# BIOCOMPLEXITY AT THE CUTTING EDGE OF PHYSICS, SYSTEMS BIOLOGY AND HUMANITIES

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# Text, Science, and Technology: Construing Text as a System

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**0.** Text is generally conceived as a literary phenomenon and is normally analysed from a linguistic and semiotic point of view. We shall try here to consider it as a technological artefact and as a physical device obeying specific natural laws. This approach to text, unusual as it may appear, shall nevertheless enable us to shed light on significant analogies between textual and natural phenomena, that turn out to be very useful for an adequate representation and handling of the text in digital form, and that can also significantly enhance our current understanding of the textual condition.

**1.** In the August 1998 issue of the authoritative scientific journal *Nature*, two Cambridge geneticists, Adrian Barbrook and Christopher Howe, jointly with two textual scholars, Norman Blake and Peter Robinson, published a paper on 'The Phylogeny of *The Canterbury Tales*'.[1] But what common ground can we find between a fundamental biological theory and the manuscript tradition of a prime

[1] A.C. Barbrook, C. J. Howe, N. Blake, and P. Robinson, 'The Phylogeny of *The Canterbury Tales*', in *Nature*, 394 (1998), p. 839.

masterpiece of English literature? The common character that biological species share with manuscript families, or particular groups of handwritten copies of the same text, is inheritance. And the transmission of inherited characters can be studied by applying similar methods. Textual scholars have developed their own techniques to identify antigraphs, or exemplar copies of a manuscript, up to a common original, so as to be able to reconstruct a sort of family tree for the whole process of transcription. Their goal is to reconstruct a lost original by retracing it backwards along the several paths of a branching line of direct descent. And it turns out that the construction of a family tree, or stemma, of a textual tradition 'is similar to the computerized techniques used by evolutionary biologists to reconstruct phylogenetic trees of different organisms using sequence data'. In the case of *The Canterbury Tales*, the number of manuscripts is so large, that the usual manual procedure carried out by philologists is really impracticable and the computerised techniques developed by biologists such as 'cladistic analysis' and the 'method of split decomposition' can and have been successfully applied.[2]

Cladistic analysis is a technique 'developed over the last thirty years by evolutionary biologists for the reconstruction of the evolutionary history of organisms from study of their shared characteristics',[3] and the method of split decomposition is a recent refinement of the phylogenetic analysis of sequence data, that is conveniently applied when it is 'inappropriate to impose a tree-like structure' on available textual data sets.[4] The 'parallels between stemmatics and cladistic systematics' had been already noted 'by several authors',[5] but the first thorough application of cladistic analysis to textual criticism was carried out in 1991 by Robert O'Hara on a data set provided by Peter Robinson from a computer collation of 44 of the 47 manuscripts of the Old Norse narrative sequence *Svipdagsmál*, comprising two poems *Gróugaldr* and *Fjölsvinnsmál* together about 1500 words long.[6] Besides being the first test carried out on data obtained 'from a [*de facto*] complete collation of an entire manuscript tradition', the cladistic analysis of the *Svipdagsmál* was decisively checked against independent external evidence, clearly proving

[2] Ibid.

[3] P.M.W. Robinson and R.J. O'Hara, 'Report on the Textual Criticism Challenge 1991', in *Bryn Mawr Classical Review*, 3:4 (1992), 331-337. Also at <http://rjohara.net/cv/1992-bmcr> (2 January 2007).

[4] Barbrook et al., 'The Phylogeny of *The Canterbury Tales*', p. 839. Cf. H.J. Bandelt and A.W. Dress, 'Split Decomposition: A new and useful approach to phylogenetic analysis of distance data', in *Molecular Phylogenetics and Evolution*, 1:3 (1992), 242-252.

[5] See for detailed references P.M.W. Robinson and R.J. O'Hara, 'Cladistic Analysis of an Old Norse Manuscript Tradition', in *Research in Humanities Computing 4: Selected papers from the ALLC/ACH Conference, Christ Church, Oxford, April 1992*, ed. Susan Hockey and Nancy Ide, Oxford, Clarendon Press, 1996, pp. 115-137. Also at <http://rjohara.net/cv/1996-rhc> (3 January 2007).

[6] Cf. Id., 'Report'.

that a significant group of manuscripts were actually 'related as given' by its proposed reconstruction.[7]

The allegation of many a textual scholar, 'that statistics and mathematics have no place in the study of textual traditions',[8] has been proven patently unwarranted by the 'remarkable results'[9] obtained by the application of cladistic methods to the analysis of manuscript relations within the *Svipdagsmál* textual tradition. Criticisms against the usefulness of mathematical methods have been repeatedly directed towards previous attempts at applying statistical and computer-assisted methods to stemmatic reconstruction. The most common applications of mathematical methods were based upon statistical techniques such as cluster analysis or multivariate analysis,[10] but quite convincingly statistical clustering techniques have been found 'less satisfactory than cladistics'.[11] Statistical clustering can be successful in grouping manuscripts containing similar readings, but cannot 'define precisely which manuscript, or group of manuscripts, might be descended from which'.[12] In the language of systematic biology, it may yield 'classification', but not 'systematization', for

> classification is the grouping of objects into classes on the basis of the properties of the objects being classified. The objects in each group are spoken of as being members or instances of their class. In contrast, systematization is the arrangement of objects into some larger whole object, and the relation that the constituent objects bear to the systematic whole is that of a connected part, rather than a member.[13]

Accordingly, purely statistical considerations cannot identify relations of historical descent. Phenomena of inheritance and evolution require more appropriate methods of analysis such as cladistic techniques. Inheritance implies the recognition of a relationship between a collective whole, or a 'taxonomic group' seen as an

[7] Id., 'Cladistic Analysis'.

[8] Cf., in particular, A.E. Housman's saying, as quoted in Robinson and O'Hara, 'Report': 'A textual critic engaged upon his business is not at all like Newton investigating the motion of the planets; he is much more like a dog hunting for fleas. If a dog hunted for fleas on mathematical principles, basing his researches on statistics of area and population, he would never catch a flea except by accident'.

[9] Id., 'Report'.

[10] For direct references see P.M.W. Robinson and R.J. O'Hara, 'Report', 'Cadistic Analysis', and 'Computer-Assisted Methods of Stemmatic Analysis', in *The Canterbury Tales Project: Occasional Papers 1*, ed. Norman F. Blake and Peter M.W. Robinson, Oxford, Office for Humanities Communication, 1993, pp. 53-74.

[11] Id., 'Stemmatic Analysis', note 3.

[12] Id., 'Report'.

[13] R.J. O'Hara, 'Systematic Generalization, Historical Fate, and the Species Problem', in *Systematic Biology*, 42:3 (1993), 231–246, p. 233.

object that 'can change indefinitely without ceasing to be the same individual',[14] and its connected parts. The constituent parts of such an 'individual' are related not because of their identical properties, but because of their participation to an identical object that comprises and connects them as its components. For an individual object of this kind, the whole is not defined by the identity of the parts, but the parts are defined by the identity of the whole. It is the sameness of the whole that creates the bond, not the similarity of the parts: the parts may change, but the 'composite whole'[15] still remains the same. Just as a text remains the same without being self-identical in all of its variant readings.

That being the case, it cannot be by sheer coincidence that all the disciplines having to do with phenomena of inheritance make use of 'trees of history', a broad class of 'branching diagrams of genealogical descent and change', that we find not only in the study of biological evolution, but also in the description of language evolution and of manuscript descent.[16] Thus, as Robert O'Hara has pointed out, 'there are at least three different disciplines that reconstruct what might be called "trees of history": systematic biology, historical linguistics, and stemmatics'.[17] And 'the opportunity now exists for systematists to contribute to the theory and practice of linguistics and stemmatics, their sister disciplines in historical reconstruction',[18] in particular through the application of their commonly used computer programmes for tree estimation. The similarities between systematic biology and historical linguistics have long been noted: 'Charles Darwin conjectured in the *Origin of Species* (1859, 422) that the tree of human languages would correspond to the evolutionary tree of the human races'. On the other hand, the similarities between systematic biology and stemmatics 'seem to have been noticed only recently', namely in the last thirty years, in spite of the fact that they have made use of similar methods since the first half of the nineteenth century: 'Charles Darwin began to sketch trees of evolutionary descent in his research notebooks' and 'nearly the same time Karl Zumpt published the first tree of manuscript descent'.[19]

**2.** If 'some cross-disciplinary help from systematics' can thus be found in linguistics and in textual studies,[20] it should not be surprising that cross-fertilisation

[14] M.T. Ghiselin, 'Species Concepts: The basis for controversy and reconciliation', in *Fish and Fisheries*, 3:3 (2002), 151-160, p. 155.

[15] Ibid.

[16] Cf. R.J. O'Hara, 'Trees of History in Systematics and Philology', in *Memorie della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano*, 27:1 (1996), 81–88. Also at <http://rjohara.net/cv/1996-milan> (4 January 2007).

[17] Robinson and O'Hara, 'Cladistic Analysis'.

[18] Id., 'Trees of History'.

[19] Id., 'Cladistic Analysis'.

[20] Id., 'Trees of History'.

could work also in reverse. For instance, 'the historical study of hybridization in evolutionary biology' is 'quite similar to the problem of detecting contamination in manuscript traditions', and it has been argued that 'some insights' can 'pass from textual criticism back into' systematic biology, from reflection on 'manuscript contamination' – the horizontal transmission of readings between manuscripts – and 'its relation to cladistic analysis'.[21] But it should be noted that both problems actually face a common difficulty, that seems to reside in the limitations of an analytical approach based on a simple tree model. Accordingly, both problems are in need of a common solution that could be provided by the newly analysed 'reticulate phylogenetic models', that 'can adequately describe such complicated mechanisms as hybridization between species'[22] and might be suitably extended to its kindred phenomenon of manuscript contamination. A sort of cross-hybridization between text critical and biological methods can then occur at a more general and deeper level. It can stem from the assumption that 'we have every reason to think that manuscripts descend from one another just as do [biological] species'[23] and that precisely for this reason 'there is a fundamental identity between cladistic systematics and stemmatics'.[24]

In conclusion, the 'remarkable results'[25] of the application of cladistic methods to the study of textual traditions clearly show that textual transmission is a phenomenon very much akin to the reproduction of biological organisms. But this identity is not only an identity of methods or abstractions, that lead to identical forms of representation. It is rather an identity between natural phenomena that involve an information transfer over and besides a material transformation. Phylogenetic or stemmatic trees are no more than *representations*, 'representations of the evolutionary chronicle', just 'as maps are representations of the earth'.[26] But as representations, such "trees of history" are all 'subject to [...] systematic generalization' (231) or abstraction, and the identity of the abstractions – or the applicability of the cladogrammes as abstract forms of representation – depends on the identity of the phenomena they represent. It is the nature of these phenomena that is really alike. They are all processes of the same kind, involving both a material and an information element. In a textual transmission, the process of manual transcription tries to ensure the invariance of the text by means of a faithful reproduction of its physical expression. But transcription, mechanical as it may be, is not a direct imprint of the original; it begets a reproduction of the

[21] Id., 'Cladistic Analysis'.

[22] V. Makarenkov and P. Legendre, 'From a Phylogenetic Tree to a Reticulated Network', in *Journal of Computational Biology*, 11:1 (2004), 195-212, p. 195.

[23] Robinson and O'Hara, 'Report'.

[24] Id., 'Cladistic Analysis'.

[25] Id., 'Report'.

[26] R.J. O'Hara, 'Systematic Generalization', p. 231.

exemplar by applying the same procedure that has led to its original making, so much as the biological reproduction of an organism is a process governed by its genetic code. And it is this relation between matter and information that we shall be taking heed of in pursuing further our examination of the analogy between textual and biological phenomena.

Trees can then be thought of as forms of 'systematic representation', (244) that become simpler the higher becomes the generalisation or the 'omission' (236) of the characters and events we decide to deal with. Just as, in reverse, the more we take into account 'higher-level relationships of a taxon' – a unit in classification – the 'more finely resolved' and 'less generalized' (244) our systematic representations turn out to be. Therefore, what we provisionally assume as *objective*, or natural and concrete, and what we assume as *subjective*, or purely abstract and representational, depends on the level of our generalisation. So what is really called in question by the construction of a tree is in fact the relationship between the events and their representations. The species problem, 'one of the oldest controversies in natural history', is then 'something more than a problem of fact or definition' and is preferably to be viewed as 'a problem in the *representation* of the natural system', (231) or perhaps more accurately as a problem concerning the relationship between natural objects and their forms of representation.

**3.** There are different ways of dealing with that relation. According to Michael Ghiselin, it is the relation between species as 'individuals', and species as 'classes'.[27] Species as classes have 'defining properties', such as being a population that determine their 'membership'. Species as individuals have 'no defining properties', nor 'instances or members'; their elements, the individual organisms they are made of, can be described as their 'parts' or 'components'. Species as classes are 'abstractions', and have 'no particular location in time and space', whereas species as individuals are 'historical entities', 'concrete particular things' that are 'spatio-temporally restricted'. Classes for which there exist 'laws of nature' are called 'natural kinds', and evolutionary biology comprises both laws of nature, that deal with classes as species and other natural kinds, and 'history', (153) which deals with species as composite individuals and other lineages.

Now, if we introduce the 'biological species concept', we identify the notion of species as a class with the notion of species as an individual:

> The biological species concept treats the most incorporative populational units, i.e. the basic units in speciation theory, as the basic units in taxonomy as well.

[27] Ghiselin, 'Species Concepts', p. 151.

Accordingly, we set an 'identity' (156) between an abstract and a concrete notion at the populational level, and we assume that the 'evolutionary chronicle'[28] of a 'taxonomic group' of organisms obeys the laws of a 'class of (population level) individuals'[29] viewed as a natural kind, favouring 'the integration of the more nomothetic branches of biology with the more historical ones'. But the level of generalisation, and hence the decision about what has to be thought of as abstract and what as to be thought of as concrete, is a matter of 'choice' and 'there is nothing to stop us from going below the populational level to that of the organism or for that matter the cell or the molecule' (156). Whether a notion should be treated as an abstract or as an historical one, would depend on the level of our generalisation, and it is important to note that there is no absolute demarcation. But what is really at issue is to establish what the implications are if we assume the identity between the abstract notion of a class and the historical notion of a composite whole.

In the first place we should note that what we actually equate are two notions or representations, albeit of a different kind. And we do not really tackle the problem of specifying the relationship between their information content and the events they refer to. If species would be 'defined in terms of their membership', they would behave as extensional sets of individual organisms and 'if one organism were to die and another to be born, the "population" would not be the same set'. In other words, species would 'supposedly exist only at a particular moment in time' and one 'unfortunate result of conceptualizing species as extensional classes' would have it that 'a species and a lineage cannot be the same individual' (158). That's why the biological species concept has to identify the notion of species as a class with the notion of species as an individual. But we are not yet out of predicament. Individuals as composite historical wholes are identified by the information that connects their component parts and acts as a sort of 'definition from the inside'. But in a cladogramme that information is treated as an abstract representation, a sort of 'definition from outside',[30] and the constituents of a collective whole, although historically related, are seen again in themselves as external objects and purely referential entities: organisms, cells, or molecules. A gene, for instance, would be seen in this perspective as a molecule and not as an information carrier together with the information it conveys. The identity of the two representations does not solve the problem and a paradigm shift seems to be needed.

From the same point of view, in a stemmatic tree of manuscript families, a variant reading would be seen as a purely graphical mark and a text would be identified with its material component. But as Cesare Segre reminds us, 'the text does not

[28] O'Hara, 'Systematic Generalization', p. 232.

[29] Ghiselin, 'Species Concepts', p. 155.

[30] F.J. Varela, *Principles of Biological Autonomy*, New York, North Holland, 1979, p. xii.

have a material nature'[31] and any attempt to identify it with a material witness whatsoever, even an autograph original, is 'an attempt to conceal [its] unavoidable problematic nature' (376). For, indeed, also 'the notion of an original', or the notion of an 'autograph' for that matter, taken 'in the sense of an authentic text that expresses the author's will', is, in D'Arco Silvio Avalle's words, 'one of the most elusive and ambiguous notions of textual criticism'.[32] For 'the text is only' and 'always an image'.[33] If we do not take into account its information content, we reduce a semiotic object like a text to its material component. And by disregarding its information content, the material component of an image ceases to be an image or a representation at all. But there is a different way of considering the relation between information and facts that does not run this kind of risk.

**4.** Nowadays, 'with the discovery of cybernetics, systems theory, information theory, and so on', as Gregory Bateson noted, 'we begin to have a formal base enabling us to think about' evolution 'in a way which was totally heterodox from about 1850 through to World War II'; and 'it is now empirically clear', as he put it, 'that Darwinian evolutionary theory contained a very great error in its identification of the unit of survival under natural selection'. For, in his opinion, the 'crucial' unit around which evolutionary theory is organised is not constituted only by 'the breeding individual or the family line or the subspecies or some similar homogeneous set of conspecifics', but has to be identified with mind. And, clearly, if we assume the 'identity between the unit of mind and the unit of evolutionary survival' we can see the relation between information and facts in a quite different way: 'cybernetic epistemology' requires a 'new approach'.[34] But how is mind to be conceived of according to this new point of view?

Bateson's basic insight is that 'the unit of mind in evolution is not only, and certainly not fundamentally, the skull, but what he calls the "message-in-the-circuit"', or what Francisco Varela would rather call 'the cognitive process of an autonomous unit, at many possible levels'.[35] Basically, what Bateson was reacting to is that 'sort of rough dichotomy' which posits the "physical world" as 'external' and 'somehow separate from an internal "mental world"',[36] and which, in Varela's

[31] C. Segre, *Avviamento all'analisi del testo letterario* [Engl. ed. *Introduction to the Analysis of the Literary Text*, with the collaboration of T. Kemeny, trans. J. Meddemmen, Bloomington and Indianapolis, Ind., Indiana University Press, 1988], Torino, Einaudi, 1985, p. 378.

[32] D'A.S. Avalle, *Principi di critica testuale*, Padova, Antenore, 1972, p. 33.

[33] Segre, *Avviamento all'analisi del testo letterario*, p. 378.

[34] G. Bateson, 'Form, substance and difference', 19th Annual Alfred Korzybski Memorial Lecture, in *General Semantics Bullettin*, 37 (1970); reprinted in Id., *Steps to an ecology of mind: Collected essays in anthropology, psychiatry, evolution, and epistemology*, San Francisco, Chandler, 1972, pp. 454-471.

[35] Varela, *Principles*, p. 270.

[36] Bateson, 'Form, substance and difference', p. 460.

words, can also be described as 'a cut between the cognizing subject and the object to be known',[37] a view that was still depending on what Gilbert Ryle described as 'Descartes' myth', namely that kind of dualism for which he also coined the metaphor of 'the ghost in the machine'.[38] But, under the impact of cybernetics and information theory, 'the great dichotomy of epistemology has shifted'[39] and the 'cognitive processes' came to be thought of as operating in a way that 'cannot truly be *separated* from [a] network'[40] of 'message pathways outside the skin'. According to Bateson, 'these' pathways 'and the messages which they carry must be included as part of the mental system'; hence,

> the individual mind is immanent but not only in the body. It is immanent also in pathways and messages outside the body.[41]

Therefore, we 'need to reconsider the traditional notion of subject', and besides taking into account 'individual organisms and their (internal) cognitive processes', we must consider higher-level 'autonomous units', that is, the cognitive processes of the units 'of which *we* are participants and components'. And an autonomous unit of that kind has 'two characteristics that make it mindlike': it 'specifies a distinction between it and not-it', and it 'has a way of dealing with its surroundigs in a cognitive (in-formative) fashion'.[42] Thus,

> in considering units of evolution [...] you have at each step to include the completed pathways outside the protoplasmic aggregate, be it DNA-in-the-cell, or cell-in-the-body, or body-in-the-environment. The hierarchic structure is not new. Formerly we talked about the breeding individual or the family line or the taxon, and so on. Now each step of the hierarchy is to be thought of as a *system*, instead of a chunk cut off and visualized as *against* the surrounding matrix.[43]

From this point of view, then,

> mind is an immanent quality, of a class of organizations including individual living systems, but also ecological aggregates, social units of various sorts, brains, conversations, and many others,[44]

[37] Varela, *Principles*, p. 275.
[38] Cf. G. Ryle, *The Concept of Mind*, London, Hutchinson, 1949.
[39] Bateson, 'Form, substance and difference', p. 456.
[40] Varela, *Principles*, p. 270.
[41] Bateson, 'Form, substance and difference', p. 467.
[42] Varela, *Principles*, p. 270.
[43] Bateson, 'Form, substance and difference', p. 466.
[44] Varela, *Principles*, p. 270.

or for that matter texts. And it is this fundamental insight that is the true rationale of the analogy between textual and biological phenomena. Information is not separable from events.

**5.** The new paradigm of biological autonomy relates to the whole range of 'sentient beings' or 'entities to which we are compelled to acknowledge an informational side, however opaque and simple',[45] and brings about also a new way of looking at texts. Beforehand, we have been considering the physical components of the phenomena of descent: the physiological characters of the organisms as opposed to their self-organising functions, on the one side, and the *expression* of the text as opposed to its *content*, on the other.[46] But in the new paradigm the analogy can be carried over from the material to the informational element. In a living system, the 'relations' that 'determine the dynamics of interactions and transformations it may undergo'– what Varela calls its 'organization' – have 'no connection with materiality', or with 'the properties of the components that define [it] as [a] physical entit[y]' – what Varela calls its 'structure'.[47] Organisation, however, is not a purely abstract notion; it is, on the contrary, an empirical or 'synthetic' notion. But

> within the synthetic one should distinguish two levels: the *materially* synthetic (i.e. where materiality enters *per se* into consideration), and the *nonmaterially* synthetic (i.e., where materiality is implied but is, as such, irrelevant) (10).

Accordingly, *organisation* is '"information", not matter or energy',[48] but is as factual as the material *structure* and components of a living system – or for that matter of a text. For a text can indeed be considered, by analogy, as a system comprising a population of manuscripts; and an individual manuscript as a particular image of the text, having an *expression*, or a *structure* of material components such as sounds or scripts, and a *content*, or an *organisation* of meaningful words and phrases. In both biological and textual phenomena, therefore, information is as much an essential element as their material components. But can the analogy be carried further?
A living system, can be described as an 'autopoietic' system, in as much as it 'generates and specifies its own organization through its operation as a system of production of its own components'.[49] In a living system, 'what makes it a unity with identity and individuality' is its own 'invariant organization', (26) that is, its intrinsic, self-definig and self-regulating information content: autopoietic systems

[45] Ibid., p. xiii.

[46] For the distinction between *expression* and *content* of a text, see Hjelmslev, *Prolegomena to a Theory of Language* (1943), Madison, Wis., University of Wisconsin Press, 1961, pp. 52ff.

[47] Varela, *Principles*, p. 9.

[48] N. Wiener, *Cybernetics*, 2nd ed., Cambridge, Mass., MIT Press 1961, p. 132.

[49] Varela, *Principles*, p. 13.

'are unities because, and only because, of their specific autopoietic organization' (15). Organisation, then, acts as an informational holistic principle of 'mutual interconnection' (102) and the relations it consits of can be qualified as 'codependent' (xv). Similarly, to describe the 'textual condition',[50] Jerome McGann makes extensive use of the notion of 'textual fields',[51] and textual fields can be thought of as organisational unities that 'arise codependently with interpretative action'.[52] Texts are endowed with 'perceptual features', that relate to its expression, as well as with 'semantic, syntactic, and rhetorical features', that relate to its content, and 'every feature represents a determinate field of textual action'. Textual fields 'might (or might not) individually (abstractly) be organized in a hierarchical form' and are all interconnected, each feature operating as the organising principle of a network of codependent relations.[53] So, textual artefacts – that is to say, 'print and manuscript encoding systems' and 'technologies' – are 'organized under a horizon of co-dependent relations',[54] and according to McGann we can conclude that

> like biological forms and all living systems, not least of all language itself, textuality is a condition that codes (or simulates) what are known as autopoietic systems.[55]

**6.** As introduced by Maturana and Varela, however, the notion of autopoiesis does not comprise coding systems, such as language or text, for it refers to the actual production of the material components of a system. Accordingly, only a system that 'continuously generates and specifies its own organization through its operation as a system of production of its own components',[56] can be described as autopoietic. On the contrary, 'mechanistic systems' which 'do not produce the components that constitute them as unities'[57] so that 'the product of their operation is different from themselves', are called 'allopoietic'.[58] That is precisely the case with artificial productions, and with manuscript, print, and electronic technology as well. Apparently,

[50] Cf. J. McGann, *The Textual Condition*, Princeton, N.J., Princeton University Press, 1991.

[51] Cf. Id., 'Texts in N-Dimensions and Interpretation in a New Key [Discourse and Interpretation in N-Dimensions]', in *Text Technology*, 12:2 (2003), pp. 1-18.

[52] Ibid., pp. 1, 3, and 6.

[53] Id., 'Visible and Invisible Books: Hermetic Images in N-Dimensional Space', in *New Literary History*, 32:2 (2001), 283-300, p. 297.

[54] Id., 'Marking Texts of Many Dimensions', in *A Companion to Digital Humanities*, ed. S. Schreibman, R. Siemens, and J. Unsworth, Malden, Mass., Blackwell Publishing, 2004, 198-217, p. 200.

[55] Id., 'Texts in N-Dimensions', p. 7.

[56] H.R. Maturana and F.J. Varela, *Autopoiesis and Cognition: The realization of the living*, Dordrecht, Reidel, 1980, p. 79.

[57] H.R. Maturana, 'Cognitive Strategies' in *L'unité de l'homme: Invariants, biologiques et universaux culturels*, ed. E. Morin et M. Piattelli-Palmarini, Paris, Éditions du Seuil, 1974, p. 460.

[58] F.J, Varela, H.R. Maturana and R. Uribe, 'Autopoiesis: The organization of living system, its characterization and a Model, in Biosystem, 5:4 (1974), 187-196, pp. 188-189.

then, language and text cannot be *prima facie* equated with autopoietic systems, for 'the idea of autopoiesis is, by definition, restricted to the idea of production of some kind',[59] but what matters here is the fact that, 'codependency pervades an autopoietic structure of relations',[60] so that it comes natural to ask to what extent the relations that characterise many kind of unities and human systems are 'isomorphic to the autopoiesis of the individuals that integrate it'. Varela observes that many systems are provided with a 'degree of autonomy', for

> they have defined a domain or space in which they exist (usually not the physical space), and they have components that integrate them and relations among these components such that the unity attains coherence and can be distinguished through the interdependence of components

and concludes that 'we can take the lessons offered by the autonomy of living systems and convert them into an operational characterization of autonomy in general', thereby describing autonomous systems as those 'defined as a unity by their organization' and by their being 'organizationally closed'.
Hence, it may well be a 'category mistake' to 'confuse autopoiesis with autonomy',[61] as Varela insists, but Niklas Luhmann did nevertheless argue that 'the concept of autopoiesis has to be abstracted from biological connotations', and generalised it in order to comprise also psychological thinking systems and social communicative systems:

> If we abstract from life and define autopoiesis as a general form of system building using self-referential closure, we would have to admit that there are non-living autopoietic systems, different modes of autopoietic reproduction, and that there are general principles of autopoietic organization that materialize as life, but also in other modes of circularity and self-reproduction.[62]

The three kinds of autopietic systems Luhmann admits of, the biological, the psychological and the social, are organisationally closed. 'They can only communicate through interpenetration',[63] and it has been maintained that 'sign and language games arise on the basis of the interpenetration of the three different autopoietic systems'.[64]

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[59] Varela, *Principles*, p. 54.

[60] McGann, 'Texts in N-Dimensions', p. 8.

[61] Varela, *Principles*, pp. 53 and 55.

[62] N. Luhmann, *Essays on Self-Reference*, New York, Columbia University Press, 1990, p. 2.

[63] S. Brier, 'The Construction of Information and Communication: A cybersemiotic reentry into Heinz von Foerster's metaphysical construction of second-order cybernetics', in *Semiotica*, 154:1/4 (2005), 355-399, p. 380.

[64] S. Brier, 'The Cybersemiotic Model of Communication: An evolutionary view on the threshold between semiosis and informational exchange', in *TripleC: Cognition, Communication, Cooperation*, 1:1 (2003), 71-94, p. 86, <http://triplec.uti.at/files/tripleC1(1)_Brier.pdf> (19 January 2007).

Luhmann, however, regards language as a 'medium', not as a system. According to Luhmann, a communication 'must take on a form, either acoustically or optically, in the media of possible perception'; but perceptibility itself does not yet constitute communication: the acoustic and optical forms we perceive as marks and signs, 'must serve, in turn, as the medium for another type of forms which then bind this medium'. This is 'achieved by language', and language makes possible 'the communication of comprehensible sentences', that are 'second-order forms – forms in the medium of what consciousness is able to process in terms of perception'.[65] Since 'media arise only when it becomes possible to break the compactness of a unity into a multiplicity of loose elements that can be recombined in different ways', language – and writing and printing for that matter – is a medium 'because by separating communication and observation it loosens the unity of the communicative act'.[66] Luhmann, then, 'distinguished media theory from system theory', but Habermas in his philosophical critique of Luhmann's contentions 'objects to this major decision' and 'points to its implied assumption about language':[67]

> What a burden is assumed by a theory that divides up linguistic structures that cover both the psychic and the social dimensions into two different systems.[68]

Hence, Habermas claims that 'it is legitimate to consider as the system what traditionally has been considered as the medium'.[69] This contention does not seem unwarranted at all, for in the present situation of media pervasiveness 'many students assume an autonomous relevance of the media as a specific system', and Luhmann himself 'presents the mass media as an autonomous functional system of contemporary society'.[70] And this appears indeed to be McGann's position, when he asserts that language, manuscript, print, and electronic technology 'are second- and third-order autopoietic systems' – what McLuhan 'famously, expressively, if also somewhat misleadingly' called[71] 'extensions of man'.[72] In this respect, and

[65] N. Luhmann, 'Speaking and Silence', in *New German Critique*, 61 (1994), 25-37, p. 29.

[66] E. Esposito, 'The Arts of Contingency', in *Critical Inquiry*, 31 (2004), 7-25, pp. 11-12, and 15.

[67] L. Leydesdorff, 'Luhmann, Habermas, and the Theory of Communication', in *Systems Research and Behavioral Science*, 17:3 (2000), 273-288, pp.279-80.

[68] J. Habermas, 'Excursus on Luhmann's Appropriation of the Philosophy of the Subject through Systems Theory', in *The Philosophical Discourse of Modernity: Twelve Lectures* [*Der philosophische Diskurs der Moderne: zwölf Vorlesungen*, Frankfurt a.M., Suhrkamp, 1985], trans. F. Lawrence, Cambridge, Mass., MIT Press, 1987, 368-85, p. 378.

[69] Leydesdorff, 'Luhmann', p. 280.

[70] Esposito, 'The Arts of Contingency', p. 22, and note 34.

[71] McGann, 'Texts in N-Dimensions', pp. 7-8.

[72] Cf. M. McLuhan, *Understanding Media: The Extensions of Man*, New York, McGraw-Hill, 1964.

to insist again on the analogy between textual and biological phenomena, it is important to note that in his book, *The Extended Phenotype*, Richard Dawkins 'suggests that the notion phenotype should include, in addition to the immediate bodily properties of animals, also some of their products such as the bird's nest, the beaver's dam, the spider's web and the like'.[73] Accordingly, and contrary to Chomsky's strictly Cartesian contention that 'external languages' – and by implication other external 'cognitive artifacts' – 'have no place in the picture of cognition', a growing number of studies maintain that 'artifacts often function as an extension of the body' and 'also as an extension of the mind/brain'.[74]

**7.** Adopting a similar approach, McGann argues that 'coding mechanisms' are 'generative components' of the organisation they serve to maintain: 'they are folded within the autopoietic system like membranes in living organisms, where distinct components realize and execute distinct extensions of themselves'.[75] It is worth reflecting on this notion of extension. As related to an individual mental or psychological system, a coding mechanism can be thought of as an extension which simulates – and therefore reifies and externalises – internal mental operations. In this respect, coding mechanisms can be described as 'machines of simulation':[76] they simulate mental operations of a psychological autopoietic system. But a machine of this kind is also 'capable of connecting itself to a host of related, equally complex information networks',[77] and can therefore be regarded as related to several autopoietic social communication systems. In this latter respect, coding mechanisms have been construed as a medium. But in either case the material component of a coding mechanism happens to be conceived of severed from its informational counterpart – which resides in individual minds or in social communication networks – and both points of view fail to recognise it as a purely partial element that provides only one constituent of a more complex system.
Husserl, on the contrary, insists that the signifying function is an 'essential' property of a sign – that is, of an otherwise purely material and perceptual object[78] – and Peirce, in its turn, insists on 'the triadic relation existing between a sign, its object, and the interpreting thought' – 'itself a sign, considered as constitut-

[73] J. Portugali, 'The Seven Basic Propositions of SIRN (Synergetic Inter-Representation Networks), in *Nonlinear Phenomena in Complex Systems*, 5:4 (2002), 428-444, p. 434. Cf. R. Dawkins, *The extended phenotype: The gene as the unit of selection*, Oxford, Oxford University Press, 1982.

[74] Cf. ibid., pp. 436-37 for detailed references.

[75] McGann, 'Texts in N-Dimensions', p. 8.

[76] Id., 'Marking Texts of Many Dimensions', p. 201.

[77] Id., 'Texts in N-Dimensions', p. 12.

[78] Cf. E. Husserl, *Logische Untersuchungen*, I-II/1-2, Halle a.d.S., Niemeyer, 1900-01, Zweiter Band, I. Teil: *Untersuchungen zur Phänomenologie und Theorie der Erkenntnis*, II/1, pp. 24-25.

ing the mode of being of a sign'.[79] Deprived of what Husserl calls its 'signifying intention' (*Bedeutungsintention*)[80] a mere 'optical' mark, or 'acoustic' vibration,[81] is not a sign; and a sign involves always a 'triadic relation' between the sign, its meaning and an interacting system: 'a sign endeavours to represent, in part at least, an Object [...] but to say that it represents its Object implies that it affects a mind'[82] – or a mind-like interpreting system anyway. A coding mechanism is not to be seen necessarily as a function of a psychological 'human agency' or of a social 'communication network',[83] but through its interactions with individual agencies or social autonomous networks it exists in itself as a semiotic system endowed with its own self-contained organisation and structure.

The sharp distinction introduced by second-order cybernetics[84] between observing and non-observing feedback systems[85] has in effect hampered the recognition of hybrid systems, such as technological semiotic systems: a text can indeed be considered both as an 'artefact',[86] or a passive non-observing system, and as an autonomous or an autopoietic system, for it clearly shares the characters of both. A semiotic system cannot be considered just as a medium, external to an autonomous system. That would amount to neglecting the constitutive and essential bond between its material component and its informational element. A text, as a semiotic system, cannot be regarded as a purely material object, severed from its information content.

The analogy between a text and a biological – and social – system has a ground in the essential connection between its material component and the information it conveys. A semiotic system is not just a channel, it cannot exist as such apart from the information it contains. Information can be seen as the *form* of the signal, as a perceived difference in the material component of the system, or as a discernible pattern or configuration beheld in the expression of the text. Information is always relative to an observer, but an observer does not perceive information as such. It is always information *as conveyed through the form of the signal* that is relative to an observer. An observing system can only perceive information through the form of the signal, that is, through a difference, or a distinction, in the configuration

[79] Ch.S. Peirce, *A Letter to Lady Welby*, CP 8.331-332, 1904.

[80] Husserl, *Logische Untersuchungen*, II/1, p. 505.

[81] Luhmann, 'Speaking and Silence', p. 29.

[82] Ch.S. Peirce, 'Some Amazing Mazes, Fourth Curiosity', CP 6.347, c. 1909.

[83] Cf. Leydesdorff, 'Luhmann'.

[84] Cf. F. Heylighen and C. Joslyn, *Cybernetics and Second-Order Cybernetics*, in R.A. Meyers (ed.), *Encyclopedia of Physical Science & Technology*, 3rd ed., New York, Academic Press, 2001. Also at <http://rjohara.net/cv/1996-rhc> (7 February 2007), p. 12: 'Artificial systems [...] are not autonomous'.

[85] Cf. H. von Foerster, *Observing Systems*, Seaside, Calif., Intersystems Publications, 1981.

[86] Cf. D.M. MacKay, 'Mindlike Behaviour in Artefacts', *The British Journal for the Philosophy of Science*, 2:6 (1951), 105-121.

of the material component of a semiotic system. And instead of considering language as a medium, external to an autonomous observing system, one can consider language as a semiotic system consisting in its material component *in as much as* it is meant or perceived as a sign by an interacting observing system. We can consider a material signal as an external medium relative to an observing system, just as we can consider an observing system as an interacting condition relative to a material token, or event, in as much as it functions as a sign. Or should we assign a privileged ontological primacy to autonomous observing systems, and prevent other forms of structural organisation to be granted the status of a system? For it seems very much well-founded to construe semiotic and textual phenomena as a specific form of systemic organisation. Text, as such, is not just an information carrier, for the information it embodies is precisely what constitutes its organisation. And if this is the condition for the very existence of the text in as much as it is a text, the text cannot be considered in isolation from the observing systems that can perceive its expression as an organised structure of meaningful signs.

The notion of text as a system, as discussed here, can be compared with the notion of 'inter-representation network' (IRN), which presents the cognitive system as 'a network composed by internal and external representations': internal representations constructed in the mind and external representations constructed by means of the 'mimetic, linguistic and artifact-making capabilities' of human beings. Such a view of the cognitive system was inspired, on the one hand, 'by Bohm's theory of order', in particular by his notions of 'implicate- and explicate-order', and on the other hand, 'by Haken's synergetics approach to self-organization', and it applies, interestingly enough, both 'to society' and 'to' the phenomena of individual 'cognition'.[87] As is well known, synergetics – or the working together of many parts – is a theory which deals with self-organisation as the fundamental property of 'open and complex systems' (437), namely systems that are open 'in the sense that they exchange matter, energy and information with their environment', and complex in the sense that 'their parts and components are interconnected in a non-linear fashion by a complex network of feedback loops' (438). What synergetics 'adds to the notion of IRN' is the view that 'the brain/mind, cognition, cognitive mapping, and the interaction between internal and external representations, are all self-organizing systems that evolve in line with the principles of synergetics' (428-29). And it is also worth mentioning in this respect that, by 'referring to Dawkins' and Dennett's "gene-eye-view" on nature and evolution' (434), one of

[87] Portugali, 'The Seven Basic Propositions of SIRN, p. 428. Cf. D. Bohm, *Wholeness and the Implicate Order*, London, Routledge & Kegan Paul, 1980; H. Haken, *Synergetics, An Introduction: Nonequilibrium phase transitions and self-organization in physics, chemistry, and biology*, 3rd ed., Berlin, Springer, 1983, and Id., *Advanced Synergetics: Instability hierarchies of self-organizing systems and devices*, 2nd ed., Berlin, Springer, 1987.

the 'basic propositions' (429) that describe synergetic inter-representation networks (SIRN) states the following: 'internal and external representations interact in a way reminiscent of the relations between genotype and phenotype' (434). We have here one more reason to stress that the analogy between textual and biological phenomena is deeply grounded in their common systemic organisation.

**8.** Construed as a kind of hybrid semiotic system, or described as an inter-representation network, text can be viewed both as a technological artefact and as an autonomous and autopoietic system of a particular type. The text is organised in a variety of interconnected fields of codependent relations, that license, in McGann's words, different 'games of self-generation and self-transformation'[88](291) among an extensive range of 'complex autopoietic forms' (298). The text acts 'simultaneously' as a technological machine, as an autonomous system, and as a literary unit. Literary and scientific approaches merge in the analysis of a poetic text: 'this kind of text' (292) most explicitly – but 'even a blank page', or 'a page of George W. Bush's prose', (298) for that matter – is 'both a perceptual and a conceptual event'. A poem – or a text – is interspersed of many a 'perceptual signal', (292) multiply organised 'in terms of various relational segmentations and metasegmentations', and exposes a host of 'strange arrangements', either 'phonemic', or 'thematic', or whatever, (297) and different 'patterns' (289) of 'characteristic formal features' (288). The perceptual, machine-like configuration and 'formal patterns' of the expression, as the reading goes on, allow for multiple and alternative 'different arrangements' (289) of the perceptual textual elements, and for 'varying and overlapping sets of textual designs, both linguistic and bibliographical' (299).
Such a dynamic 'interplay' (297) of textual fields implies that a 'critical representation' of the text is 'no more (and no less) than a certain perspective' on it (287). Any single 'segment' (298) or perceptual feature of the text can be recombined in a different arrangement. Interpretation, then,

> stands in a dialectical relation to its object, which must always be a transcendental object so far as any act of critical perception is concerned. This transcendental condition is a necessity because the object perpetually shifts and mutates under the influence of its perceivers (287).

A *Gestalt* shift in the perception of formal textual patterns opens 'doors of perception' towards 'new' interpretational 'opportunities and points of view' (288). Hence, 'no poem' – no text – 'can exist without systems of "overlapping structure"', (290) and if we find 'acceptable' a 'very broad definition' of the textual

[88] McGann, 'Visible and Invisible Books', p. 291.

structure as 'the set of the latent relations among the parts' of a literary work,[89] then 'the number of possible structural determinations applicable to the text is potentially infinite'.[90] Every text is structurally ambiguous and indetermination can be assumed as an essential feature of the textual condition.

In a codependent autopoietic structure, any internal unit is defined by the set of its relations with all the other internal elements and with the overall structure as a whole. A structural shift changes the entire network of internal relations and affects the whole range of textual units. Hence, structural indetermination allows for ambiguities and 'duplicities', and in a textual field 'no unit can be assumed to be self-identical'[91]. All texts 'are incommensurate with themselves at all points' (288) and 'no textual event is ever self-identical or self-transparent' (292). As literary analysis shows in concrete examples,[92] in a poetic text the author deliberately 'plays'[93] with this kind of structural indeterminacy of the 'material forms' (298) of the textual units, but the same applies to any kind of text as its reading goes on.

As an overall rearrangement of the internal structure of the text, a structural shift induces discontinuity. A complex whole can only change by being different from itself and a *Gestalt* leap is a discrete discontinuous phenomenon. Literary and

> aesthetic space is organized like quantum space, where the "identity" of the elements making up the space are perceived to shift and change, even reverse themselves, when measures of attention move across discrete quantum levels (297).

The textual condition essentially requires the interaction with an 'interpretive agent',[94] and the author too can be treated as such. Alternative structural arrangements can only be relative to a structural shift perceived by the reader or intentionally induced by the author. The following observation by René Thom,

> in quantum mechanics every system carries the record of every previous interaction it has experienced – in particular, that which created it – and in general it is impossible to reveal or evaluate this record,[95]

[89] Segre, *Avviamento all'analisi del testo letterario*, p. 44.

[90] D. Buzzetti, 'Digital Representation and the Text Model', in *New Literary History*, 33:1 (2002), 61-88, p. 80.

[91] McGann, 'Visible and Invisible Books', p. 290.

[92] See McGann's examination of poetical texts by Hopkins, Rossetti, Rochester, and Keats in his 'Visible and Invisible Books'.

[93] Ibid., p. 296.

[94] Id., 'Texts in N-Dimensions', p. 15.

[95] R. Thom, *Structural Stability and Morphogenesis: An outline of a general theory of models*, trans. D.H. Fowler [*Stabilité structurelle et morphogenèse: Essai d'une théorie générale des modèles*, Reading, Mass., W. A. Benjamin, 1972], Reading, Mass., W.A. Benjamin, 1975, p. 16.

has been rephrased in a straightforward way by Jerome McGann, for the literary scholar's sake: 'In poetry every work carries the record of every previous interpretation it has experienced – in particular, that which created it – and in general it is impossible to reveal or evaluate this record'. It is impossible, to wit, because the record is 'indeterminate'. A literary work is not self-identical, but 'an emergent function in an autopoietic field that comprehends the interpretive agent', and textuality can be thought of as 'a dynamic space that can be organized in an indefinite number of perspectives'.[96]

In a dynamic textual field, textual units are continually rearranged in formal patterns of material features that are implicitly embodied in the expression of the text, or explicitly flagged out by self-referring textual expressions, which in turn can change their self-reflexive role and assimilate themselves to purely material and ordinary textual tokens. Variations in perceptual and perspective mirroring are or can be marked down all along the historical process of handing down the text, and the dynamics of the textual machine can be studied "ontogenetically" and "phylogenetically" like the evolution of a biological organism. Cladistic analysis has been successfully applied to the phylogeny of textual transmission and computerised techniques have proved to be very helpful. So we have grounds to wonder whether a digital representation of the text could be of service also in the analysis of the ontogeny of textual dynamics.

**9.** Technology matters to the working of a machine. What advantages, then, can we expect from the transposition of the textual machine in a digital environment? A digital text representation is a digital object and a digital object can be processed. Hence the ontogenetic life cycle of a text or its phylogenetic evolution can be modelled and processed by a computer programme. A stemma of the *Svipdagsmál* textual tradition was obtained by means of the computer programme PAUP (Phylogenetic Analysis Using Parsimony),[97] and 'a phylogenetic tree showing the relationships between 58 extant fifteenth-century manuscripts of "The Wife of Bath's Prologue" from *The Canterbury Tales*' was reconstructed by using 'the method of split decomposition implemented in the program SplitsTree, in addition to the cladistic analysis of PAUP'.[98] Likewise, in view of a possible implementation, a model for the ontogenetic textual dynamics could tentatively be described and we may even consider how the two kinds of models would possibly interact.

[96] McGann, 'Texts in N-Dimensions', p. 15.

[97] Cf. Robinson and O'Hara, 'Report', and D. L. Swofford, *PAUP: Phylogenetic Analysis Using Parsimony*, Macintosh Version 3.0r, Illinois Natural History Survey, Champaign, Illinois, 1991.

[98] Barbrook et al., 'The Phylogeny of *The Canterbury Tales*', p. 839; cf. D.H. Huson, 'SplitsTree: Analyzing and visualizing evolutionary data', in *Bioinformatics*, 14:1 (1998), 68-73.

The text 'shifts and mutates under the influence of its perceivers'.[99] Its structural instability depends on the range of possible rearrangements of its 'perceptual features' (292, 297). It is the reader's perception that organises the material and visual elements of the text in different formal patterns and dispositions. The mobility of textual structures can be described as a synergetic phenomenon, for it has been observed 'that strong analogies exist between the process of perception on the one hand and the dynamic instabilities studied in the frames of synergetics and the nonlinear thermodynamics of nonequilibrium systems on the other hand'.[100]

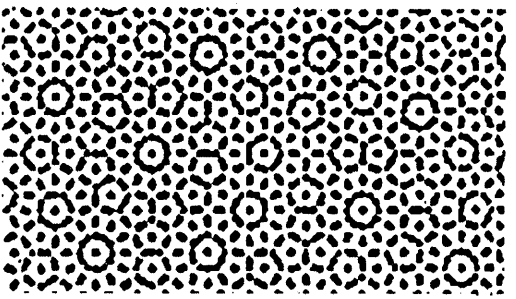

**Figure 1**

The phenomena of textual mobility are strictly connected with phenomena of 'multistability, fluctuation and enslavement effects in perception' such as can be observed in Figure 1,[101] where 'the observable fluctuations (random oscillations) are a constitutive moment of self-organisation'.[102]

Alternative patterns of self-organisation imply distinction and discontinuity. The complex whole of all virtual relations among its constituent parts, because of its internal rearrangements, alters and converts into something that is not identical with itself. The overall structural switch affects the whole structure and all of its elements: they change their functional position and produce a discontinuous shift between alternative configurations. Because of its inner instability and indetermi-

[99] McGann, 'Visible and Invisible Books', p. 287.

[100] G. Caglioti, 'Ambiguity and Symmetry Reduction in the Emergence of Structures and the Nucleation of the Visual Thinking', Abstracts of the Workshop 'Virtual Worlds, Artificial Societies' presented at the International Nonlinear Sciences Conference 2003 (INSC 2003), University of Vienna, February 7th-9th, 2003, <http://www.plancton.com/Vienna_2003/caglioti.pdf> (25 January 2007).

[101] D. Hansch und H. Haken, 'Zur theoretischen Fundierung einer integrativen und salutogenetisch orientierten Psychosomatik', in *Gestalt Theory*, 26:1 (2004), 7-34, p. 20. Cf., for the image, M. Stadler and P. Kruse, 'The Self-Organization Perspective in Cognition Research', in H. Haken and M. Stadler, eds., *Synergetics of Cognition*, Proceedings of the international symposium at Schloss Elmau, Bavaria, June 4-8, 1989, Berlin, Springer, 1990, pp. 32-52.

[102] Id., 'Wie die Psyche sich selbst in Ordnung bringt', in *Psychologie Heute*, 31:7 (2004), 36-41, p. 39.

nation, the system 'is not self-identical':[103] it maintains its integral organisational identity, but alters its internal structure and leaps across different states.
When a possible and implicit structural rearrangement of the material components of the text happens to be perceived, it can be made explicit and marked self-reflexively through a variety of self-referring or diacritical expressions. Also the structural function of a diacritical sign, however, is unstable. It can be perceived as a new and variant element of the expression of the text, belonging to its object-language, or as an external metalinguistic notation, an instruction to the reader to choose between alternative structures and interpretations.
An interpretation can be viewed as a rearrangement of the structural components of the informational content of the text. Textual content is in its turn affected by the same structural instability as the expression of the text and undergoes the same process of self-organisation and structural shifts. The instability of the content compensates the stability of the expression and viceversa. Diacritical marks perform an ambiguous role and provide a mapping between the sets of possible values of two internal variables of the system, the expression and the content of the text. Expression and content behave like the undetermined observable states of a quantum system.

**10.** The complex web of structural relations and self-referring expressions constitutes, in a text, the mobile and shifting interlacing pathway of structural tensions and overall restructurings. It defines the lines of force of dynamic instabilities within the textual fields. In a digital representation of the text the internal network of structural patterns is represented by *markup*. Like any diacritical sign markup is essentially ambiguous. It is a 'technique for representing structure' and it is itself a 'form of structure'; it is 'part of the text, yet distinguishable from it'.[104]
As an explicit form of representation of possible arrangements of textual unities, the markup exhibits the connections between distinct states of textual instability. Its ambiguity describes the oscillations between structural configurations of the expression and structural rearrangements of the content of the text and this kind of textual mobility can be illustrated by means of a diagram:[105]

[103] Mc Gann, 'Texts in N-Dimensions', 15.

[104] D.R. Raymond, F.W. Tompa and D. Wood, 'Markup Reconsidered', paper presented at the First International Workshop on Principles of Document Processing, Washington DC, October 22-23, 1992, Abstract and p. 3 <http://softbase.uwaterloo.ca/~drraymon/papers/markup.ps> (27 February 2007).

[105] D. Buzzetti, 'Digital Editions and Text Processing', in *Text Editing, Print, and the Digital World*, Proceedings of the AHRC ICT Methods Network Expert Seminar (London, King's College, 24 March 2006), ed. M. Deegan and K. Sutherland, forthcoming.

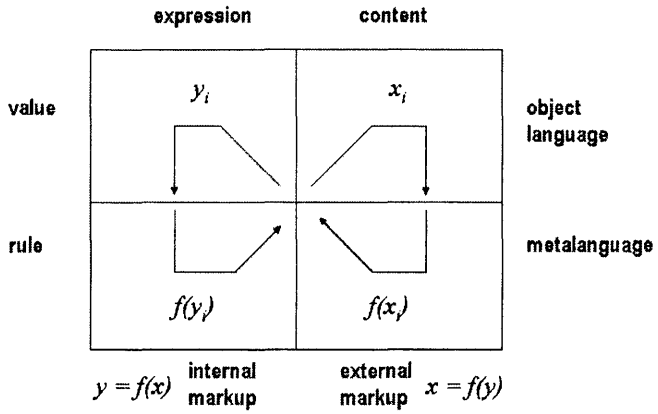


Figure 2

To illustrate the diagram and its dimensions, let us recall that structural distinctions can refer either to the *expression* or to the *content* of the text. A markup expression can also be understood both as a *value*, or the result of an operation, and as a *rule*, or an operation onto the content or, for that matter, the expression of the text. Moreover, the markup can be considered as belonging to the *object-language* of the text, or to a *metalanguage* describing it. All these dimensions can be displayed in the diagram. To round off our description, we can point out that markup structures can be 'embedded' and 'present in the data', or severed apart as 'non-embedded structure'; accordingly, we can distinguish between *internal* structure or markup, and *external* structure or markup – the 'so-called *out-of-line* markup'.[106] These two dimensions are also displayed in our diagram to complete its multi-dimensional space.

The unfolding of textual instability and indetermination can be described as an oscillation or a cycle. Referring to our diagram we can locate the result of a marking operation – a modernised punctuation mark, for instance, inserted in a transcription of a medieval manuscript – in the upper left corner. Such a diacritical ambiguous mark can be construed also as an instruction for an operation of restructuring of the information content of the text and located in the left lower corner of the diagram. As an external form of markup, the value of such an operation can be placed in the upper right corner, and then construed in its turn as an instruction for a restructuring of the expression of the text positioned in the lower right corner.

[106] Raymond et al., 'Markup Reconsidered', pp. 3-4.

**11.** It may be even possible to describe more formally such operations of textual restructuring in purely mathematical terms. We have pointed out that markup, as a diacritical type of expression, can be seen both as a representation of a textual structure and itself as an objectivised textual structure. A 'principle of representation-theoretical self-duality' applies to markup conceived of both as structure and representation of the structure of the text, for it is precisely the 'identification [...] between structures and the collection of all representations of the structure' that is 'expressed in the principle of self-duality' as introduced by Shahn Majid.[107]
According to Majid, 'an evaluation *f(x)* can also be read *x(f)*, where *f* is an element of a dual structure', and in the language of mathematics, 'such an "observer-observed" reverse interpretation of the mathematical structure can always be forced, but will the dual interpretation also describe physics?'[108] – or text, construed as a physical device? In the case of physics, Majid has shown that Hopf algebras, one of the simplest self-dual 'categories', or types of mathematical structures, can provide 'models in which quantum mechanics and gravity are unified into one mathematical structure'.[109] In our case, where we refer to the textual condition, we have seen that a restructuring operation from an expression unity to a content unity can be easily reversed, since a diacritical sign or markup element of the expression can be seen as a representation of the structure of the content, just as a structural unit of the content can be seen as a representation of the structure of the expression. In other words, as we have shown, markup elements, either internal or external, can be seen both as signs, or values, and as instructions, or operations. In physics, self-duality implies that a theory 'should admit a "polarisation" into two halves each of which is the set of representations of the other', so that we 'should be able to reverse interpretations'.[110] And that is precisely how we can construe the polarisation between the expression and the content of the text.
We can assume this analogy as a starting point for a formal description of the phenomena of what McGann has called 'quantum poetics'.[111] In quantum mechanics, observables or 'coordinates like *x*, *p*', the position and momentum of particles 'become operators **x**, **p** and **xp** no longer equals **px**', for 'the operators do not commute'. This non-commutativity of position and momentum coordinates

[107] S. Majid, 'Principle of Representation-theoretic Self-duality', in *Physics Essays*, 4:3 (1991), 395-405, p. 396. On Majid's philosophy of physics, see M. Heller, 'Algebraic Self-Duality as the "Ultimate Explanation"', in *Foundations of Science*, 9:4 (2004), 369-385.
[108] Id., *Foundations of Quantum Group Theory*, Cambridge, Cambridge University Press, p. 293.
[109] Id., 'Principle of Representation-theoretic Self-duality', p. 402.
[110] Id., 'Quantum Groups and Noncommutative Geometry', in *Journal of Mathematical Physics*, 41:6 (2000), 3892-3942. Also at <http://arxiv.org/PS_cache/hep-th/pdf/0006/0006167.pdf> (4 January 2007), p. 61.
[111] Cf. McGann, 'Visible and Invisible Books', p. 297.

> has the interpretation that it matters which you measure first, **x** or **p**, and this in turn is related to the famous Heisenberg uncertainty principle, that you cannot measure both of them accurately at the same time.

The same relation occurs between markup elements, that can be construed both as the observable representations of structural units either of the expression or the content of the text, and as operators that produce a rearrangement of textual units and a restructuring of textual contents and expressions. And just as textual reorganisations are discontinuous, 'non-commutativity leads to a kind of "finite difference" or discretization', which is a 'general feature' of physical self-dual structures.[112] The shift from a first-order object-language interpretation to a self-reflexive second-order, or a metalinguistic interpretation of a diacritical mark[113] can be seen as a shift from a classical to a quantum interpretation of the textual condition.

**12.** The analogy between textual and self-dual physical structures could be pursued even further to extend this kind of ontogenetic representation of textual dynamics into a phylogenetic model of textual evolution. To take evolution into account, the braided structure of Figure 2 should be extended and comprise a third dimension besides expression and content – Peirce's 'thirdness'[114] – to represent perceptual restructuring operations. The result would be a trefoil knot structure (Figure 3), whose 'invariant', or defining characteristic, can be described in terms of non-commutative geometrical structures such as quantum groups.[115]

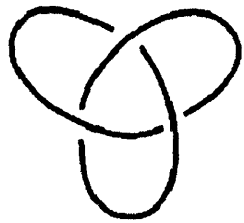

**Figure 3**

The time dimension could be introduced, as shown in Figure 4,[116] where the vertical axis is interpreted as time and the knot as describing the trajectories of self-dual elements *V* and *V** flowing down the page (Figure 4*b*).

[112] S. Majid, 'Non-commutative Geometry and Quantum Groups', in *Philosophical Transactions of the Royal Society of London*, Series A, 358:1765 (2000), 89-109, pp. 90-91.

[113] Cf. Buzzetti, 'Digital Editions and Text Processing', notes 37 to 41.

[114] Cf. Ch.S. Peirce, *A Letter to Lady Welby*, CP 8.328, 1904, and note 80 above.

[115] See Majid, 'Non-commutative Geometry and Quantum Groups', pp. 98ff.

[116] Ibid., p. 99.

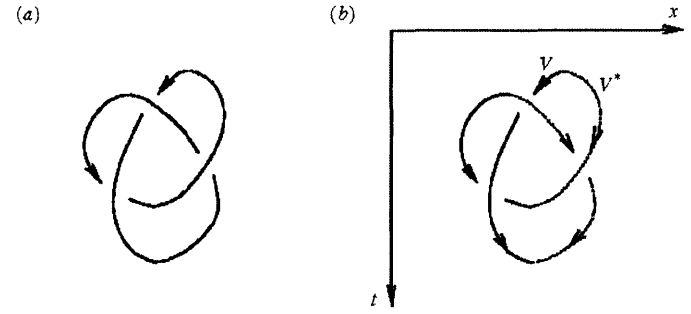


**Figure 4**

**13.** These last considerations are purely tentative and meant only to propound an evocative line of research. In this respect, it may be interesting to note that psychoanalysts find it necessary to expose the kind of discourse that constitutes their analytic practice expressly through an interlacing of the Real, the Symbolic and the Imaginary[117] as represented by a kindred structure of the trefoil knot, known as the Borromean link – or rings, or knot (Figure 5):

> The Borromean knot, is defined as the way in which we *imagine* the *real* effect of the *symbolic*.[118]

Could we say that a textual structure lives its life precisely in its enacting an analytic practice? But perhaps more in line with the thrust of our argument is to recognise that structures like the trefoil knot or the Borromean rings, as shown in Figure 3 to 5, 'are topological diagrams, not geometrical representations'.[119] As such, they provide, to use Maturana and Varela's terminology, the *organisation*

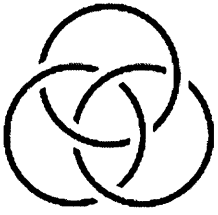

**Figure 5**

[117] Cf. J. Lacan, 'Au-delà du "principe de réalité"',(1936) in *Écrits*, Paris, Seuil, 1966, pp. 73-92.

[118] Ph. Julien, *Pour Lire Jacques Lacan*, 2e éd., Paris, E.P.E.L., 1990, p. 221.

[119] Chengde Mao, Weiqiong Sun, and N.C. Seeman, 'Assembly of Borromean Rings from DNA', in *Nature*, 386 (1997), 137-138, p. 137.

of an information carrying physical *structure* of sorts – be it a biological organism, a semiotic system, or a molecule, as in the case of the use of 'DNA components' to forge molecular Borromean rings.[120]

What we have been continually insisting upon, with regard to the different types of systems we have taken into account, is the essential bond between material structure and information. The organisation of an autonomous system is itself information, but it provides also a form, or a kind of transcendental structure of all possible observable states of the system, each of which can be assigned an information content or a meaning. The study of the topological and algebraic structures that describe and characterise a system is an investigation of the essential connection that binds together physical structure and information and defines the range of its possible interactions and transformations. As our examination shows, that kind of relationship between matter and information seems to constitute a crucial concern of both the sciences and the humanities and it can provide a common ground for an ongoing cross-disciplinary fertilisation.

[120] Ibid.