Mc Daniel (1978).

1.4 Motion Qualities and Their Labelling

The perception of motion has to fulfill at least three main functions (cf. Richards, 1977: 427):

- It must disregard the effect of the average flow of motion to perceive differential local movement.
- The motion analyzer "should be made up of antagonistic pairs of units, in which each of the subunits (arrows) responds optionally to movement in the same direction" (ibidem).
- It must be able to pay selective attention to different motion channels.

Our knowledge about the neural mechanisms achieving these functions is, however, poor. We can only consider very basic principles, such as the one realized by the Barlow-Levic motion detectors. Given a general direction of motion, one can distinguish the perception of moving "bugs" and moving edges. The excitation of the detector is symbolized by \rightarrow^+ the correspondent inhibition by \rightarrow^- .

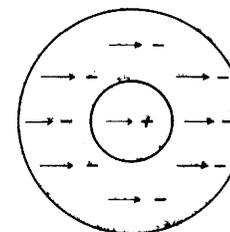


Fig. 8a

"bug"

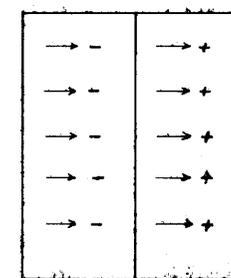


Fig. 8b

"edge"

The mechanism is similar to the opponent-cell scheme mentioned in the last section. It also points to a dynamic model containing antagonistically organized fields. We shall propose a first dynamic description of these antagonistically organized fields.

In the first sections of this chapter we pointed out archetypal activities which are evolutionarily very old and whose control and recognition is biologically prestructured. At an intermediate level between fundamental motion perception and archetypal activities we find simple movements like walking, running, jumping. These are locomotion-schemes, which are partially inborn (the newborn shows walking reflexes, which are lost in later development).

The studies of Johansson (1973, 1975, 1977) show that human locomotion has a very clear structure which can be described as a composition of cyclical movements of critical points of the body. In Johansson, 1977 : 391 he traced on film lines of movement by attaching light spots to the joints of a person and in Johansson, 1975 : 384f he presented a vector-analysis of the movements of hip, knee and ankle in human locomotion. Our hypothesis is that the funda-

mental cyclic motion schemes underlying these structures are parallel to the contraction movements of the heart, which is an archetype of human locomotion (in a more general sense). We shall elaborate this hypothesis in chapter four. This principle has already been applied in the opponent-cell scheme and in the scheme of differential movement recognition.

1.5 Bipolarity in the Naming of Qualities

It is a well known fact that many adjectives, especially those which are gradable:

- (1) occupy, antagonistic positions in the underlying quality space (in a specific quality dimension),
- (2) that they are context-dependent in the sense, that their denotation depends on the nominal head which is modified, or even on larger contexts of use.

In linguistic literature these adjectives are called "relative adjectives" (Bartsch, 1972), "measure adjectives", "adjectives of degree" (Cresswell, 1976) or "polar adjectives" (Kaiser, 1979). The problem is a traditional one, but the formal treatments up to now have not caught the fundamental mechanisms of this field of word semantics. If we consider criteria (1) and (2) above in the light of the psychological analyses in the last passages of this chapter, we will notice that in (1) the principle of antagonistic organization reappears. This has already applied in the opponent-cells scheme and in the scheme for differential movement recognition. The criterium (2) (above) is strongly related to the constancy effects we have already noticed. That is to say, features are detected in contrast to a uniform background. The fact that many adjectives tend to bipolarity seems to be a universal. The cross-cultural application of the semantic differential by Osgood, May & Mivon (1975 : 352) showed a remarkable stability of the typical polar scales used in this method.

The hypothesis of a universal bipolar nature of modifiers would be too strong. One has to consider:

- (1) The multi-sense or even homonymous nature of many adjectives.
- (2) The different relations an adjective can take to other adjectives. The semantic opposition is one of the most salient features of the semantic organisation of modifiers.
- (3) One precondition for bipolarity is the existence of an underlying scale, i. e. the adjectives must refer to different degrees of a quality scale.
- (4) We have to consider compromise values in the domain of a bipolar scale, i. e. the subdivision of the scale can be tripartite.
- (5) A scale can also be broken down into partial scales, i. e. an iteration of the polarity-principle is possible.
- (6) One end of the scale can be taken as *pars-pro-toto* in considering the whole scale. This is the case in sentences like:
 - (i) Tim is five years old

The adjective "old" stands for the whole scale, whereas in (ii) it stand only for a specific domain of the scale:

- (ii) Andrew is old

We shall consider some fundamental features of this important field of word semantics in section 4.4.2. The concepts of scale and of dominant zones of the scale call for a dynamic treatment in our framework.

1.6 The Main Tasks of a Dynamic Model in Word Semantics

In the last few sections of this chapter we have sketched a series of fundamental problems in the domain of word semantics, which call for a treatment in the framework of a theory of word semantics. The list of problems could easily be extended to semantic fields and to diachronic changes in the lexicon. We have chosen to deal with rather fundamental problems because our descriptive tools are not yet fully developed (the research done in Wildgen, 1979a is the first since Thom proposed his theory in the late sixties).

The next chapters will develop a larger semiotic framework, in which our model can be embedded. The dynamic theory of semantics is not a new variant of structural or logical semantics; one has to go further back both historically and in relation to the semiotic foundations of semantics, to describe its philosophical presuppositions.

2. The Semiotic Basis of Our Topological-Dynamic Modelling

We must go back to the semiotics of Charles Sanders Peirce (1839–1914) who was a contemporary of Frege¹. His logical and semiotic conceptions are a good framework for the development of a dynamic semantic theory, because he is not yet affected by the reductionism typical for the semantics proposed by logicians (Wittgenstein was the most lucid critic of this "philosophy"; cf. Wildgen, 1977a: 128–133).

Peirce understands the semiotic sign as a triadic (irreducible) relationship between: representamen, interpretant and object.

"A sign, or *representamen*, is something which stands to somebody for something in some respect or capacity. It addresses somebody, that is, creates in the mind of that person an equivalent sign, or perhaps a more developed sign. That sign which it creates I call the *interpretant* of the first sign. The sign stands for something, its *object*. It stands for that object, not in all respects, but in reference to a sort of idea, which I have sometimes called the *ground* of the representation. "Idea" is here to be understood in a sort of Platonic sense very familiar in everyday talk;" (Peirce, 2.228)

¹ Frege's "Begriffsschrift" appeared in 1879, the main ideas of Peirce emerged in 1865/67 (cf. Oehler, 1979: 10f). It would be an interesting task to compare the positions of Frege and Peirce in the philosophical context of the late 19th century. As Todt (1977) pointed out, Frege was rather a philosophical and mathematical traditionalist, who distrusted the new developments in the mathematics of the end of the last century. It seems that the conflict between Frege and Peirce, which did not take place historically, would still be of much interest.

A first consequence of the irreducible triadicity of the sign is that although semantics is primarily concerned with the relation between *representamen* (sign form) and *object*, the relation of both to the interpretant cannot be simply eliminated. Unlike realistic semantics we must consider the “subjective – internal” aspect of meaning. Semantics without consideration of the user is nonsense, because objects are only correlated with signs (*representamens*) in the context of the semiotic activity of a sign user. A secondary consequence concerns the relation of semantics to psychology and sociology. As the semiotic act has psychological and sociological aspects, every semantic analysis has to be integrated into the field of socio- and psycho-linguistic research. The splendid isolation of logical semantics is theoretically unsound.

The relation between *representamen* and *object* (Peirce’s Secondness) can be subdivided into three aspects:

- Icon
- Index
- Symbol

These aspects are ordered insofar as Index uses iconic principles and Symbol makes use of iconic and indexical devices. The iconic aspect is therefore the fundamental aspect of the relation between sign and object. Semantics must for that reason have an iconic foundation.

“The only way of directly communicating an idea is by means of an icon; and every indirect method of communicating an idea must depend for its establishment upon the use of an icon. Hence, every assertion must contain an icon or a set of icons, or else must contain signs whose meaning is only explicable by icons.” (Peirce, 2,278)

An icon can be an *image*, a *diagram* or a *metaphor* (Peirce, 2.277). Its prominent feature is the similarity of object and *representamen*. The philosophical reflections of Peirce become more concrete, if we interpret our perception and memory as a sort of similarity transformation from the “outer world” which is perceived and experienced to the “inner world” of thought and behavioral planning. The iconic basis of semantics is in this perspective correlated with a world of cognitive analoga in the mind of the sign users.

Peirce’s conception of a similarity as the basis of the iconic aspect of signs is too rough. There are two dimensions which have to be added:

(1) Stability.

As the similarity underlying the iconic relation is always partial, it is astonishing that changes in situations and different constellations of sign users (*interpretants*) do not destabilize the similarity. Each term of the triadic relation is exposed to deformations. The object in the triad can take different forms in time. The sign can change in time or with different sign users. The *interpretants* themselves are exposed to social and psychological variation. Moreover the kernel of the similarity relation, i.e. those features which are constitutive for the existence of a specific iconic relation can change without dramatically altering the relation. The calculi

developed in differential topology over the last twenty years allow a theoretically much preciser modelling of the nature of the iconic relationship.

(2) Selectivity.

Even a photograph reproduces the object only modulo certain simplifications. Selectivity becomes even more dramatic, if we consider diagrams or metaphors. Two sources of selectivity can be considered:

(a) Catastrophic selectivity. Our internal model of the world selects prominent features, i.e. it prefers dramatic (high energy) features over smooth (low energy) features. Looking at a picture, the eye follows the edges, the lines which separate relatively smooth areas. The borderlines are lines of catastrophic changes (changes from one area to another). Looking at an event we select periods of rapid change for the scoping of our attention and for memory storage (cf. chapter 1.2.).

(b) Social selectivity. Certain features are of special interest for our self-evaluation, social position and our goal-oriented activities.

In our theory of archetypal dynamics we shall consider the dimensions 1 and 2a; dimension 2b should be elaborated in a socio-psychological framework. We call this level “socio-attributive dynamics”.

The concepts of “structural stability”, of “invariance of structure under the influence of dynamic deformation” and of “catastrophic jump” are central concepts of catastrophe theory. We shall therefore sketch the mathematical framework of this theory.

3. Techniques of Catastrophe Theoretical Modelling

In this chapter we shall give a very brief introduction to the mathematical tool we want to employ. For a more detailed description cf. Bruter, 1976: 47–247, Poston, 1979, Poston & Stewart, 1978 and Wildgen, 1979a: 51–108. We shall first consider the most simple dynamical systems (= differential equations) and introduce a mathematical correlate of the preformal notions “deformation” and “structural stability” which we have already used in the last sections.

3.1 Some Simple Dynamical Systems and the Concepts of “Deformation” and “Structural Stability”

We consider real-valued and smooth functions $f: \mathbb{R}^n \rightarrow \mathbb{R}$ (\mathbb{R} = real numbers, \mathbb{R}^n = n-dimensional space of real numbers). We can distinguish two principal types of functions (in case $n = 1$):

$$\left. \begin{array}{l} \text{(a) } f(x) = x \\ \quad f(x) = x^3 \\ \quad \cdot \\ \quad \cdot \\ \quad \cdot \\ \quad f(x) = x^{2k+1} \end{array} \right\} \text{the exponent is odd}$$

$$\left. \begin{array}{l} \text{(b) } f(x) = x^2 \\ f(x) = x^4 \\ \vdots \\ f(x) = x^{2k} \end{array} \right\} \text{the exponent is even}$$

We shall first consider the main characteristics of these functions, especially their dynamic features. Second we shall “deform” them to check their stability under deformation.

- (1) $f(x) = x$
This function is linear ($f: \mathbb{R} \rightarrow \mathbb{R}$) and has no critical point (maximum, minimum, saddle). We can prove this by computing the first derivation:
- (1') $f'(x) = 1$
The graph of $f'(x)$ is a line parallel to the x-axis; it does not intersect with the x-axis.
- (2) $f(x) = x^2$
The first derivation gives us:
- (2') $f'(x) = 2x$
This function has one root at $x = 0$. The second derivation gives a constant:
- (2'') $f''(x) = 2$
The critical point of this function is a minimum.

If we consider the function $f(x) = -x^2$, we get a maximum instead of a minimum. Fig. 9 shows the graph of $f(x)$ and its derivations. The first derivation can be represented by a vector-field as in Fig. 10. The arrows along the x-axis indicate the force and direction of the vector-field at several points on the x-axis.

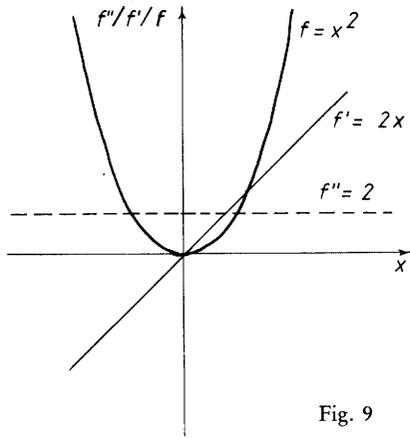


Fig. 9

(As our framework is a topological one we can neglect the specific metric of the scales.)

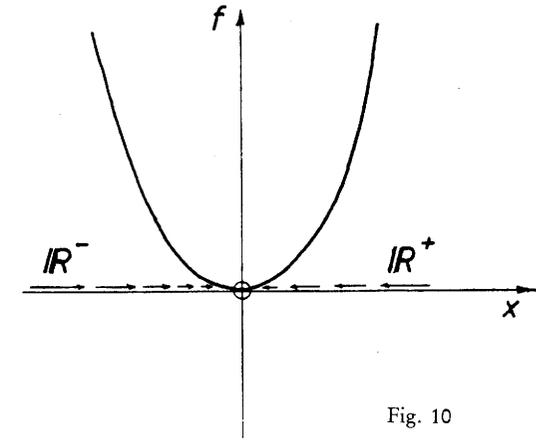


Fig. 10

We can now *deform* the function $f(x) = x^2$ by adding a function $p(x) = 2\epsilon x$; ϵ is a small constant.

- (3) $f(x) + p(x) = x^2 + 2\epsilon x = g(x)$
Seeking for critical points we consider:
- (3') $g'(x) = 2x + 2\epsilon$
The critical point is situated at $g'(x) = 2x + 2\epsilon = 0$ i.e. at $x = -\epsilon$.

Fig. 11 shows the original function $f(x)$ and the function $g(x)$ produced by the *deformation* of $f(x)$. ϵ is assumed to take the value 2.

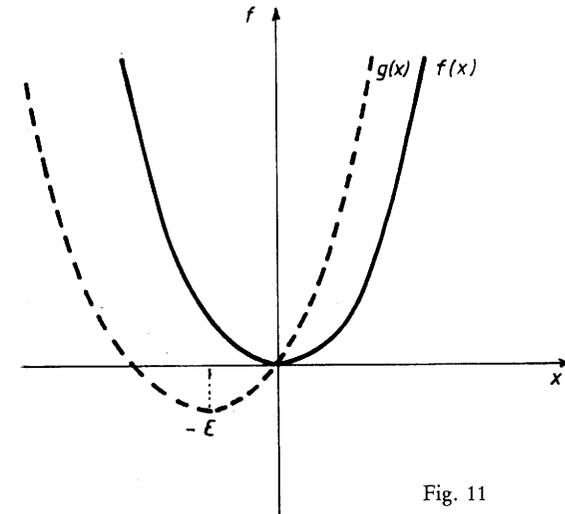
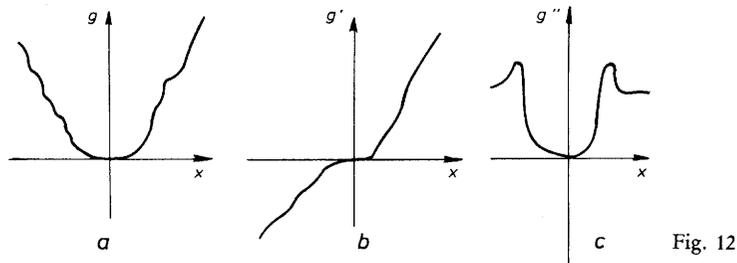


Fig. 11

The two functions $f(x)$ and $g(x)$ are equivalent (by “diffeomorphism”) as their difference can be eliminated by a simple transformation of the

coordinates. They have the same number and type of critical points (i.e. a minimum). In this case we say that the function $f(x) = x^2$ is *structurally stable*. Small deformations can be reduced by a smooth transformation of the coordinates. The term "small deformation" can be defined, if we compare not only the function $f(x)$ to the deformed function $g(x)$ but also the corresponding derivations. Fig. 12 (cf. Callahan, 1974: 222f) shows a deformation which is not small. Whereas $g(x)$ is still similar to $f(x) = x^2$ (and this similarity can be extended to $f'(x)$ versus $g'(x)$), $g''(x)$ is not at all comparable to $f''(x)$ ($f''(x)$ is a line having no critical point whereas $g''(x)$ has three critical points).



We can conclude that the function $f(x) = x^2$ is *structurally stable under small deformations*. This is not the case for the following functions:

- (4) $f(x) = x^3$
- (4') $f'(x) = 3x^2$
- (4'') $f''(x) = 6x$

Fig. 13 shows the graph of the function and those of its derivations:

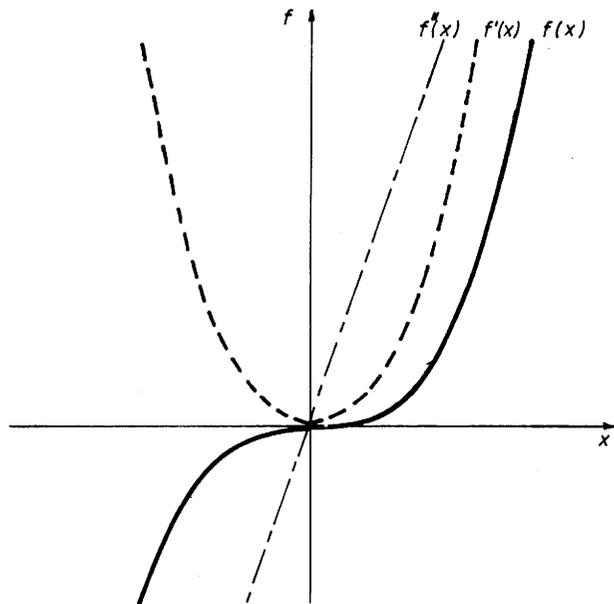


Fig. 13

We can deform this function adding $p(x) = \epsilon x$; ϵ is a small constant.

(5) $f(x) + p(x) = x^3 + \epsilon x = g(x)$

As Fig. 14 shows, $g(x)$ is not structurally stable; different values of ϵ lead to structurally different results. Whereas $f(x) = g(x)$ ($\epsilon = 0$) has one critical point (a saddle), $g(x)$ ($\epsilon < 0$) has two critical points (a maximum and a minimum) and $g(x)$ ($\epsilon > 0$) has no critical point.

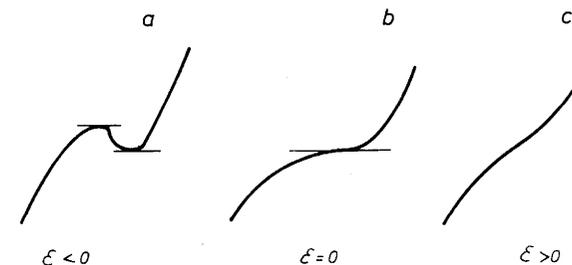


Fig. 14

The situation is similar for the following functions; we abbreviate our description by giving only the graphs corresponding to Fig. 14.

- (6) $f(x) = x^4$
- (7) $g(x) = x^4 + \epsilon x^2$

When ϵ is negative, the function $g(x)$ has three critical points:

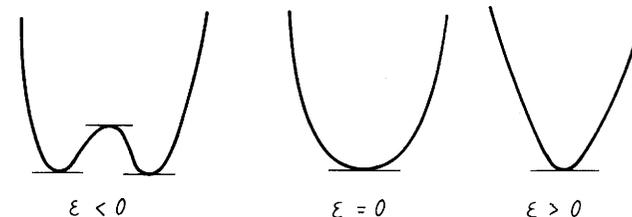


Fig. 15

(8) $f(x) = x^5$

The graph of this function is similar to that of $f(x) = x^3$, but it is more flat at the origin. Fig. 16 shows that the deformed function $g(x)$ takes maximally four critical points.

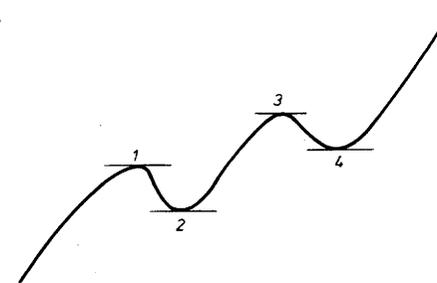


Fig. 16

For a fuller treatment compare Wildgen, 1979a: chapter three.

3.2 Universal Unfolding and the Classification of Elementary Catastrophes

In the last section we have shown the basic distinction between structurally stable functions (dynamical systems) and structurally unstable ones. The consideration of deformations of the first monomic functions has suggested that the evolution of these dynamical systems after deformation is rather systematic. We can ask ourselves now if there are general laws governing the evolution of such systems after destabilization. If such laws exist we should be interested in two questions:

- (1) Are these evolutions structurally stable? If they are, we can consider them as basic types of processes.
- (2) Can we find a classification of types of stable evolutions of dynamical systems? If such a classification exists, it could be the basis for a typology of fundamental processes.

The theory of stable unfoldings developed by Thom, Arnol'd, Zeeman and others gives a positive answer to these questions. In the present context we must confine our treatment to the main results obtained in this field, namely the list of elementary catastrophes (= simple universal unfoldings with corang ≤ 2).

The factors which in the last section "deformed" the original function are now systematically classified. They are called *external variables* or *unfolding variables*. The universal unfoldings are those (versal) unfoldings which cannot be further reduced. They are *irreducible* in the sense that they contain only those external variables which are necessary for the stability of the unfolding. The variables contained in the organizing center of the unfolding (the "germ") are called *internal variables*. Consequently the unfolding function has two argument positions: $f(x, u)$ such that $x = \{x_1, \dots, x_n\} \in \mathbb{R}^n$ and $u = \{u_1, \dots, u_k\} \in \mathbb{R}^k$. $f(x, u) : \mathbb{R}^n \times \mathbb{R}^k \rightarrow \mathbb{R}$.

\mathbb{R}^n : is the space of *internal variables*. Zeeman calls it the *state space* or the *behavior (effect)-space*.

\mathbb{R}^k : is the space of *external variables*. Zeeman calls it the *control space*, because external variables are often interpreted as factors which control (or cause) processes and activities.

As the classification of universal unfoldings is mathematically very difficult and lengthy we refer to Zeeman & Trotman (1973) (an introductory exposition is given in Wildgen, 1979a: 95–98).

Table 1 shows the seven elementary universal unfoldings, their germs, their names and their classification (Arnol'd number, corang, codimension).

Class	Name	Germ	Unfolding	Corang	Co-dimension
A ₂	fold	x ³	x ³ + ux	1	1
A ₃	cusp	x ⁴	x ⁴ + ux ² + vx	1	2
A ₄	swallow-tail	x ⁵	x ⁵ + ux ³ + vx ² + wx	1	3
A ₅	butterfly	x ⁶	x ⁶ + tx ⁴ + ux ³ + vx ² + wx	1	4
D ₄ ⁻	elliptic umbilic	x ² y - y ³	x ² y - y ³ + ux ² + vy + wx	2	3
D ₄ ⁺	hyperbolic umbilic	x ² y + y ³	x ² y + y ³ + ux ² + vy + wx	2	3
D ₅	parabolic umbilic	x ² y + y ⁴	x ² y + y ⁴ + uy ² + vx ² + wy + tx	2	4

Table 1

This very sketchy exposition of a central part of catastrophe theory should be commented on:

- (1) The unfoldings mentioned are very large equivalent classes; the functions contained in Table 1 are only normal form.
- (2) The classification is strictly *local*, i.e. one only considers singular points and their environment. The combination of simple dynamical systems to global ones is part of the "syntax" of catastrophes. The very difficult problems of global catastrophe theory are not yet solved (cf. Jänich, 1977 for some issues in this domain).
- (3) The set of internal variables (cf. the corang) can be augmented by the addition of expressions containing other variables. Such an enrichment does not change the classification of universal unfoldings as these forms can be splitted off.
- (4) We can also augment the number of external variables by considering versal unfoldings.

The applicability of this classification of types of evolutions in dynamical systems is therefore much larger than the enumeration in Table 1 suggested.

3.3 Gradient-Dynamics and Catastrophes

The mathematical framework outlined in the last sections will be specified by postulating additional features of the dynamical systems under consideration. The first specification introduces the notion of "gradient-field". We assume

for our applications that all the attractors of the dynamical system are points (in \mathbb{R}^n : the space of internal variables). This assumption is rather restrictive as many other types of dynamics are possible. Fig. 17 opposes point-attractors with oscillating attractors (type "Hopf").

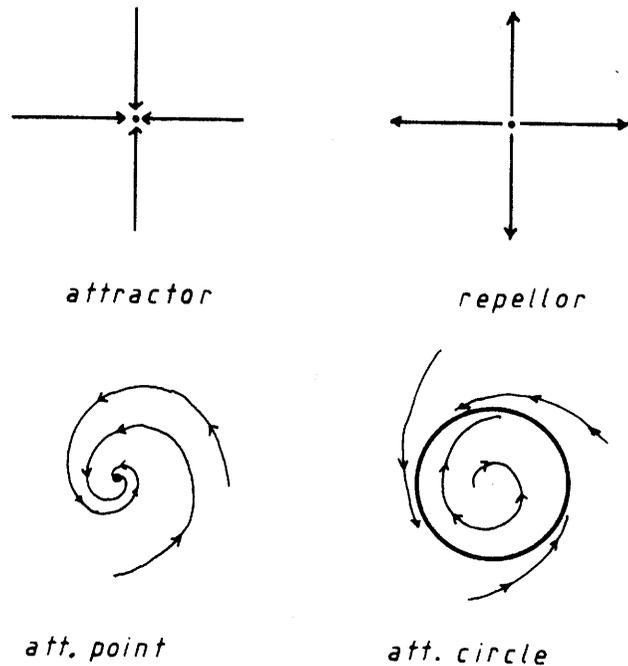


Fig. 17

This assumption is motivated by the great amount of physical applications of this type of dynamics (cf. the gravitational dynamics) and by the fact that this is the simplest assumption. Bruter (1978: 8) says:

“La théorie des catastrophes *élémentaires* ne fait appel qu'à des dynamiques gradients. On peut donc, à ce titre, la considérer comme la *plus simple* parmi toutes les théories de catastrophes possibles. On peut justifier l'attention portée à cette théorie de la manière suivante: l'expérience nous a appris que la Nature, pour autant qu'elle le peut, tend à opérer par les voies les plus simples. Puisque les dynamiques gradients possèdent cette qualité de simplicité, on doit s'attendre à ce que ces dynamiques soient très répandues. Il en est bien ainsi en physique: gravitation, électromagnétisme et optique, thermodynamique parfois.”

One can imagine the effect of gradient-dynamics by considering a hilly district with peaks (maxima), valleys, basins (minima), shelves, passes (saddle points) etc. If an object falls into this landscape it will not rest on the peaks but rather roll into the valleys and eventually stay in some basin. The peaks are called (unstable) *repellors*, the basins are called (stable) *attractors*. The force

applying to the object as it rolls down the valley is called *gradient*. In the case of our example the object falls *down*: we consider the *negative* gradient. We can now introduce in a more formal way concepts we have already used more informally.

For each point u ($u = (u_1, \dots, u_k)$) of the controlspace (\mathbb{R}^k) the *potential field* at the point u is considered: V_u . If $u = 0$ and if we have only one internal variable x , the gradient of V_u can be represented by a vector-field on the x -axis (cf. Fig. 10). In the case of two or more internal variables the computation of the gradient is more complicated. We have to consider partial derivations.

Example:

V_u has the internal variables x_1 and x_2

$$(1) \text{ grad } V_u(x_1, x_2) = \left(\frac{\delta V_u}{\delta x_1}, \frac{\delta V_u}{\delta x_2} \right)$$

that is to say the gradient results from two vectors, one pointing to the maximum in the direction of the variable x_1 the other going in the direction of the variable x_2 . Fig. 18 shows in a graphical way the procedure applied.

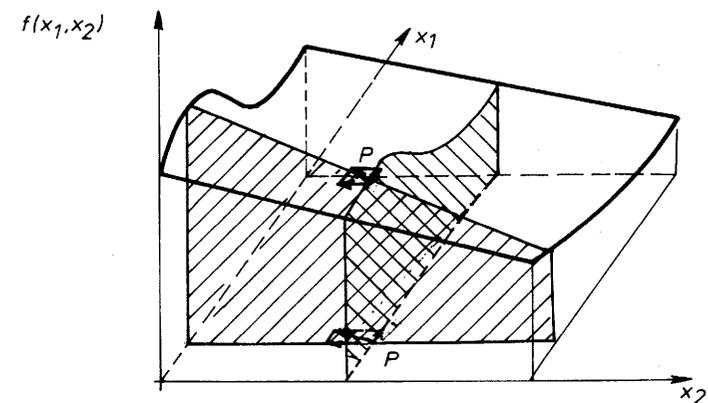


Fig. 18

As we shall only elaborate on unfoldings with one internal variable, the generalization to n variables is not immediately relevant (but we need the notion of partial derivation).

We can define some basic notions of catastrophe theory presupposing the notions of potential field and the separation into the state-space \mathbb{R}^n and the control-space \mathbb{R}^k . The following definitions are based on manifolds in \mathbb{R}^n and \mathbb{R}^k (cf. Bröcker and Jänich, 1973: 1)

$$M \subset \mathbb{R}^n, C \subset \mathbb{R}^k$$

Def. 1: Given a potential field $V_u(x)$, then the pair $(x, u) \in M \times C$ is a *critical point* of $V_u(x)$, if $\text{grad } V_u(x) = 0$.

In the case of $x = x_1$, it follows that critical points must fulfill the equation (2)

$$(2) \text{ grad } V_u(x_1) = V'_u(x_1) = 0.$$

Def. 2: The set of *singularities* of $V_u(x)$: Σ is defined as: $\Sigma = \{(x, u)/(x, u) \text{ is a critical point of } V_u(x)\}$ (also called *catastrophe set*).

Def. 3: The *bifurcation set*: $\text{Bif}(V_u(x))$ contained in Σ is defined as:

- $\{u \in C/\exists x \in M, \text{ such that}$
 (1) (x, u) is a critical point
 (2) $V_u(x)$ is degenerate in $u\}$

Remarks concerning the term: "degenerate":

(a) In the case of $x = \{x_1\}$, i.e. $M \subset \mathbb{R}^1$, the function $V_u(x)$ is degenerate if $V''_u(x_1) = 0$.

Example: In Fig. 13 we showed the derivations of the function $f(x) = x^3$; the critical point was given by: $f'(x) = 3x^2 = 0$, i.e. it was situated in the origin ($x = 0$). At this point the second derivation is also zero: $f''(x) = 6x$ at $x = 0$ gives $f''(x) = 0$. We can say that the origin of this function is a degenerate critical point.

(b) In the case of $x = \{x_1, x_2\}$ i.e. $M \subset \mathbb{R}^2$, the function $V_u(x)$ is degenerate if the Hesse-determinant is zero. The Hesse-determinant can be computed on the basis of the matrix:

$$\begin{bmatrix} \frac{\delta^2 V}{\delta x_1 \cdot \delta x_2} & \frac{\delta^2 V}{\delta x_2^2} \\ \frac{\delta^2 V}{\delta x_1^2} & \frac{\delta^2 V}{\delta x_2 \cdot \delta x_1} \end{bmatrix}$$

The computation of the Hesse-determinant follows the rule:

$$\det \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} = \alpha_{11} \cdot \alpha_{22} - \alpha_{12} \cdot \alpha_{21}$$

(c) If $M \subset \mathbb{R}^n$ ($n > 2$) we must consider the Hesse-matrix and its submatrices. (Cf. Wildgen, 1979a: 83–85 for an example with $x = \{x_1, x_2\}$).

The set of bifurcation points represents one type of catastrophic points, because the dynamics change drastically in the environment of these points. Fig. 13 and 14 give a good impression of a structural change in the environment of a bifurcation point. We shall present further examples in the next section. Another type of catastrophic points exists: these are called conflict-points (or conflict-strata). They occur if two minima have the same potential. Such a point of dynamic equilibrium is unstable.

Def. 4: The set of *catastrophic points* consists of:

- (a) the bifurcation points (cf. Def. 3),
 (b) the conflict points, where two minima of $V_u(x)$ have the same potential.

The term "catastrophic", like the term "catastrophe", refers to similar dynamic features of natural catastrophes (for example the breaking of a dam where continuous and slow processes (changes in the rock, the augmentation of the water level by the rain etc.) have a sudden dramatic effect by which a prior state of stability is changed and a new stable state is reached. In our more abstract use of catastrophe theory these associations of the term "catastrophic" are of minor relevance.

We can distinguish two different types of catastrophes depending on the amount of delay we assume before the change takes place. The choice of one of these types depends on informal considerations; Thom introduced the label "delay convention" for this.

(a) The *perfect-delay-convention*.

The dominance of an attractor (a minimum) is preserved until the attractor disappears. Fig. 19. gives an impression of this type. The catastrophic points are always bifurcation points (cf. Def. 3).

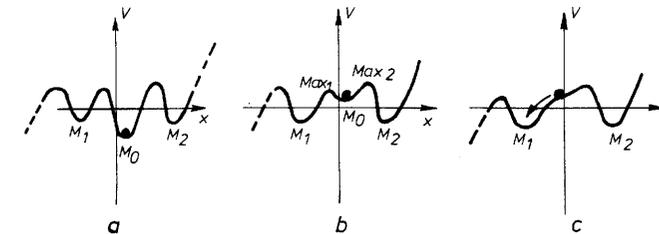


Fig. 19

(b) The *Maxwell-convention*.

The catastrophic change already occurs when the dominant (i.e. the deepest) attractor ceases to be the deepest. The catastrophic point is always a conflict point (cf. Def. 4). Fig. 20 illustrates this type of process.

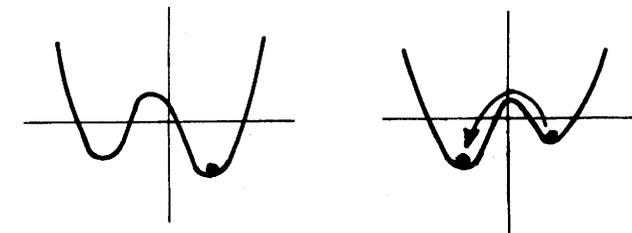


Fig. 20

In the next section we shall apply the techniques introduced up to now and study the geometry of the first two unfoldings: the fold and the cusp.

3.4 The Geometry of Two Elementary Unfoldings:
The Fold and the Cusp

(a) The fold

- Organizing center: (1) $V = x^3$
- Unfolding: (2) $V_u = x^3 + ux$
- Set of critical points Σ : (3) $\{(x, u) : \text{grad } V_u = 3x^2 + u = 0\}$
- Bifurcation set $\text{Bif}(V_u)$: (4) $\{u : \exists x(x, u) \in \Sigma \text{ and } \frac{\delta^2 V_u}{\delta x^2} = 6x = 0\}$

Fig. 21 shows the unfolding of $V = x^3$, which is a curved plane in \mathbb{R}^3 . Comparing Fig. 21 with Fig. 14 we recognize that the external variable has similar effects as the deformation by the small factor ϵ in section 3.1.

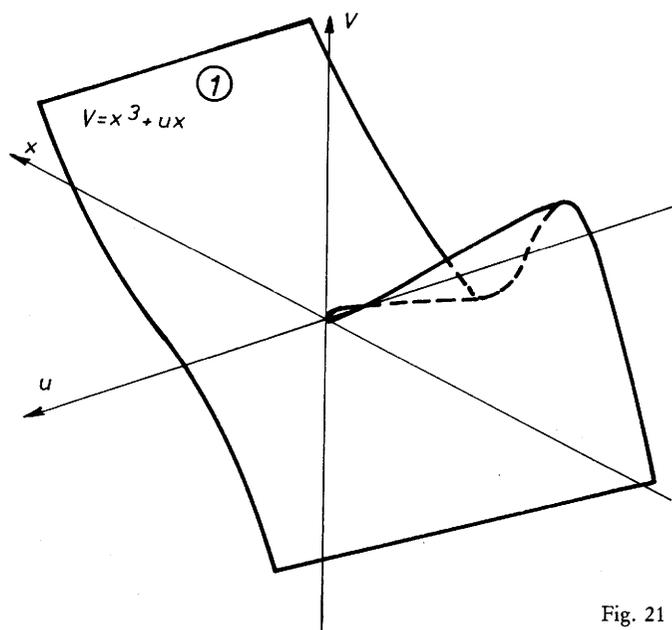


Fig. 21

Fig. 22 gives the graph of Σ (the set of critical points) which contains at the origin the bifurcation point. The arrows indicate the orbits of the vector-field. As we only have one external variable, u , the axes of observable, real (relatively slow) processes have to be parametrized by u . The fast dynamics, i. e. the internal dynamics responsible for the stability or the instability of states is represented in Fig. 22 by its orbits (= classes of vectors) which are marked by double arrows. In the domain of $u > 0$ we have only one orbit (\mathbb{R}). At the bifurcation point this orbit is separated into three orbits ($\mathbb{R}^+, \mathbb{R}^-, 0$). The fast

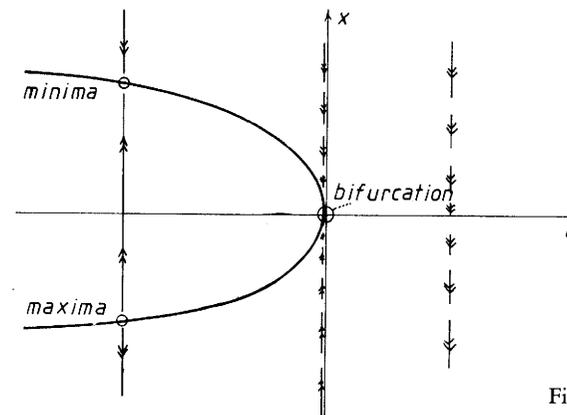


Fig. 22

dynamic has an equilibrium position at $x = 0$. In the domain of $u < 0$ we have five orbits. The upper line of the parabola $x^2 + u = 0$ contains attractors (= minima), the lower line contains repellers (= maxima). One gets a good idea of the fast dynamics if one imagines a ball rolling down the plane represented in Fig. 21. In the domain of $u < 0$ it is caught by a minimum, whereas in the domain $u > 0$ it goes straight down the plane. If we apply definition four to the fold, we see that one catastrophic point exists: the origin. As this point is a bifurcation point, it follows that only processes following the perfect-delay convention can be handled by this elementary catastrophe.

(b) The cusp

- Organizing center: (1) $V = x^4$
- Unfolding: (2) $V_u = x^4 + ux^2 + vx$
- Set of critical points: Σ (3) $\{(x, u, v) : 4x^3 + 2ux + v = 0\}$
- Bifurcation set: $\text{Bif}(V_u)$ (4) $\{(u, v) : \text{i} : 4x^3 + 2ux + v = 0$
 $\text{ii} : 12x^2 + 2u = 0\}$

The solution of (i) and (ii), such that the internal variable x is eliminated, gives us a semi-cubic parabola described by

$$(5) 27v^2 + 4u^3 = 0.$$

As the unfolding of $V = x^4$ is contained in \mathbb{R}^4 (the dimensions being: V, x, u, v) we cannot represent it graphically. Fig. 23 gives the graph of the set Σ .

We can represent the graph of the function V for single points in the plane of external variables (u, v) . The lines L_1, \dots, L_4 in Fig. 23 show that the number of critical points depends on the values one chooses in the (u, v) -plane. In Fig. 24 we show the potential function V along the parallels L_1, L_2, L_3 and L_4 (lines in (x, u, v) with u and v constant).

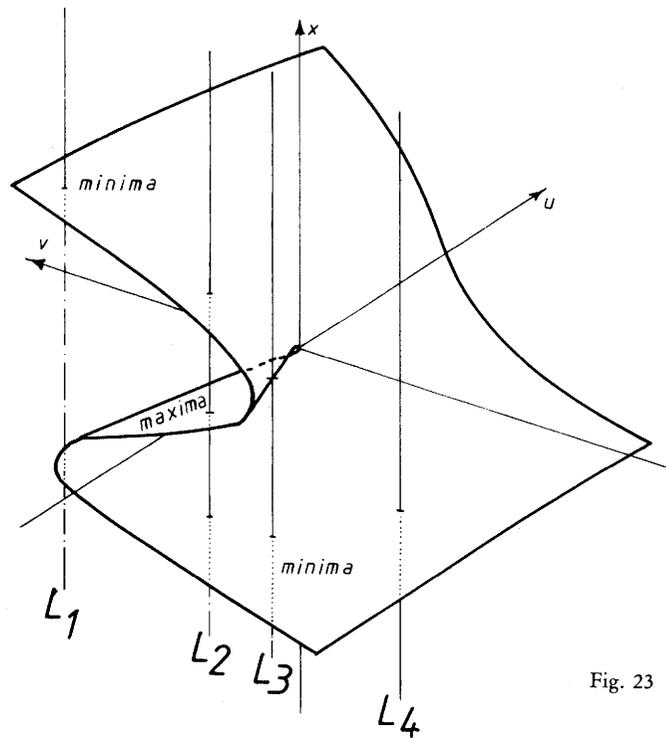


Fig. 23

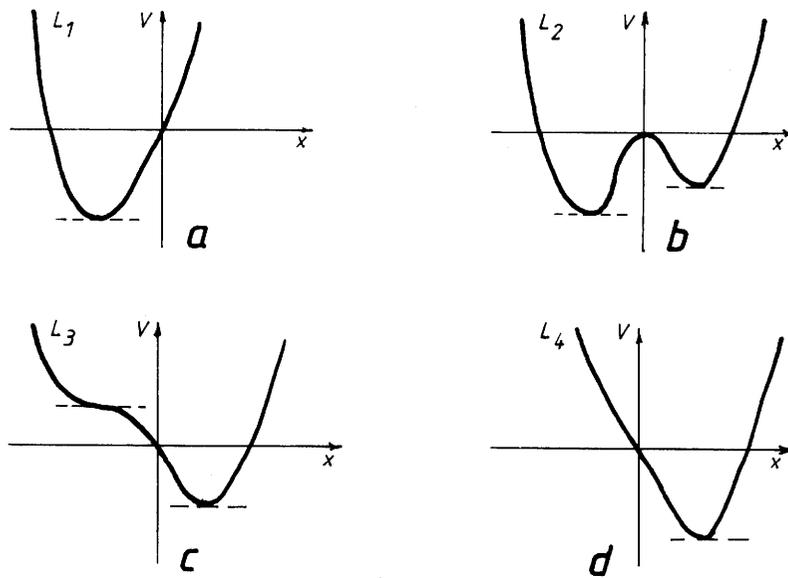


Fig. 24

In Fig. 24 (a) and (d) (the lines L_1 and L_4 cut the catastrophe set Σ only once) the potential V has just one minimum; in (c) there is a saddle-point and in (b) the function V has three critical points: two minima and one maximum. Line L_2 cuts through the "conflict-area" where two attractors (minima) coexist. The different areas are defined by equation (6). Fig. 25 shows the graph of the semi-cubic parabola together with the graph of the function V at single points in the (u, v) -plane.

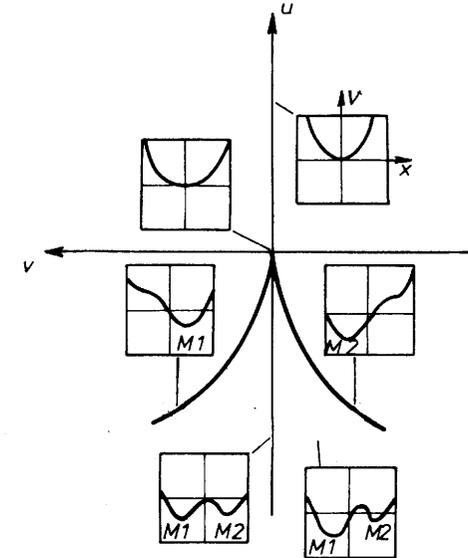


Fig. 25

As the actual processes described by this dynamic model change the control parameters u and v , we can represent them by different paths in the plane (u, v) . There are four structurally different classes of paths in the bifurcation plane (Bif) of the cusp (cf. Wildgen, 1979a: 215–227). Fig. 26 shows the paths K_1, K_2, K_2' and K_3 .

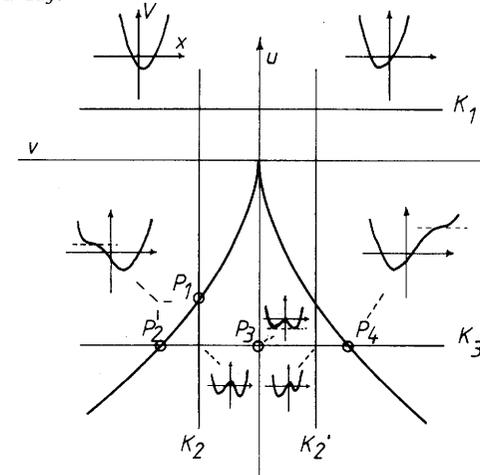


Fig. 26

The character of the corresponding processes can be read from the representation of the function $V_u(x)$ at different points of the paths. Fig. 26 shows the "evolution" of $V_u(x)$ along K_1 , where no dramatic change is happening. On the path which describes the evolution along K_2 a simple minimum bifurcates and we get a conflict of two minima. On the path K_3 we have a conflict area in the middle. There is a new minimum appearing at the intersection of K_3 with the bifurcation line at P_2 . The old minimum disappears at point P_4 . The conflict of minima is resolved by a change in dominance. Whereas K_2 encounters one catastrophic point (P_1) which is a bifurcation-point, K_3 crosses two bifurcation points and one conflict point (P_3) in the middle of the conflict area. K_3 is therefore catastrophically richer than K_2 .

We shall give equivalents of these basic processes as empirical models in the next chapter.

4. Dynamic Models in Word Semantics. Foundation and Applications

This chapter will first present basic principles and definitions which control the application of catastrophe-theoretical structures to semantics. The second section gives a summary of the semantic archetypes which can be derived from the elementary catastrophes. The details of the derivations are contained in Wildgen, 1979a: 253–411. In sections 4.2. to 4.4. we treat those problems of word semantics which have already been introduced in chapter 1 (1.2.–1.5.).

4.1 Basic Principles

We need principles for the correlation of the purely mathematical structures of catastrophe theory to the semantic structures underlying language. The principles which we enounce could certainly be further specified and augmented so that the methodologically important activity of interpreting formal structures in terms of an empirical model would be further clarified.

First principle

The *stable attractors* of an elementary catastrophe are interpreted as *static semantic entities* involved in processes, events and activities. Their characteristic realizations are nouns, adjectives, nominals and terms.

Remark: The categories noun, adjective and term belong to the realizational level of language. These structures can only be arrived at after a series of further derivations, which are of another type than those considered here. Semantic archetypes belong to the level of "mentation" and not the level of "action" (active realization) (cf. Goldman-Eisler, 1958, 230).

Second principle

The type of dynamic 'accidents' (= catastrophes) happening along a path through the bifurcation set are fundamental sources for *verbs* and *verbal expressions*.

Remark: Verbs are no longer classified as static relations, operators with operands etc. They are rather an integral part of propositional gestalts. One can refer to Tesnière's metaphor that verbs "govern" the sentence. In our model they are rather the dynamic center of a gestalt, the nominal agents being the necessary fillers for the case frame of the verbal center. This principle will become clearer when we derive the list of basic propositional gestalts in the next section.

Third principle

The semantic archetypes are *local* structures in the sense that we consider only the environment of singular points in the bifurcation set. As the set of elementary catastrophes has a subordinating structure, we can embed simple archetypes into complex ones, such as to build a structure of "scenes" and "perspectives" (in the sense of Fillmore 1976 and 1977b).

Remark: This principle integrates the main ideas of the "frame-and-scenes" semantics in Fillmore (1976, 1977b). The hierarchy of elementary catastrophes gives a natural explanation of the semantic facts observed by Fillmore.

Principles one and two can be further specified as we distinguish different entities which can take the status of attractors in a dynamic field. Some of these distinctions have already been utilized. The most basic type of interpretation is the *localistic interpretation*. The dynamic field is a domain. The points regulated by the fast dynamics (they are 'caught' by the attractor) are individuals (objects, animate beings).

The localistic interpretation presupposes a space-time substratum. This is the reason why we can consider it the most fundamental interpretation. The next type is related to the first one, as space-time is replaced by a more abstract location in the space of qualities. Normally very specific subspaces form the background of simple dynamic schemes (only these can be derived from elementary catastrophe theory). We call this interpretation the *qualitative interpretation*. The "domains" of a process can also be phases in the flow of events and actions. The catastrophes are, in this case, phase transitions. If such an interpretation is considered, we call it *phase interpretation*. These interpretations are also localistic in a wider sense; the domains are defined as stable states of a dynamic system.²

² The fact that localistic relations are basic for the theory of cases was first stated by Maximus Planudes (1260–1310 A. D.). This theory had a first renaissance in the early nineteenth century

It is typical of the above mentioned interpretations:

- the localistic interpretation,
- the qualitative interpretation,
- the phase interpretation,

that we have *one* central agent (object or animate being) which is affected by the process without really being part of it (the stability of this agent and its existence are not in danger).

A second group of interpretations differs from the first by the fact that the attractors are interpreted as agents of the process. This group of interpretations is linked to the localistic types (in the wider sense) by the fact, that the agents may subsist all over the catastrophes considered, it is only their relation (dominance, freedom, possessor-possessed, body - body-part, controlled-released) which is changed by the process. The notion of a deeper subsistence of actors has been exposed by Thom (1973: 641):

“Par une généralisation naturelle, on peut admettre que tous les actants subsistent, en se partageant l'espace fibre des variables internes. . . . On dispose ainsi d'un moyen très général pour représenter géométriquement les types les plus fréquents d'interaction spatiale entre actants, notamment ceux qui apparaissent dans la régulation biologique.”

We can call these interpretations *agent interpretations*. They were at the beginning of Thom's development of dynamic semantics (cf. the lists of archetypes in Thom, 1970: 248 and in Thom, 1977: 312). Our treatment generalizes Thom's proposals which were much influenced by the applications of catastrophe theory in morphogenesis (cf. the title of Thom's book; Thom 1972/1975/1977a).

The agent interpretations can be subdivided into:

(a) *possession / transfer of possession archetypes*

The dominance relation defined by the Maxwell convention is interpreted as a relation of possession, control, keeping, containing between individuals (stable gestalts).

(b) *(instrumental) interaction archetypes*.

The agents are involved in different kinds of actions which can be reduced to the elementary types of “capture” and “emission” (cf. 4.1.3.). The structure of the elementary interactions which are derived from paths in the bifurcation space of elementary catastrophes, defines different roles which can be roughly compared to the “schémas actantiels” proposed by Tesnière (1959) and to the “case frames” classified by Fillmore (1968,

(cf. as an example Wüllner, 1827). In 1935 Helmslev reviewed the work of the localists and proposed his own system of cases which is partially localistic. In recent times Anderson (1971, 1977) and Ikegami (1976, 1978) have presented different models on the basis of localistic assumptions. The connection of the catastrophe-theoretical model to other theories in semantics has been discussed in Wildgen, 1979a: 109-194.

1977a) (cf. section 4.3.). The basic difference between these structures and the semantic archetypes consists:

- (1) In the *preverbal* character of archetypes. The structures proposed by Tesnière, Fillmore and others are only generalizations of linguistic structures found in natural languages).
- (2) The foundation of the classification of archetypes in a formalism which is supposed to be basic for many biological systems. It is therefore universal in a very deep sense and it is of interdisciplinary relevance.
- (3) The semantic archetypes are *irreducible gestalts*. They are not composed in a simple combinatorial way. This fact constitutes a major difference in Thom's theory against all theories proposed up to now. Some of these have tried to describe field-like structures, but as no tool for consequently doing so was available they all drove away irresistibly attracted by the static-logical paradigm.

After these very theoretical remarks we can proceed to a first definition of the term: *semantic archetypes*.

The finite classification of elementary catastrophes allows the derivation of a finite list of elementary process types. If these are interpreted following the principles enumerated above, we get semantic interpretations of the elementary process types. These are called: *semantic archetypes*³.

4.2 A Summary of the “Propositional Gestalts” Derivable from Elementary Catastrophes

In this section we shall give a rather informal summary of the derivation of propositional gestalts exposed in Wildgen, 1979a: 253-431. The archetypes found by Thom in Thom (1970, 1977a) have been integrated into our list. His proposals are the heart of our own treatment. We shall, however, not discuss the many differences and augmentations contained in our treatment.

4.2.1 The Zero-Unfolding

The organizing center of this unfolding is $V = x^2$ and we have already shown in chapter three that it is structurally stable under small deformations. Consequently no fundamental process type can be derived from this “unfolding”. Nevertheless, the internal stabilization of this function under deformation has analoga in the field of word semantics.

- (a) The semantics of mass terms (gold, water, wood etc): It is characteristic for the referents of these terms that they can be deformed and divided without changing their identity (not including the molecular or atomic levels of de-

³ The term “archetype” refers to the philosophy of Plato. It is also related to the psychological theory of archetypes developed by Jung, 1976. Further information is contained in Wildgen, 1979a: 112-117.

composition). Their independence from influences and deformations can be correlated with the stability of the 0-unfolding. This *archetype of stable existence* is a specialization of principle one which interpretes every attractor (attractors have locally the shape of the 0-unfolding) as nominal entities. In the case of mass terms the regulation of the stability and identity of the objects referred to is particularly simple. Other objects need complicated mechanisms to regulate their stability, this is most obvious in the case of living beings. These mechanisms are, however, not elementary and cannot be described in our framework. The archetype of stable existence is a sort of mother type for the semantics of nominals.

(b) We arrive at more interesting structures, if we consider versal unfoldings of the same function. Fig. 27 shows the germ $V = x^2$ unfolded by a versal (non universal) parameter p .

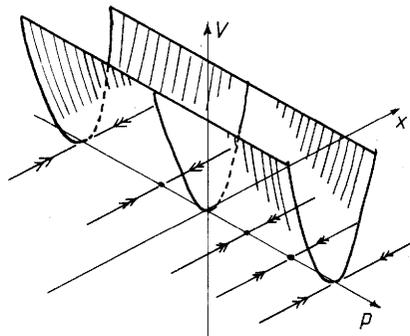


Fig. 27

The external parameter p is the axis of possible processes (the external time). This is the archetype of continuous processes without accidents. Schematically we can represent it by a line which has open ends at both sides.

diagram 1

The interpretations are rather simple:

- *localistic*: to be (exist, live, stay) in an unbounded domain.
example: *A* exists (somewhere)
- *qualitative*: persistent quality
In case an individual who possesses the quality in question is presupposed as the background, we get the type of inalienable qualities. They appear and end with their support; relative to their background (possessor) they are unbounded.
example: *B* is animate / human / ...
If *B* is a human being this quality is inalienable; i. e. those qualities which constitute the identity of an object are invariant qualities of this object as long as it exists (in its proper form).

- *possession*: In the case of inalienable possession the possessed object is stable as long as the individual who possesses it exists.
example: *B* has his head (on his neck)
- *interaction*: the basic archetype is that of living, belonging to the field of potential interaction. As the same process structure can be derived from the cusp ($V = x^4$) which is the next 'compact' catastrophe, if we consider the class of paths K_1 (with $u > 0$), this archetype is very often realized as a perspective of higher archetypes. The following examples point to such higher archetypes.
examples:
B sits, lies, stands / is placed, situated on/at/in *P*
B owns, has, contains (some object *O*)

More generally we get positions of rest before or after a phase of change which is not explicitly mentioned. It is clear that a person sitting in a chair can move, or that a town situated on the coast can be displaced (after some political "catastrophe"). In a local (restricted) perspective the verbs: *sit, lie, stand, be situated at, own* refer to a state of stability. The integration of this low archetype into higher archetypes has already been indicated in principle three (cf. section 4.0.).

4.2.2 The Fold

The geometry of the fold and its catastrophe and bifurcation set have been described in chapter 3.5. The unfolding contains only *one* external variable, which must be chosen as the process axis. We can distinguish three main areas around the bifurcation point. Diagram 2 shows the separation between areas where a stable attractor exists and areas where none exists.

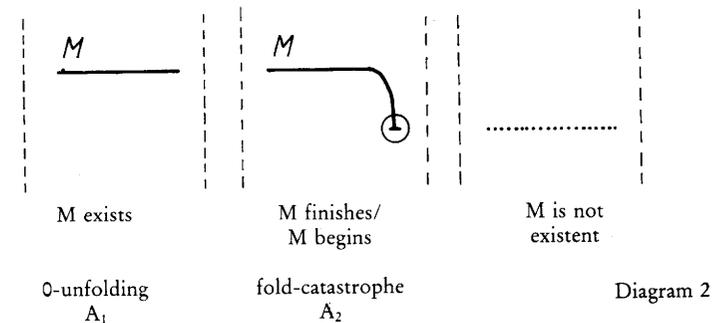


Diagram 2

(a) The localistic interpretation.

For the derivation of the localistic interpretation it is more suggestive to consider a second, versal parameter in addition to the universal one. This gives us Fig. 28 which shows the domain of stability *M* and its edge (along the versal

parameter which transforms the bifurcation point into a bifurcation line without changing the dynamic structure of the whole).

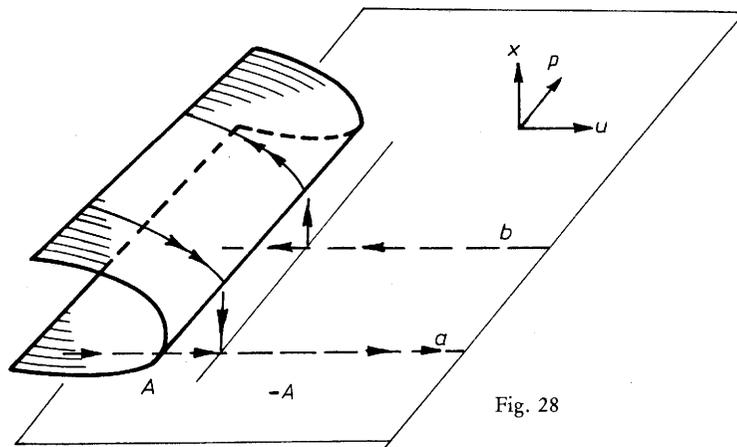


Fig. 28

The corresponding phases of the process are analyzed in diagram 3.

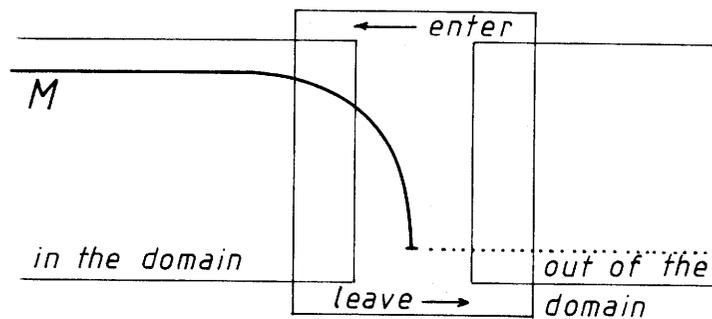


Diagram 3

P is (still/already) in the domain M		P leaves/enters the domain M		P is not (no more/not yet) in the domain M
---	--	---------------------------------	--	---

The choice between *leave* and *enter* depends on the direction of the process.

(b) *The qualitative interpretation*

The stable domain M is occupied by some *alienable* quality; the loss of the quality does not specify another quality (the loss of a stable quality can, however, be labelled by an adjective as in *alive – dead*, *married – single* (unmarried) where the asymmetry of the opposition is not so clear as in the case of negated adjectives). The opposition between the domains M and -M is a complementary or contradictory one.

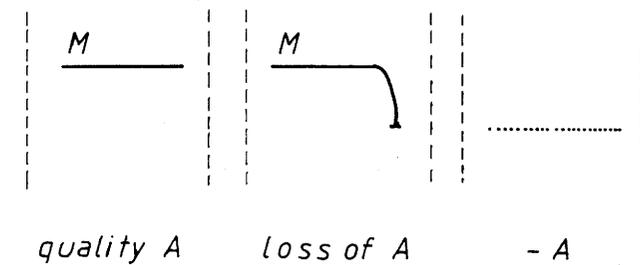


Diagram 4

Those adjectives which are typical realizations of complementary oppositions are not gradable. As we dispose of the general means of negation of qualities, we can realize the archetype of complementary opposition between qualities using any adjective or nominal.

(c) *The phase interpretation*

Many verbs refer to a change between stable and unstable states and vice-versa. The differences between stability and instability are, however, often context dependent. The most general change in stability is expressed by the verbs:

die (= a living being loses its stability, its stable identity) *to come to life* (french: *naître*) (= a living being gains its identity, its stability as a creature)

In the domain of body movements we encounter similar complementary constructions as in:

<i>come to M</i>	<i>go away from M</i>
<i>arrive at M</i>	<i>start from M</i>
<i>reach M</i>	<i>leave M</i>

Lyons (1977) calls these pairs of verbs “directional oppositions”. Each of these verbs contains a contrast between the stability of a later (come) or a prior state (go away) and the complementary instability of the prior or the later state. The complementary state is not given explicitly. It is only qualified in a negative manner as being different from the stable state which is indicated. This asymmetry is not an absolute one, the archetype derived from the fold can be embedded in a correspondent archetype of the cusp, which describes the change between two states in bipolar opposition. The propositional gestalt: *A comes to M₂* and *A leaves M₁* can thus be embedded in the symmetric gestalt: *A moves from M₁ to M₂*.

(d) *The possession interpretation*

The archetypes derived under this interpretation are very similar to the former ones:

A loses O (= destabilization of A’s possession of the object O)
A finds O (= stabilization of possession)

In the hierarchy of propositional gestalts we have at the lower level (= zero unfolding): *A has 0*; at the higher level (= cusp) we get: *0 changes from A to B*, where *A poss 0* and *B poss 0* are stable states of possession.

(e) *The interaction interpretation*

- Agent A appears, comes into the scene, . . .
- Agent A disappears, leaves the scene, . . .

This very simple archetype reappears as local perspective in the higher archetypes of capture and emission (cf. next section).

4.2.3 *The Cusp*

The unfolding of the germ $V = x^4$ has two external variables *u* and *v* and an infinity of paths can cross the (*u*, *v*) plane. In Wildgen (1979a) we have classified these paths (a similar classification was suggested by René Thom) and derived the corresponding archetypes. We shall only consider one class of paths (K_3) which is dynamically very rich. Diagram 5 gives the characteristic features of the process type corresponding to K_3 .

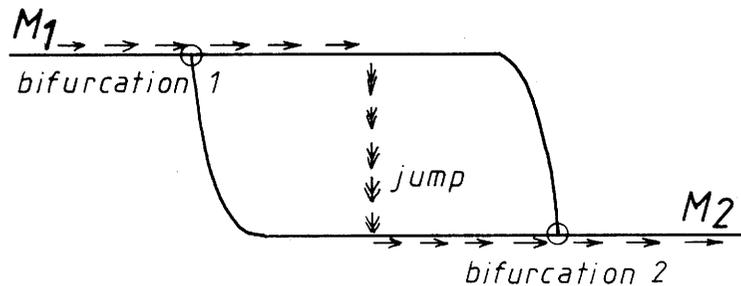


Diagram 5

A short look at diagram 3 and 4 shows that this process type contains two perspectives which correspond to archetypes derived from the fold. The phenomenon of a "jump" between two attractors and the partial coexistence of two attractors is, however, a totally new phenomenon.

Our description of the different interpretations of this process type can only be a short summary, for more details cf. Wildgen (1979a: 265–307).

(a) *The localistic interpretation*

We get the *archetype of local change* from place (domain) M_1 to place M_2 . *A moves from M_1 to M_2 (walks, drives, travels, . . .)*

(b) *The qualitative interpretation*

We get the archetype of bipolar quality change. The dynamics can be illustrated if we consider the pair of adjectives: awake – asleep.

Fig. 29 shows the areas of the two qualities 'awake' and 'asleep' and considers to processes in the quality space corresponding to

- A falls asleep*
- A wakes up*

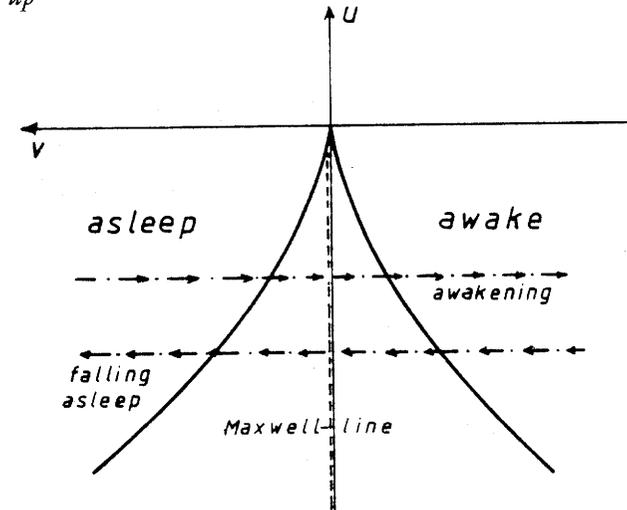


Fig. 29

The bipolar organization of a quality scale is a very productive principle in all languages. The methodology of the semantic differential introduced and applied by Osgood (cf. Osgood, Suci and Tannenbaum, 1967 and Osgood, 1976) takes advantage of this universal principle.

examples:

- good – bad active – passive
- strong – weak nervous – calm
- big – small

(c) *The phase interpretation*

If instead of quality scales we consider phases of activities, we get the following bipolar oppositions as realizations of the archetype. Corresponding processes (changes) can easily be imagined:

examples:

- rest – tension
- war – peace
- attack – flight
- gas – liquid

(d) *The possession interpretation*

We obtain the *archetype of change in possession*. As this archetype has only two stable attractors, the object which changes the possessor is not focused

on. The archetype of "giving" can be derived from the next compact catastrophe in the hierarchy, the butterfly ($V = x^6$). Some realizations of the archetype of change in possession are:

Object O changes from/passes from possessor M_1 to M_2 (O is an invariant of the process; it is not the interpretation of an attractor but stands for the point which moves on the path K_3 through the bifurcation plane).

All the interpretations of the process type illustrated by diagram 5 can be subsumed under the heading "change" (cf. Thom, 1977a: 312).

(e) *The interaction interpretation*

This interpretation is the one which motivated René Thom most. We have two attractors M_1 and M_2 which come into conflict. The central "jump" can be interpreted as a change in dominance (presupposing the Maxwell convention) thus yielding another archetype of change.

We can, however, consider separately the two bifurcations in diagram 5. If the attractors M_1 and M_2 are interpreted as agents we obtain very naturally the *archetypes of capture* and *emission*. They model those basic processes which have already been described in section 1.2. as basic biological activities.

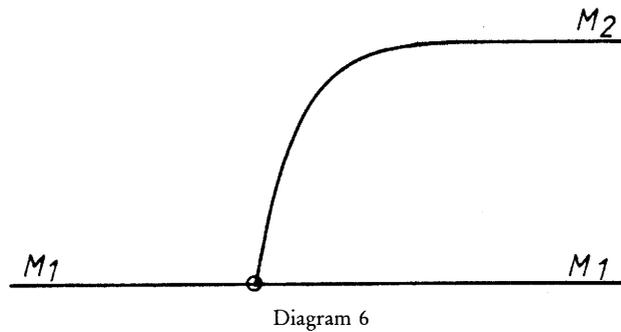


Diagram 6

Agent M_1 emits/throws/gives away/ lets free/ secretes agent M_2

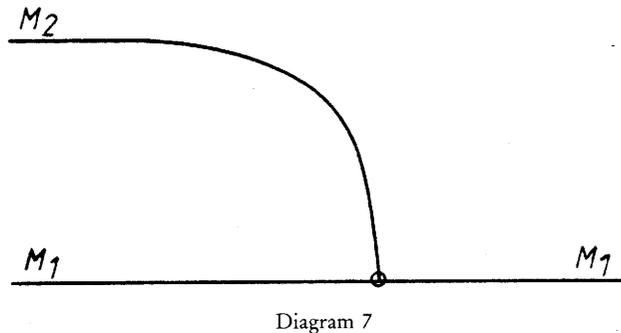


Diagram 7

Agent M_1 catches/takes/graps/subjugates/absorbs/devours agent M_2

The process diagram allows also the separation of two types of agents:
 M_1 : the *primary* agent, is *not* created or destroyed by the catastrophe
 M_2 : the *secondary* agent, is created/destroyed by the catastrophe.

This dynamic distinction can be correlated with traditional semantic labels such as: agent – object (agentive case – objective case), agent – experiencer, causer – affected/effected. The transposition of the dynamic characterization to syntactosemantic structures cannot be elaborated in the frame of this paper.

(f) *The instrumental interpretation*

The interactions described under (e) are biologically basic as we can find similar dynamic interactions in all living beings. In later evolutionary stages almost all creatures have developed an opposition between central and peripheral body parts. With the existence of limbs and the prolongation and differentiation of limbs by the use of instruments new action types have evolved, which can be called *instrumental*. The secondary agent can now be interpreted as a limb or an instrument. Applying this interpretation to diagrams 6 and 7 we get the following (instrumental) interactions:

- (a) reaching, tending (with the arm, with the instrument)
- (b) taking back (the limb), recovering (the instrument)

The actions performed with the aid of limbs and instruments very often have a cyclical and repetitive character. If we consider cyclical paths in the bifurcation set of the cusp, we can derive some basic archetypes of body movements.

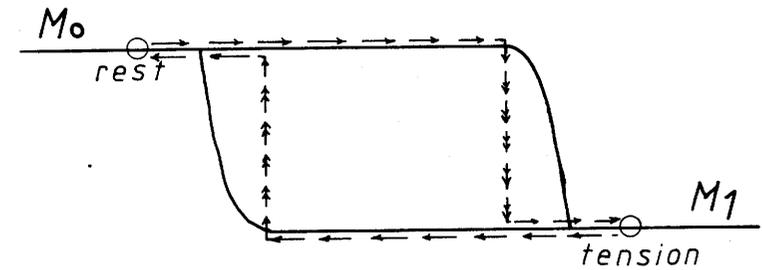


Diagram 8

We consider M_0 as a state of rest and M_1 as a state of tension. According to Zeeman (1972) we obtain a qualitative model of heart beating (where the two states are called diastole and systole). The *archetype of beating* which can be derived is rather rudimentary as it describes only the change between two states:

- (a) the body has its limb close to itself (in a neutral position of rest): M_0 ,
- (b) the body has emitted/erected the limb (instrument) (in a position of tension): M_1

examples:

Agent A beats (with its limb/instrument B)

Agent A jumps

If the cycle is run through repeatedly, we get:

A waves, wags, etc.

More generally it can be said that most movements such as *walk*, *run*, *dance* . . . are perceived as combinations of such "beating" processes (cf. Johansson, 1976, 1977 for experimental results confirming this hypothesis).

There remains the class of abstract interpretations, which are transpositions of physical actions to the domain of mental, emotional and social activities. We prefer to treat these on the level of attributional dynamics as they are too remote from basic biological mechanisms which are the proper domain of the universal morphology developed by René Thom. Our separation of different interpretations of basic process types was already a first step into this domain, although we aimed exclusively at a better approximation of the semantic structures of natural languages. Attributional dynamics needs a broader interdisciplinary foundation especially in social psychology and anthropology (ethnomethodology included).

4.2.4 The Butterfly

Organizing center: (1) $V = x^6$

Unfolding: (2) $V_u = x^6 + tx^4 + ux^3 + vx^2 + wx$

The set of critical points (catastrophe set) $\Sigma: \{(x, t, u, v, w):$

(3) $\frac{\delta V_u}{\delta x} = 6x^5 + 4tx^3 + 3ux^2 + 2vx + w = 0\}$

The bifurcation set is defined by (3) and (4): $\{(t, u, v, w): (3) \wedge (4)\}$:

(4) $\frac{\delta^2 V}{\delta x^2} = 30x^4 + 12tx^2 + 6ux + 2v = 0$

It is very difficult to show the geometry of this catastrophe. Even the bifurcation set which has four variables (t, u, v, w) can only be illustrated with the aid of partial graphs where at least one of the four variables is held constant. The number of types of paths is also considerably augmented. For a detailed analysis of this catastrophe and the archetypes which can be derived from it, we must refer to Wildgen (1979a: 340-371). We shall only consider one characteristic and dynamically rich path in the plane of the variables (u, v); the other external variables w and t take constant values (t is negative and w is small). Fig. 30 shows the graph of the bifurcation set under these conditions. We consider a path parallel to the parameter u which cuts the "swallowtail" just above the conflict point where three conflict lines (= lines of unstable equilibria) intersect. The potential field for the points a, b, c, d, e, f, g, i, j on the path are shown in diagram 9 together with a schematic representation of the attractors, their bifurcations and the "jumps". The strong line indicates

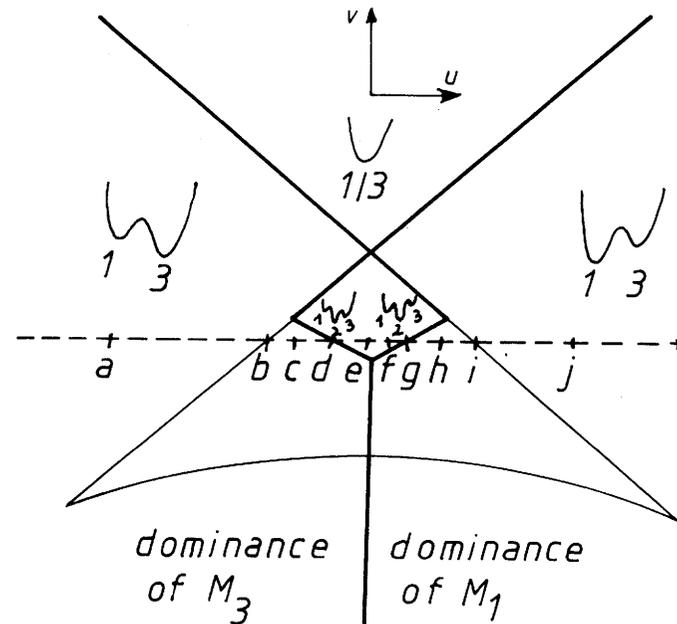


Fig. 30

the changes in dominance. At the left side we have two attractors M_1 and M_3 ; M_3 is deeper (relative to the potential V) and therefore dominates. At point (b) we meet a first bifurcation point. A new attractor, M_2 is "emitted" by the dominant attractor M_3 . At point (d) the attractors M_2 and M_3 have an unstable conflict point (= point of unstable equilibrium). Immediately after (d) the dominance changes from M_3 to M_2 ; the first catastrophic jump occurs. M_2 dominates only up to point (g) where a new conflict point is met. The second catastrophic jumps leads to the dominance of M_1 . At point (i) the attractor M_2 which was "emitted" from M_3 at point (b) is "caught" by the attractor M_1 .

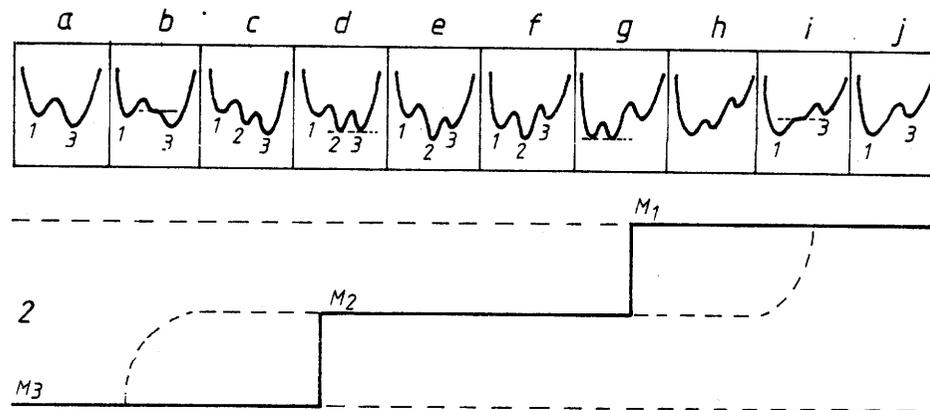


Diagram 9

This path (or class of paths) is the only one where:

- (a) A zone of three coexistent attractors exists.
- (b) The middle attractor M_2 gains dominance.
- (c) The attractors M_1 and M_3 are *not* created/destroyed, but persist throughout.

In a simpler case where (c) does not hold, we derived the archetype corresponding to the Path-case of Fillmore (1971). The three attractors are interpreted as:

M_1 : source, M_2 : path, M_3 : goal

example:

John travels from Munich (M_1) to Rome (M_3) via Florence (M_2)

In the process type described by diagram 9 we do not have isolated domains of existence for M_1 , M_2 and M_3 rather a conflict structure between M_1 and M_3 which is complicated by the appearance of M_2 . The changes in dominance are therefore the principle characteristics of this process type. Fig. 31 shows the interrelation of the conflict strata (curved planes in the space (v, w, u); t is a negative constant).

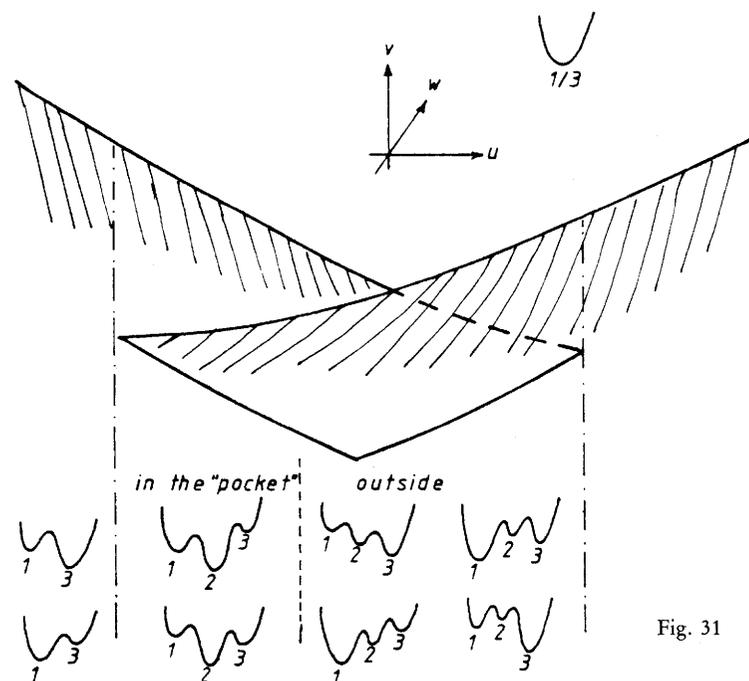


Fig. 31

The small pictures in the lower part of Fig. 31 show how the conflict strata are embedded into the bifurcation set (the strong lines are conflict lines and represent sections of the conflict plane in the (v, w, u) plane above). The

graph in Fig. 31 is also called the “compromise pocket” in allusion to the first archetype we can derive from it.

(a) *The qualitative interpretation*

The primary attractors M_1 and M_3 establish a bipolar opposition comparable to the qualitative interpretation of path K_3 in the bifurcation set of the cusp. If the path cuts across the “compromise pocket” (cf. Fig. 30 and 31), the conflict between two opposed qualities splits up and a new intermediate attractor situated between the two extremes is created. Isnard & Zeeman (1976) used these dynamic structures to model the compromise zones in political decisions (hawk – versus – dove, cf. also Zeeman 1976). The compromise zone is qualitatively different from the other areas in the bifurcation set as it is strictly bounded, relatively small and as a change in the external parameters t and u causes the compromise zone to disappear. This zone is therefore called *metastable*.

The qualitative interpretation of this dynamic phenomenon is straightforward. We have two stable extremes M_1 and M_3 and a metastable “compromise” M_2 between them.

examples

Extreme: M_1	compromise: M_2	extreme: M_3
young	middle old	old
good	indifferent	bad
true	indefinite	false

It is important that the compromise value is *not* a differentiation of one of the two extremes; it rather focusses on the indifference zone between the two extremes making it an attracting domain. The following example illustrates a process in such a three-valued qualitative domain.

extreme: M_1	compromise: M_2	extreme: M_3
war	armistice	peace
	mobilization	

In this case we have a delay phenomenon such that the catastrophe line depends on the direction of the process. “Armistice” and “mobilization” are two different compromise zones. These zones can develop into one stable compromise zone which is called “cold war”. This state has much relevance in a world under the influence of two political blocks, where the state of war is too risky.

(b) *The transfer interpretation*

If we interpret the dominant attractor as a state of possession (or as a state of stable control, stable social relationship), we can elaborate the archetypal

structure found in section 4.2.3.(d). Fig. 32 shows the process along the path indicated in Fig. 30 and analysed in diagram 10 (below). Fig. 32 contains only the external parameter u to which the path is parallel (cf. Fig. 30). Introducing the internal variable x we can now show a section of the catastrophe set Σ (with u , v , and t constant).

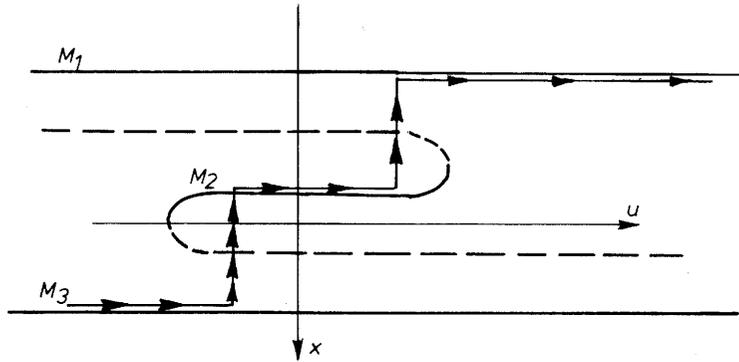


Fig. 32

The stable state of possession: M_3 on the left changes into an intermediate state of possession: M_2 , which is metastable; M_1 is the final state of possession, the result of the process. The changes among these three states define the *archetype of transfer*. Diagram 10 illustrates this interpretation (in the diagram the repelling maxima are omitted).

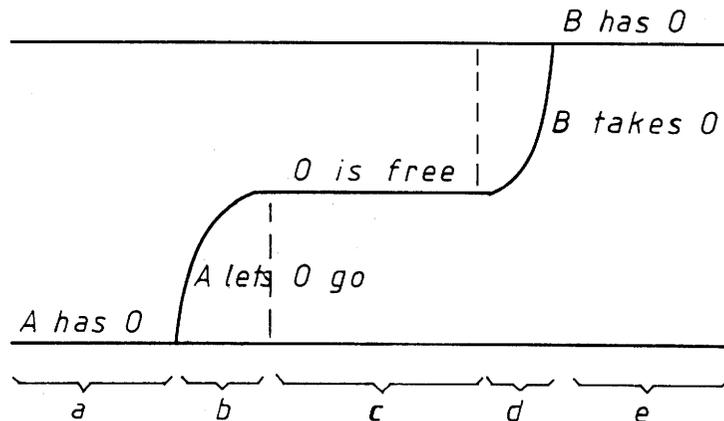


Diagram 10

Strictly speaking we should only say that *A has O* in the stretch of the process where A has emitted O and dominates it. If, as Thom suggests, we consider the agents as fundamentally coexistent (in the fibre space of internal

variables, cf. Thom, 1973: 641) the emission of O is to be interpreted not as the beginning of existence of O but as the separation of O from A , O enters the scene as an agent which can potentially play a role in the interaction. The domain (a) is therefore one of stable possession (O does not act freely), in (b) O starts to become independent from A but it is still controlled by A , in (c) O is free from the dominance of A , it is dominant itself, in (d) O is again dominated by one of the coexistent and primary agents: M_1 . If we change the parameter v which controls the path, the zone of dominance of (c) is narrowed and disappears, i.e. the prominence of the object and its intermediate independence is governed by another mechanism. In Wildgen (1979a: 339ff) these controls are called: *higher archetypes*. The following sentences show that the phase of "self-possession" of the object is variable in natural realizations of the archetype of transfer.

- (i) *Eve gives Adam the apple*
 M_3 M_1 M_2
- (ii) *Eve hands the apple to Adam who takes it*
- (iii) *Eve throws the apple towards Adam, who catches it*

In (i), the fact that the apple has a field of independence between Eve and Adam is not explicitly stated, in (ii) we have at least a separation of two partial processes and in (iii) the apple obtains a certain independence (as long as it is in the air).

(c) *The instrumental interpretation*

If we consider cyclical paths through the bifurcation set and if the attractors are interpreted as agents, we can derive the *instrumental archetype* with three attractors (M_0 = agent/source, M_1 = instrument, M_2 = experiencer/goal). Diagram 11 shows the shape of this process type which is a prolongation of the process described by diagram 10.

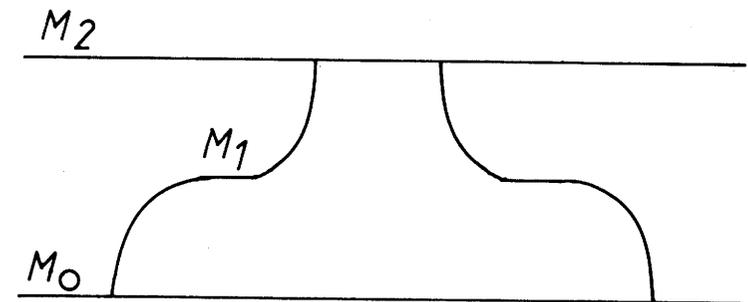


Diagram 11

The instrument M_1 is emitted by the agent/source M_0 , it hits (touches, affects) the experiencer/goal M_2 and comes back to be integrated into the agent/source

which is marked as the neutral position of the process. This archetype elaborates the archetype of hitting (affecting) derived in section 4.2.3.

example:

The farmer hits the donkey with a stick
 M_0 M_2 M_1

In this section we enumerated the most important semantic archetypes derivable from elementary catastrophes with *one* internal variable. In Wildgen (1979a) we tried to derive:

- (a) all elementary archetypes,
- (b) the principal secondary archetypes,⁴
- (c) the main higher archetypes.⁵

Although the geometry of unfoldings with more than one internal variable is not yet fully known, we have been able to derive some special instrumental archetypes from the compactified umbilics. As these derivations can only be described after a detailed mathematical introduction we shall only mention the principal types of propositions described by these archetypes.

(a) *The archetype of the messenger*

This has *four* attractors, besides the basic actions of capture and emission (affecting and effecting in traditional terminology) we have a new type called *dynamic binding*: an agent controls the movement or action of another agent without catching or emitting it (two attracting domains communicate by a pass between them). The new attractor is called a *messenger*, it carries or directs the middle attractor (cf. diagram 10) from M_3 to M_1 .

The agent/ source M_1 transfers the object M_2 to the experiencer/goal M_3 using the messenger M_4

examples:

The girl sends a letter to her friend by mail
 M_1 M_2 M_3 M_4

The hunter shoots the deer (with a bullet) using a gun
 M_1 M_3 M_3 M_4

(b) *The archetype of instrumental capture*

The agent/source M_1 emits an instrument M_2 which binds the experiencer/goal M_3 and brings it to M_1 where it is bound to M_1

⁴ Secondary archetypes are derived from paths in elementary catastrophes such that parts of these paths have already been interpreted by "primary" archetypes. Secondary archetypes are mostly not realized by simple sentences but rather by consecutive sentences.

⁵ Higher archetypes interpret processes which control elementary processes; they modify elementary semantic archetypes.

example:

The cowboy catches the calf with the aid of a lasso
 M_1 M_3 M_2

(c) *The archetype of instrumental dissection*

The agent/source M_1 emits an instrument M_2 which influences/touches an experiencer/goal M_3 , so that it is split into M_3 and M_4 ; M_4 is caught by the instrument which takes it to the agent/source M_1 .

example:

The mother cuts a piece from the cake with her knife
 M_1 M_4 M_3 M_2

(d) *The archetype of instrumental binding/unbinding*

The instrument M_4 emitted by the agent/source M_1 binds the experiencer/goals M_2 and M_3 such that the instrument M_4 is recovered by the agent/source M_1 unbinding M_2 and M_3 .

This archetype has two perspectives which are symmetrical. On the one side of the process two agents/objects are bound together, on the other side they are separated.

example: (perspective 1)

The farmer M_1 ties the goat M_2 to the tree M_3 with the help of a rope M_4

The table of morphological archetypes in Thom (1977: 312) contains these archetypes but no derivation. The derivation proposed in Thom (1970: 239ff) has been partially invalidated by Thom's suggestion in Thom (1977a: 91):

"En ce qui concerne les ombilics, on ne pourra les associer à une catastrophe de bifurcation localement stable qu'en les considérant dans le déploiement universel de la singularité $V = x^4 + y^4$ (le "double cusp", selon C. Zeeman). Cette singularité est de codimension algébrique égale à huit (topologique sept): elle n'apparaît donc génériquement que par des associations de catastrophes sur \mathbb{R}^4 . Le déploiement du double cusp peut présenter quatre minima; on peut donc obtenir dans le déploiement universel de cette singularité, des interactions comportant le conflit de quatre régimes. Certaines de ces interactions peuvent être localisées au voisinage d'un ombilic parabolique; on leur donnera, au chapitre 13, une interprétation linguistique."

The geometry of the umbilics had been investigated by Godwin (1974) and Woodcock and Poston (1974) (cf. also Bröcker and Lander, 1975). They showed that the parabolic umbilic has maximally two minima; the derivations in Thom (1970) were therefore inadequate. In Wildgen (1979a: 385-410) we have shown that Thom's proposals in 1970 can be substantiated using the compactified versions of the umbilics (embedded in the double cusp). The main results of our analysis were:

- (a) The archetypes with specialized instrumental functions can only be derived from the compactified umbilics, i. e. from the double cusp.
- (b) The archetype of the messenger can be derived from the compactified *elliptic* umbilic (using the results reported in Posten and Stewart, 1978: 240, where applications to the mechanics of fluids were considered).
- (c) The derivation of the archetypes (b), (c) and (d) is presumably possible on the basis of the compactified parabolic umbilic. The geometry of the compactified version of the parabolic umbilic has not yet been fully explored, so that we could not prove this assumption in detail.

As a summary we can state that the list of propositional gestalts derived from paths in the bifurcation set of elementary catastrophes results in:

- (a) a fundamental classification of verbs (as the dynamic centers of propositional gestalts);
- (b) a fundamental classification of semantic roles occupied by nominals (stable attractors of the dynamics).

We can distinguish four types of such semantic roles occupied by nominals:

- (a) *Primary agents*: They are not existentially changed by the catastrophe.
- (b) *Secondary agents*: They are created or destroyed by a catastrophe (they appear or disappear in the scene of interaction).
- (c) *Metastable agents*: They represent intermediate stages (as in the Path case) or transferred agents/objects.
- (d) *Binding agents*: They control/guide/influence the function of primary instruments (which are secondary agents in the sense of (b)).

In the two following sections we shall summarize these important aspects of propositional gestalts.

4.3 A List of Archetypal Structures in the Verbal Lexicon

The semantic classification of verbs is a traditional domain in linguistic research. Nevertheless the analyses proposed up to now have had only poor results. They come about in more or less accidental subdivisions of the verbal lexicon. Most systems agree with a fundamental subdivision into stative and nonstative verbs. The nonstative verbs are subdivided into verbs describing processes, events and actions (cf. Bartsch, 1976: 369) and further into verbs of movement, communication, mental verbs etc. (for a summary of the classifications proposed for German verbs cf. Orthen, 1976: 95–106). The most serious drawback of these proposals comes from the fact that the verbal lexicon is grouped around some class labels whose choice is almost arbitrary. The criterium of proximity used in this procedure is usually not made explicit (for an informal access to this problem cf. Ballmer & Brennenstuhl, 1978). The semantic unity of the verb classes proposed remains insecure.

A first attempt to represent the content of verb classes in a quasi-iconic way was made by Schank (1972), but the optic indexes used were not systematically justified, they are rather conventional diagrammatic representations.

The aim of our classification is to define basic semantic structures which are language-free in the sense that they belong to a prelinguistic stage of gestalt-perception and recognition. We hope to evince by this means the circularity of the classifications proposed up to now. The schematic representation of the interaction of attractors along paths in the bifurcation set furnishes a quasi-iconic language for the description of verbs.

We can obtain a first basic subdivision in the set of archetypal processes by opposing the class of structurally stable functions (which have only versal unfoldings and *no* catastrophe point) to structurally unstable functions (which have one or more catastrophe points). The subclassification of the non-stative verbs is much more difficult. On the one hand we have a list of basic dynamic schemes derivable from the set of elementary catastrophes (i. e. from typical paths in the bifurcation set). On the other hand these schemes demand a more specific interpretation. We have to decide how the attractors and their bifurcations have to be interpreted (cf. section 4.0.). The principles of interpretation presuppose basic processes of social perception, social focussing on special relevancies and social attributions (simple phenomena of causation and of agent responsibility). Experimental results of Michotte (1963) have proved that this basic level of attribution is independent of semantic features and special contexts. Confronted with light dots which move on a screen people tend to interpret systematic correlations between points as *holding*, *letting free* and *causing* the movement of the other dot (cf. also Miller & Johnson-Laird, 1976: 94–100). The integration of these fundamental attributional principles in our description of propositional gestalts was therefore not an arbitrary expansion of the mathematical structures found in catastrophe theory. Our system of interpretations differs from the one proposed by Thom (1970: 234) who distinguished:

- (a) Physical interpretations,
- (b) biological interpretations.

We consider instead:

- (a) Localistic interpretations,
- (b) action/interaction interpretations.

Whereas Thom had the field of physical and biological sciences in mind, when he designed his interpretations, our access is rather integrated into the framework of language philosophy and communication studies. We believe that the two accesses are congruent.

We shall now briefly summarize the types of verbs found in the previous section. Our exclusion of abstract verbs has to do with our reluctance to enter the proper domain of attributional dynamics. We think, however, that many mental activities and feelings are labelled in analogy with concrete process types; i. e. the structure of this part of the lexicon is secondary to the one dealt with here (cf. Perls, 1969, for arguments in favor of this assumption). The verbs with four attractors (nominal participants) whose derivation had been sketched

in the last section are not included in our list. We presume that further analyses of the double cusp catastrophe underlying these verbs will result in a larger list of propositional gestalts with four attractors.

germ	name of the catastrophe	localistic	phase	possession/control	interaction	instrumental
$V = x^2$	0-unfolding	to be (in a domain)	to rest, to live	to have to own	to be (in the scene)	-----
$V = x^3$	fold	to leave/enter (a domain)	to die/be born	to lose/to find	to appear/disappear (in the scene)	-----
$V = x^4$	cusp	to move (from A to B)	contract/relax	to take/to let have	to emit/to catch	to beat/to push
$V = x^5$	swallowtail	From this catastrophe only semi-elementary and higher archetypes could be derived (they are not treated in this article).				
$V = x^6$	butterfly	to travel (from A to B via C)	to pause (intermediate state)	to give: A gives B to C	to propel (to a goal)	to hit, to touch (with an instrument)

Table 2

germ	name of the unfolding	formal characteristics	interpretation
$V = x^2$	0-unfolding	M_1 (stable)	stable existence (the prototype of the nominal)
$V = x^3$	fold	$M_1, -M_1$	complementary and asymmetric opposition between two roles (nominals)
$V = x^4$	cusp	$M_1, M_2, -M_1, -M_2$	bipolar, symmetric opposition between two roles
$V = x^5$	swallowtail	$M_1, M_2, -M_1, -M_2, -M_1 \cdot -M_2$	two complementary oppositions (cf. the fold) intersecting in a small area and disconnected in another
$V = x^6$	butterfly	$M_1, M_2, M_3, -M_2$ (in the section considered in 4.1.)	symmetrical opposition between two poles, existence of a metastable compromise attractor between the two extremes

Table 3

4.4 A List of Nominal Roles Contained in the Set of Propositional Gestalts

The following list summarizes the role-structures of nominals in the propositional gestalts which were derived in section 4.2. The semantic roles correspond roughly to the "deep cases" proposed by Fillmore (1968) and to the participant roles described in valence theory (Tesnière, 1959; Helbig, 1969). The archetypal level is, however, deeper as it is not derived from distributional or syntactic features of sentence realizations. We can distinguish two levels:

- (a) the purely formal level of process structures,
- (b) the elementary attribution of semantic content by the different types of interpretation.

4.5 Archetypal Structures in the Lexicon of Qualities

4.5.1 The Color Lexicon and its Differentiation

In section 1.3. we have argued that the mechanism of color perception follows the opponent-cell scheme. The dynamic structure of perception in this domain is therefore bipolar, i. e. we have two attractors in opposition (or in conflict). This conflict domain is a zone where two centers of a quality scale compete. We can assume two frontiers of the opponent reaction which correspond roughly to the bifurcation lines of the cusp. The cusp is a first dynamic model of the phenomenon, which could be replaced by a more specific model which mirrors the quantitative results of research in color perception. Our aim in this section is, however, to develop a first qualitative model for a larger class of phenomena, which can be related to our use of perceptual adjectives.

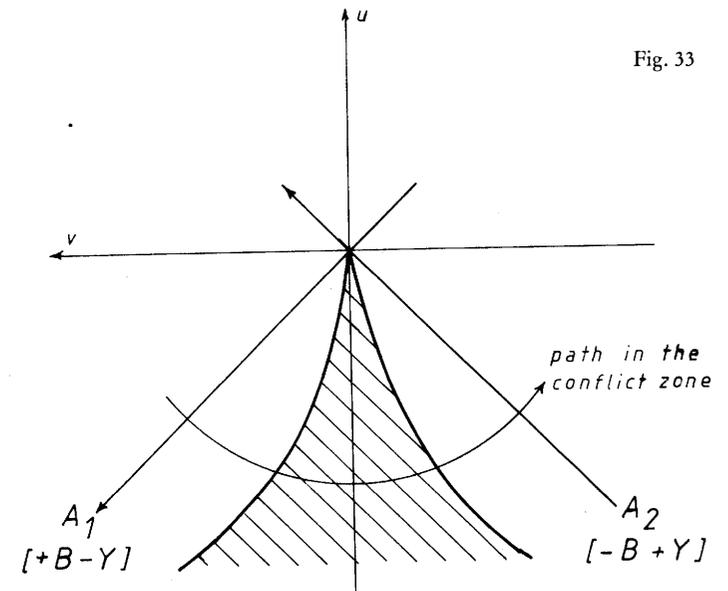


Fig. 33

Fig. 32 shows a special use of the cusp catastrophe, where the axes u and w are rotated at an angle of 45° (cf. Isnard & Zeeman, 1976: 73 for the application of rotated cusps).

The bipolarity of the cusp-catastrophe models the opponent cell scheme. The conflict zone is a zone of indifference, where the cell shows no specific reaction. The bifurcation lines are thresholds for the reaction of the cell.

The development of color terminology in a linguistic community is governed by dynamic principles situated at another level. The basic principle is that of bipolar splitting and differentiation; it is not modelled by a path parallel to v (cf. Fig. 32) but a path parallel to u . In his applications Zeeman calls this external variable *splitting factor*.

Two different dynamic principles seem to apply in the case of the differentiation of our color terminology: a fold-like differentiation between white (positive) and black (negative) and a cusp-like recursive differentiation of the domains *white* and *black*.

(a) The differentiation between light-warm and dark-cool

We have one positively characterized term: light-warm which labels the existence of an excitation and one negatively characterized term; the absence of luminosity: dark-cold. In section 4.1. we have shown that this type of asymmetrical constellations is modelled by the fold (germ: $V = x^3$). Fig. 33 illustrates this application.

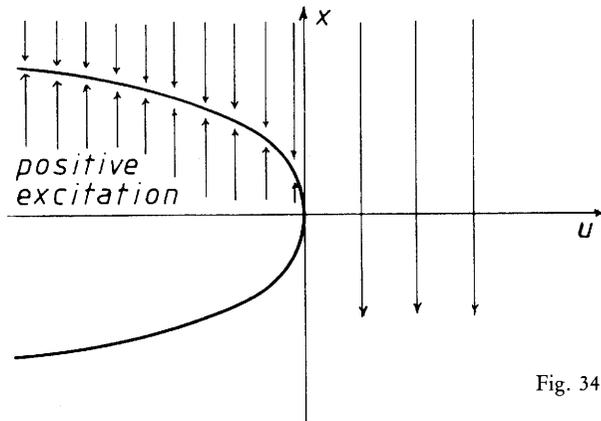


Fig. 34

positive excitation by luminosity
light-warm

no excitation by luminosity
dark-cool

(b) The process of bipolar differentiation (splitting)

The domain which is positively specified is first separated. With the differentiation light-warm the negatively defined complementary field is enriched by contrast and can be differentiated in its turn. We can thus reconstruct

the results obtained by Kay & McDaniel (1978) (cf. section 1.3.). Fig. 34 illustrates the process of differentiation along the vertical axis

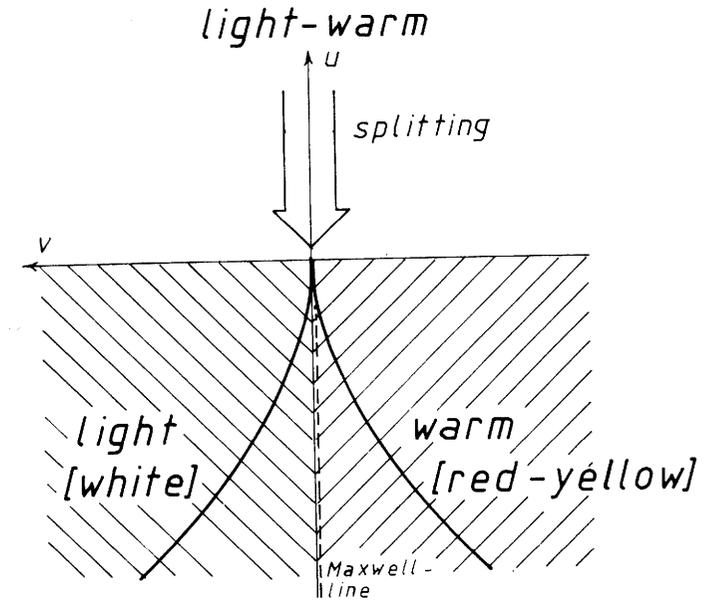


Fig. 35

The further stages of the process of color differentiation apply the same principle to the results of previous processes.

Stage 2: light-warm
light — warm

Stage 3: (a) warm — red — yellow
(b) dark-cool — cool (grue) — black

Stage 4: The results of (a) and (b) are composed, such that a five-valued color system appears:
{white, red, yellow, grue, black}

Stage 5: cool (grue) — green — blue

The result of this phase of differentiation constitutes the system of *primary colors*:

primary colors: {white, red, yellow, green, blue, black}

The process of color differentiation can be called a linguistic "unfolding" of latent perceptual categories. The degree of unfolding depends on the cultural context, whereas the structure of the unfolding is governed by the mechanisms of color perception.

We presume that similar mechanisms underly other qualitative differentiations.

4.5.2 Dynamical Structures in the Lexicon of Adjectives

In section 4.2. we have already shown that there exists a systematic qualitative interpretation of process types derivable from elementary catastrophes. We shall first summarize the main results of this interpretation and then comment on a subclassification of adjectives proposed by Seiler (1978) and Thom (1978).

A list of adjectives derivable from elementary catastrophes:

germ	general character	examples
$V = x^2$	inalienable qualities	physical, human, animate (against a nominal background)
$V = x^3$	alienable qualities (and their complements)	dead-alive married-single (opposition by negation)
$V = x^4$	bipolar domains on a quality scale	big-small strong-weak right-left young-old
$V = x^5$	no elementary modifiers, secondary modifiers like very, ... or almost, ... can be derived	
$V = x^6$	bipolar opposition on a quality scale with a "compromise pocket"	young-middle old-old right-center-left

Table 4

In the following we shall comment on the proposals made by Seiler (1978) and Thom (1978). Seiler distinguishes four semantic categories of adjectives:

- affective adjectives* such as: marvelous, dreadful, stupid. They are only poorly related to perception.
- evaluative adjectives* such as: beautiful-ugly, big-small, poor-rich, ...
- color adjectives*: green, red, ...
- matter adjectives*: wooden, golden, ...

These adjectives can be situated on a scale between the extremes: perception (iconic, extensional) – and – conception (symbolic, intensional) (cf. Lieb,

1979 for the term *conception* which designates the construction of possible objects, processes and events in variation of structures perceived and memorized). The allusion to the scale: *icon-symbol* and to the opposition: *extension-intension* tries to extract communalities from otherwise rather disparate theoretical accesses. Diagram 16 is therefore only a rough synthesis.

perception	matter	color	evaluat.	affect.	conception
iconic	adj.	adj.	adj.	adj.	symbolic
extensional					intensional

Diagram 16

We presume, however that the partition of the scale into matter adj./ color adj./ evaluative adj./ affective adj. does not mirror the basis and universal subdivisions. We assume that the following dimensions are basic.

(a) Adjectives dependent on the perception of objects

Adjectives whose meaning is more or less controlled by perceptual data are assembled in this domain. As the structure of our sensory organs is varied, we must differentiate among visual, acoustic, tactile, olfactory and gustatory qualities. The result of our perceptual analysis is much richer in the visual domain than in the gustatory domain for example.

(b) Adjectives dependent on our internal drive system

In the case of affective adjectives it is clear that this field is governed by primitive and evolutionarily old mechanisms (desire-aversion). The structure of these mechanisms which can be roughly localized in central domains of the brain (hypothalamus, subcortical kernels, parts of the reticular formation, cf. Bruter, 1976: 127–132) serves as basic organizational scheme for the more abstract quality spaces. This leads to the evaluative scales mentioned by Seiler (1978). These phenomena corroborate the basic bipolar distinction proposed by Thom (1978: 80), between the object (perceived) and the interpreter (perceiver).

The further differentiation seems to be more complicated so that the proposals of Seiler (1978) and Thom (1978) can only be considered as first approximations. We think that the syntax of the noun phrase can only give rough hints at the basic semantic categories.

In Thom (1973, 1978) further proposals for the semantic organization of the lexicon are discussed. As they are on the one hand speculative and on the other hand mathematically difficult we shall not discuss them in this context.

5. Some Conclusions

The models proposed in this article constitute a first elementary level of a dynamic theory of semantics. The domain of word semantics as well as that of

“deep” syntax call for a dynamic treatment, as they cannot be exhaustively described with the help of combinatorial (distributional) or algebraic tools. The surface forms are too poor and the basic organizational principles are not realized morphologically or syntactically. We assume that the methodology applied in this article which brings together results from psychology (neurophysiology) and new mathematical results in differential topology is fundamentally adequate to the problems of word semantics.

Our results are shadowed by the fact that this is the first systematic application of catastrophe theory by a linguist. As a consequence many questions are still open. We shall give a list of desiderata hoping that other investigators will join this very new and promising field of research.

List of desiderata:

- (a) The dynamic principles underlying nominal composition. As the work of Brekle (1970), Kürschner (1974), Levi (1978) and many others suggest a finite list of propositional types is used in nominal composition. In Wildgen (1979a: 444–467) we have shown that the basic types used by Brekle (1970, 1976) and Warren (1978) can be reconstructed in our framework and that by this we obtain a highly structured basis for the generation and interpretation of nominal compounds.⁶
- (b) The ellipsis of the main verb in pidginized speech. In Wildgen, 1978b and Wildgen, 1979a: 438–443 we applied our methodology to a sample of elliptical sentences from the Heidelberg Corpus.
- (c) Vagueness and the dynamics of words. Many of the phenomena described in quasi-quantitative terms by fuzzy-semantics can be modelled qualitatively in the framework of dynamical semantics (cf. Wildgen, 1980b).
- (d) Lexical fields. If the empirical aspects treated in this article are further elaborated, a dynamical theory of lexical fields will be the natural continuation of it.

All these applications should not hide the fact that:

- (a) Up to now only elementary catastrophe theory can be applied as the non-elementary structures are not yet classified (in a simple and perspicuous way). Our mathematical tool can therefore only be applied to semantic phenomena which are not combinatorial (syntactical) in their nature. We hope that the mathematical basis will be broadened by future research (cf. Chillingworth, 1976 and Thompson & Hunt, 1978).
- (b) The whole field of Attributional Dynamics has not been developed up to now. We need more sophisticated tools (for example game theoretical models equipped with dynamical concepts) and more empirical research in this domain (cf. Görlitz et alii, 1978 for recent advances in attribution theory).

⁶ A larger research on the generation and understanding of nominal compounds which is empirically and experimentally oriented is being undertaken at the University of Regensburg under the direction of Prof. Herbert E. Brekle.

These severe restrictions must be kept in mind otherwise the advantages of the model exposed in this article vanished and triviality would be the consequence (cf. some of the criticism in Sussman & Zahler, 1978).

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