Towards a Semantic Web for Culture

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Contents

Abstract
Today's semantic web deals with meaning in a very restricted sense and offers static solutions. This is adequate for many scientific, technical purposes and for business transactions requiring machine-to-machine communication, but does not answer the needs of culture. Science, technology and business are concerned primarily with the latest findings, the state of the art, i.e. the paradigm or dominant world-view of the day. In this context, history is considered non-essential because it deals with things that are out of date.

By contrast, culture faces a much larger challenge, namely, to re-present changes in ways of knowing; changing meanings in different places at a given time (synchronically) and over time (diachronically). Culture is about both objects and the commentaries on them; about a cumulative body of knowledge; about collective memory and heritage. Here, history plays a central role and older does not mean less important or less relevant. Hence, a Leonardo painting that is 400 years old, or a Greek statue that is 2500 years old, typically have richer commentaries and are often more valuable than their contemporary equivalents. In this context, the science of meaning (semantics) is necessarily much more complex than semantic primitives. A semantic web in the cultural domain must enable us to trace how meaning and knowledge organisation have evolved historically in different cultures.

This paper examines five issues to address this challenge: 1) different world-views (i.e. a shift from substance to function and from ontology to multiple ontologies); 2) developments in definitions and meaning; 3) distinctions between words and concepts; 4) new classes of relations; and 5) dynamic models of knowledge organisation. These issues reveal that historical dimensions of cultural diversity in knowledge organisation are also central to classification of biological diversity.

New ways are proposed of visualizing knowledge using a time/space horizon to distinguish between universals and particulars. It is suggested that new visualization methods make possible a history of questions as well as of answers, thus enabling dynamic access to cultural and historical dimensions of knowledge. Unlike earlier media, which were limited to recording factual dimensions of collective memory, digital media enable us to explore theories, ways of perceiving, ways of knowing; to enter into other mindsets and world-views and thus to attain novel insights and new levels of tolerance. Some practical consequences are outlined.

> The problem of whether the machine is alive or not is, for our purposes semantic and we are at liberty to answer it one way or the other as best suits our convenience. As Humpty Dumpty says about some of his more remarkable words: "I pay them extra and make them do what I want."
>
> Norbert Wiener, *The Human Use of Human Beings*[1]

1. Introduction

The dictionary tells us that semantics is the science of meaning. Hence we would expect that a semantic web would introduce new dimensions of meaning to the Internet and the World Wide Web. There is little evidence of this at the moment. When Tim Berners Lee first outlined his vision of a semantic web at WWW 7 (Brisbane, 1997), he focussed on using logic to ensure which things were true and which things were not, in order that one could trust what was being shared. The following year at WWW8 (Toronto, 1998), this aspect of reliability was underlined. The semantic web was presented as synonymous with a web of trust. In the course of the next years (1999-2001) there was increasing emphasis on acronyms[2] and on trust with respect to transactions.

1.1. World Wide Web

In the early days of the WWW, there was always a sense of concern whether their solutions would be taken up by the major players and have a fundamental impact on the industry. By WWW 2002 (Honolulu), those fears had largely evaporated. The major players especially IBM, Sun, AT&T, HP and Microsoft were all there. The context of the semantic web had now taken a new turn. There was so much discussion of new acronyms such as Simple Object Access Protocol (SOAP),[3] Universal Description, Discovery and Integration (UDDI)[4] and Web Service Definition Language (WSDL) also known as Web Services Description Language (WSDL),[5] that a newcomer would have been forgiven for thinking that they had mistakenly come to a conference on EDI (Electronic Data Interchange),[6] rather than the World Wide Web.

At WWW 2003 (Budapest), industry was a little further in the background and the emphasis had shifted once again from transactions to scheduling. The semantic web was now about solving problems of complex appointments. Indeed, as Jim Hendler went further to explain: the semantic web offers complete solutions "to all the problems that we never knew we had." The semantic web was presented as if it were some extremely complex concept of physics or higher mathematics where one, almost desperately, needed to find a simple example in order to make the problem accessible.

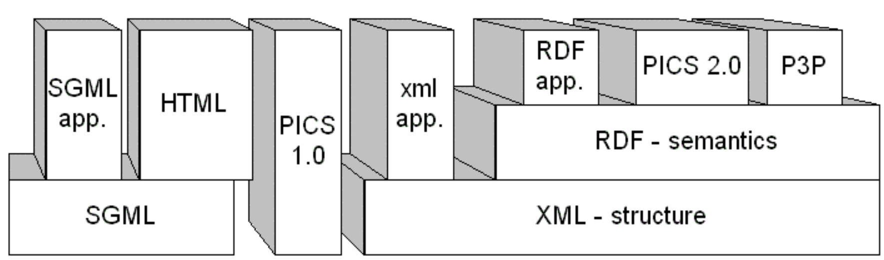

Figure 1. One of the original block schemas to describe the semantic web in 1997.

Parallel with these developments was a diagram to explain how the semantic web was to be achieved. Understandably, in its earliest versions in 1997, it was quite primitive (figure 1).[7] The essential idea was quite clear. One began with a basis of Standard Generalized Markup Language (SGML) and eXtensible Markup Language (XML), which provided structure or syntax. On top of this was a layer for the Resource Description Framework (RDF) that promised to provide semantics or meaning. Alongside there would be SGML, XML and RDF applications, a Protocol for Internet Content Selection (PICS) and privacy features (P3P).

Each year, new features were added to the ever growing "layer cake." By XML 2000 this was called the "Semantic Web Wedding Cake"[8] (figure 2). Even so problems remained in deciding how much XML would accomplish and to what extent one needed to relegate functionalities to RDF. The minor detail that precise contents of RDF had not yet been defined made this challenge more elusive.

These details, it was explained would soon be resolved using Schemas. So XML schemas and RDF Schemas entered the limelight briefly. Meanwhile, the fundamentals of the cake also shifted from SGML and XML to Unicode plus Uniform Resource Identifiers (URI).[9] Many in the WWW community were unaware that within the Internet Society (ISOC), Larry Masinter[10] had disbanded the original Internet Engineering Task Force (IETF URI) committee because the challenges of URIs were too formidable.[11]

As it became clear that XML and RDF were mainly about sharing information efficiently, the O(ntology) word entered the scene to address difficulties with meaning. Ontologies became the order of the day. The virtues of Ontology Inference Language (OIL)[12]

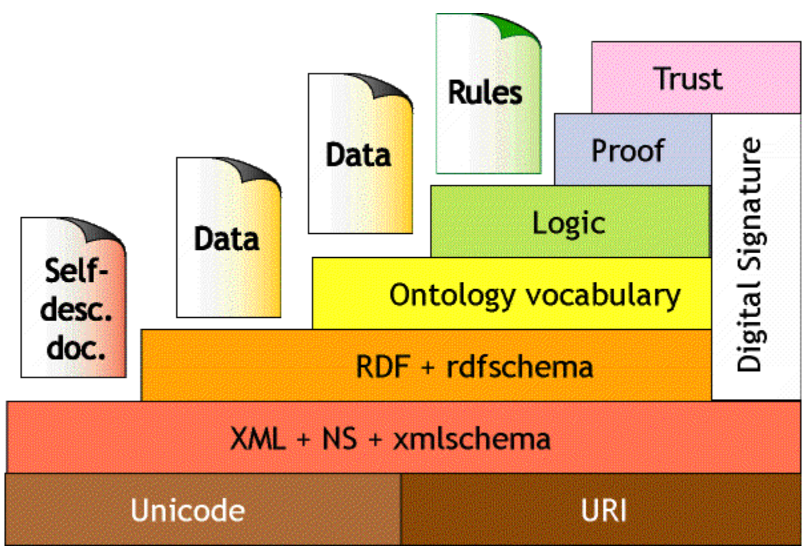

Figure 2. The semantic web wedding cake model used to explain the structure of the semantic web as developed by World Wide Web Consortium.[13]

were extolled and as the limits of these virtues came into focus, America came to the rescue with DARPA Advanced Modelling Language (DAML). Now DAML +OIL was the new acronym to explain how meaning was, or at least would be, addressed. Those rash enough to raise questions about precisely how this fitted together were quickly pointed towards the OWL, not of Minerva, but rather in the sense of Web Ontology Language (WOL spelled OWL).[14]

Tim Berners Lee had always insisted on the role of first order logic as an underlying framework for the semantic web. By 2002, experts of the day claimed instead that description logic was the key to the progress of OWL.[15] At the WWW 2003 (Budapest) conference there was a chasm between followers of first order logic and description logic. Fortunately the day was saved because the wedding cake (figure 2) spoke only generally of an ontology vocabulary on top of which there were those reassuring words, logic, proof and trust. Even more fortunately, no one was so rude as to ask what had happened to the elusive concept of meaning, which the 1997 diagram had linked neatly with RDF. Nor did anyone ask why the dimension of meaning keeps being pushed up the layers of the cake to a level that is not yet working.

One informal explanation why meaning has been downplayed[16] is that logical meaning is the only objective dimension of meaning; that all other meaning is subjective and therefore unimportant. In this view, the semantic web rightfully limits itself to the realms of logic. In science, technology and business this claim leads to pragmatic results.

A more serious reason offered unofficially by Tim Berners Lee, is that the full range of meaning is ultimately too elusive a field; that given the limitations of machines, one can only hope to tackle dimensions that can be expressed in formal logical terms. If so then the only meaning that can be conveyed in machine-to-machine communication is in terms of what John Sowa calls semantic primitives (figure 3). One of the problems is that different disciplines have very different terminology for even these basic terms (figure 6).

If we accepted these explanations at face value, this essay would be limited to a brief survey of how aspirations for a semantic web in a deeper sense have failed because of the limitations of logic and machines. We would need to conclude that a semantic web which deals only tangentially with meaning might more accurately be called the transactions web (EDI *redivivus*) or the logic web.

Logic solves many challenges of machine-to-machine communication and may offer an admirable solution for some dimensions of science and technology and basic transactions, which are essential for business. Our concern, however, is with the needs of culture where human-to-human and human-to-machine-to-human challenges go far beyond these simple logical criteria. We shall show that while the study of semantics in a strict sense is just over a century old, the study of meaning goes back at least two and a half thousand years. An awareness of this history and especially of contributions made in the past century is essential a) to understand the needs of users in the cultural fields and b) to recognize potential solutions that could increase dramatically the scope and depth of the semantic web.

Primitive	Informal Meaning	English Example
Existence	Something exists.	*There is a dog.*
Coreference	Something is the same as something.	*The dog is my pet.*
Relation	Something is related to something.	*The dog has fleas.*
Conjunction	A and B.	*The dog is running, and the dog is barking.*
Negation	Not A.	*The dog is not sleeping.*

Figure 3. Five semantic primitives according to John Sowa (2000).[17]

1.2. Sowa's Knowledge Representation

In one of John Sowa's many articles we find a very clear reference to five logical principles or semantic primitives that play a central role in today's semantic web (figure 3). These five semantic primitives are frequently seen as the starting point and the final goal of meaning within the semantic web.

Sowa's major book on *Knowledge Representation* provides an excellent survey of classical contributions to logic by Aristotle, the role of Porphyry's tree of being, which he calls the first semantic network, contributions of Leibniz, Kant, Peirce and Whitehead. Interestingly enough, Sowa ends with Whitehead as if effectively nothing has happened since about 1925.

Sowa is very important because he is typically cited by developers of the semantic web and the World Wide Web community as a whole as one of the fundamental sources with respect to knowledge organisation.[18] From the viewpoint of those concerned with cultural and historical dimensions of knowledge, however, there are a number of serious omissions and shortcomings in Sowa's approach.

From a general, historical viewpoint Sowa covers logic (traditionally called dialectic), which is only one of the seven liberal arts (and sciences). Historians of culture need to consider all seven of the liberal arts (figure 27) and a long history, whereby the seven liberal arts and sciences gradually evolved into the many disciplines of the modern world.

1.3 Five Issues not Covered by today's Semantic Web

More specifically, Sowa[19] and the pioneers of today's semantic web overlook at least five basic issues relating to the history of knowledge organization, knowledge representation and meaning.
A first issue relates to world views and changing paradigms. Sowa, and the pioneers of the semantic web, in the best traditions of the Artificial Intelligence (AI) community,

focus on the existence of things in terms of their substance, much the way Aristotle did. Accordingly, their data structures and databases focus on what a thing is (its substance), and do not allow for a gradual historical shift from substance to function. As a result the AI and semantic web communities create data structures that assume a single world-view. Every thing is presented as if this is the way "it is" ontologically, rather than providing frameworks whereby what a thing "is", what it means, and how it relates to other things, change as the framework changes. This dimension is needed a) to explore the interplay between facts and the frameworks or world-views used to explain them and b) to explain an historical shift from a quest for a single ontology to a need for multiple ontologies. Needed is an approach where entities can evolve in meaning.

Second, Sowa's approach, which is used by the semantic web community, assumes that a definition is only about existence (what a thing "is"). This overlooks distinctions, which have been made between ostensive, nominal and real distinctions by experts in knowledge organisation of the past century.

Third, the champions of the semantic web typically believe that their challenges are strictly in terms of natural language; the assumption being that if only one collects all the words used then one understands all that is happening linguistically. This overlooks a series of developments in the past century whereby terminologists distinguish carefully between everyday usage of words and scientific or professional concepts; between natural language and terminology.

Fourth, Sowa reduces the notion of relation to a (semantic) primitive of something being related to something else. This focus on the logical dimension overlooks distinctions, which have emerged in the 20th century between subsumptive, determinative and ordinal classes of relations. Sowa is not alone. The pioneers of computer science have expanded the power of the computer by abandoning many earlier distinctions. Needed is an approach to semantics that places it in a larger context of semiotics, lexicology, lexicography, semasiology and onomasiology.

Fifth, Sowa and those in the semantic web, focus on finding one, unequivocal, logical, static definition for each term. Cultural terms have local, regional, national and international variants, which change over time. Data structures and databases of static terms are therefore not useful to the cultural community. We need databases to reflect that meaning changes both temporally (whence etymology) and spatially, even within a culture (e.g. national, regional and local differences) and especially between cultures. For this reason traditional quests for dictionaries to provide exact equivalents in different languages have given way to new strategies that entail mappings, walkthroughs, and bridges among words and concepts. Present day semantic web models are still in terms of traditional dictionaries. Needed are models, which reflect an historical shift from traditional dictionaries (in terms of what something is) to modern versions of dictionaries that map between meanings without reducing them to a simplest common denominator. Needed is an approach that is multi-lingual and multi-cultural.

1) World views and paradigms

2) Types of definition

3) Words versus concepts

4) Classes of relations

5) Dynamic meaning.

Figure 4. Five issues that need to be integrated into a cultural semantic web.

This paper explores the historical context and development of these five issues (figure 4) to show why an integration of these dimensions is crucial for a cultural semantic web. These five issues point to a sixth issue with which we cannot deal in detail. Digital communication is not simply another step in the tradition of a new medium adopting the content of its predecessors. Once materials are digital they can be translated back to other media without difficulty. Potentially, a digital text can be output as a printed text, as oral-audio text or, using stereo-lithography, even as cuneiform text.[20] Implicit in this insight is a sixth challenge: How can we create a more comprehensive semantic web with information systems that both reveal these new potentials and allow us to recognize explicitly the differences (both qua strengths and limitations) of earlier media?

There are also other issues. We know that the rise of combinatory logic linked cognitive science with semantics. This separated perceptual and conceptual dimensions, focussing so much on mental dimensions that a recent survey of trends could ask: Does representation need Reality?[21] Future models need to explain the physical world and to bridge physical and mental worlds.[22] The details of this challenge are beyond the scope of our paper.

There are also other issues which we cannot address such as deeper linguistic dimensions of semantics.[23] Nor can we explore the deeper arguments between artificial intelligence and cognitive science where "the issue of semantic interpretation is probably the riskiest quagmire on the terrain of the philosophy of AI."[24]

A full treatment of these issues would take us far beyond the bounds of an article. It would need to address the history of major systems of knowledge organisation around the world, integrating the profound contributions of Indian philosophy and science;[25] those of China;[26] those of the Mayans and other cultures of the world. Hence, we shall limit ourselves to an outline of key developments in the Western tradition to understand the central importance of the five above issues for a semantic web in the domain of culture.

The first of these issues has a complex history with its origins in Antiquity at the time of Plato and Aristotle, which we need to examine in order to understand links between causes, substance and accidents (section 1.4-5). An excursus will outline a shift towards language and mathematics that led to both a chain of being and the emergence of modern disciplines of knowledge to reveal that relationships between facts and world-views are historically and culturally defined (Appendix 1-4). Understanding these shifts helps to understand a shift from substance to function (section 2).

This leads to a review of twentieth century distinctions between different kinds of definitions (issue 2 in section 3); between words and concepts (issue 3 in section 4); and classes of relations (issue 4 in section 5). We shall outline how new distinctions between universals and particulars can add clarity to future knowledge organization (section 6), before continuing with dynamic models of knowledge (issue 5 in section 7). In light of this we shall review briefly the history of semantics as a field in order to reassess activities relating to the semantic web today (section 8), to explore some practical consequences (section 9) and to draw conclusions (section 10).

Since those with scientific, technical or business training often perceive the past as distracting, or even as an unnecessary detour from contemporary issues, detailed historical discussions have been relegated to appendixes. For culture, these historical dimensions are crucial in order to appreciate the rise of different ways of knowing; alternative ways of understanding the world. Since every culture focuses on some aspects of knowledge and ignores others, history is essential to understand both the sources of our views and the limitations of the frameworks or worldviews with which we present them. As such it offers one of the most effective means of going beyond an attitude where we measure others solely by our own solution.

1.4 Greek Principles

It has been said that the whole of Western philosophy is a series of footnotes on the work of Plato and Aristotle.[27] Plato focussed on the importance of universals. Aristotle focussed on the importance of particulars. Universals entail a deductive, top-down world of theory. Particulars entail an inductive, bottom-up world of practice. These ideas of universals and particulars arose at a time when oral knowledge was shifting to hand-written knowledge. Almost two and half millennia later, the shift from printed to digital, multi-medial and multi-modal knowledge is introducing new possibilities in knowledge organization. Returning briefly to these origins will help to understand contemporary challenges.

This is all the more crucial because our present day approach to the semantic web assumes that we can simply deal with data and facts without paying attention to the medium in which they are presented. Significantly, a central goal of the computer community since the time of Claude Shannon, and especially since the evolution of Standard Generalised Markup Language (SGML) in the 1970s, and more recently eXtensible Markup Language (XML), has been an assumption that can one separate neatly the content of a text from the ways in which it is presented. If these ways of presentation are linked integrally with different media, this dimension needs to be considered in the further development of SGML and XML models.

Aristotle’s concepts of causes, substance, and accidents produced a framework for Western philosophy and approaches to knowledge. In the centuries thereafter, philosophers focussed their energies on language and mathematics. This gave rise to the *trivium* (grammar, dialectic and rhetoric) and *quadrivium* (geometry, arithmetic, astronomy and music), now known as the seven liberal arts.

With the revival of Aristotle, especially in the twelfth century, attention turned increase-ingly to particulars in the context of Aristotle's categories of being, which led to many disciplines of knowledge as we know them today. The centuries that followed saw further study of material and form categorial relations, which entailed a gradual shift from substance to function.

The twentieth century brought new studies of Aristotle's basic categories, namely, his accidents. Thinkers such as Ranganathan and Dahlberg[28] linked form-categorical relations to syntax. Perreault introduced classes of relations. Closer study of these classes in the context of Aristotle's distinctions sheds new light on problems of universals and particulars, and opens new avenues for the growth of knowledge. To achieve this we need networks to provide systematic, multilingual access to knowledge through Distributed Electronic Dynamic Resources. Thus a study of and new access to past knowledge can shape advances in knowledge organization. Our cumulative memory and heritage points to evolving, dynamic models of knowledge and ways of knowing. .

1.5. **Causes, Substance, and Accidents**

Socrates, generally recognized as one of the fathers of Western philosophy, became famous for his Socratic questioning, which appeared to raise questions about everything, but focused on questions of: Why? Socrates' best student, Plato applied his approach to the realm of metaphysics focusing on the why of universals. Plato's best student, Aristotle further developed this approach to include the why[29] of particulars. One of

Universals - Genus - Species	(Not in Space-Time)	
Causes (Determinative Relations)	Description	Example
Final Cause	Goal (Telos), Purpose	Function of House
Formal Cause	Essence, Substance, Definition	Head Bricklayer[1]
-----------------------------------Space-Time Horizon---		
Particulars-Individuals	(In Space-Time)	
Material Cause	Suffering (Processes)[1]	Bricks, Stones
Efficient Cause	Action (Operations)	Carpenter

Figure 5. Aristotle's Four Causes.

Logic Computer Science	Being Existence	Identity	Inclusion Coreference	Exclusion Negation	Intersection Conjunction
Philosophy	Substance	Accidents	Abstraction/ Partition	Opposition	Function
Grammar	is	is/has	is a/ is a part of	is not	is about
Library Science	Equivalence		Hierarchical		Associative

Figure 6. Parallels between logical categories, material concept relationships, verbs.

Aristotle's major contributions was to distinguish between four kinds of Why? which he called the four causes,[30] namely, the final, formal, material and efficient causes. These have inspired over two millennia of discussions on determinative relations and debates concerning determinism versus freedom.

Aristotle's final and formal causes pertain to the realm of universals,[31] whereas efficient cause and material cause are in the realm of particulars and individuals under the space-time horizon[32] (figure 5). Hence two causes are outside of time, whereas two are time-bound. Implicit in this framework is an approach that requires and needs a bridge between the theory of universals and the practice of particulars. This need has led both to the exploration of subsumptive relations: type/kind, whole/part and subject/property and the creation of what has come to be known as the chain of being.

Aristotle's focus on causes, particularly final and formal causes, led him to see meta-physics as more important than physics. Whereas his teacher, Plato, focused on the metaphysics of universals, Aristotle was also interested in the metaphysics of particulars. This led Aristotle to ask his best student, Alexander the Great, to bring back samples and souvenirs from his journeys through Asia Minor to countries surrounding India.

Being	1. Substance
1. Inanimate (air, water, stones etc.)	2. Quantity
2. Animate (plants, animals)	3. Quality
3. Mental (human)	4. Relation
4. Divine (spiritual)	5. Place
	6. Time
	7. Position
	8. State
	9. Action
	10. Passion (Affection).[1]

Figure 7. Aristotle's four categories of being and his ten basic categories (substance and nine accidents).

Aristotle	Being-Substance Content Substance (Concrete Objects)	Accidents Form (Abstract Principles)		
Dahlberg	Entities	Properties Quantity Quality Relation	Activities Action (Operation) Suffering (Process) State	Dimensions Space Time Position
Perreault:	Subsumptive Relations		Determinative Relations	Ordinal Relations

Figure 8. Aristotle's accidents, Dahlberg's basic categories and Perreault's relations.[33]

At the level of universals, this meant that Aristotle began to explore a) a number of basic categories of (abstract) formal relationships, which evolved into logic and b) the material concept relationships including abstraction (genus, species, individuals), although he did not describe them as such and did not associate them directly.

It is striking that slightly different names for his logical terms are now associated with the semantic primitives[34] of first-order logic (e.g. existence, co reference etc. First order logic also has a fifth semantic primitive, relation that will be discussed in section five). At the level of individuals, Aristotle's contributions went far beyond his insistence on relating universals (genus and species) to individuals (particulars). He defined four categories of being and ten basic categories consisting of substance and nine basic accidents (figure 7). In his *Categories*, Aristotle also made a fundamental claim:

> No one of these terms, in and by itself, involves an affirmation; it is by the combination of such terms that positive or negative statements arise. For every assertion must, as is admitted, be either true or false, whereas expressions which are not in any way composite such as 'man', 'white', 'runs', 'wins', cannot be either true or false.[35]

In other words, truth only enters into the picture when words are combined and related to one another and claims are made concerning their relation. Implicit in this claim also is that the principles of logic are reflected in the functions of language through grammar (i.e. through material functional relationships in syntax). We shall see that this basic idea plays an important role in 20th century developments in knowledge organization (see below section 5.3.4 ff.).

These four categories of being and ten basic categories for knowledge remain valid today although there have been shifts in name and meaning. For instance, today a combination of a being category with one of Aristotle's ten categories is still one of the starting points for generating subject categories. Substance-Accident is now often called Content-Form (and usually in reverse order as form and content). Action is now associated with operation(s),[36] while suffering or passion (in the sense of to undergo, L. *patior*) is associated with process(es). Dahlberg has called Substance, Entities, and has classed Aristotle's nine accidents under properties, activities and dimensions (figure 8).

In retrospect, if we use Dahlberg's headings in combination with Perreault's classification of relations, the magnitude and limits of Aristotle's approach are readily brought into focus. Aristotle's concern with causes led to the study of activities and determinative relations. This causal concern was intertwined with his concern to define essence, substance, quiddity (literally the whatness of a thing) through concepts such as entelechy (namely, the final goal towards which an object tends, e.g. an acorn towards an oak tree). The insistence on quiddity required a bridging from general substance to particular substance and thus inspired the study of subsumptive relations. It led also to his study of properties and accidents concerning dimensions, now called ordinal relations (figure 8, cf. figure 22).

In the seventeenth century, when Francis Bacon suggested that philosophers and scientists should abandon study of final causes, i.e., the ultimate why question; the formal cause as Aristotle had understood it, was transformed largely into a definition of How? rather than Why? Thereby, the quest for understanding the quiddity of things, their What? also diminished. Lists of all properties were no longer the order of the day. Instead attention turned to another of Aristotle's nine accidents as a key to understanding, namely relation. But whereas Aristotle had focused purely on the comparative relation (e.g. larger than, higher than, i.e. πρός τί), subsequent thinkers explored the potentials of relation in general. Cassirer has recounted this story in his *Substance and Function* (cf. section 2).[37] A long-term consequence of this focus on relations has been a compression from four major areas, namely entities-properties-activities-dimensions to three subsumptive-determinative-ordinal relations.[38] To understand why such categories are of vital importance for current challenges in knowledge organization and the quest for a semantic web, a further excursus on historical categories of knowledge is needed (Appendix 1).

2. Substance to Function

These enormous changes in knowledge organization were accompanied by a general shift from simple definition of substance to a concern with function and relation. Cassirer, in his fundamental study, *From Substance to Function*[39] has provided a masterful account how the Aristotelian world-view that focused on Why? and What?, in the sense of essence and quiddity, gradually evolved into the world-view of early modern science that focused on quantitative aspects of the What? and concentrated on questions of How? Aristotle would have asked: What is (the essence of) a pump? Leonardo da Vinci and subsequent scientists increasingly asked: How does a pump work, function? Not surprisingly, the Renaissance saw the rise of How to do it books as an important genre. Instead of defining objects, there was increasing attention to their function and thus to the relations and connections between them.

In terms of categories of being (figure 30), this entailed a basic shift in attention from the Godly and the Human to a focus on the Alive and especially the Lifeless. As a result, categories of action and suffering relating to Human and Alive, were increasingly replaced by active operations and passive processes. The universe, which Aristotle had conceived as a living *Organon*, became transformed into what Dijksterhuis has elegantly described as the *Mechanization of the World Picture*.[40]

Gradually, as Koyré has shown, the static notion of a finite universe shifted to a notion of an infinite universe.[41] This world which stretched towards the infinitely large as telescopes developed, stretched also towards the infinitely small as microscopes evolved gradually into electron tunnelling microscopes and other high-resolution devices. In the process, as Toulmin[42] has outlined, the timeless, eternal model of the Greeks gave way to spatial-temporal models.[43] Static knowledge led to models of dynamic knowledge.

Ever since the Ancient Greeks, natural philosophers had assumed that they were finding ways to describe the physical world of matter,[44] beginning with basic elements such as earth, air, fire and water. In the 1770s and 1780s Priestley and Lavoisier demonstrated that none of these was an element per se.[45] In the course of the next century, the discovery of the elements of the periodic table, which laid the foundations of modern physics and chemistry, completed the shift from substance to function that Cassirer described. The development of electromagnetism, field theory, and subsequent studies at the atomic and sub-atomic levels, further transformed physics into high-energy physics as we know it today. What had begun as a study of the material world thus became a study of energy and forces at levels invisible to the eye. As a result many of the categories in today's Physics and Astronomy Classification (PACS)[46] would have meant nothing to the Greeks. Meanwhile, the systematic study of nature continued with respect to both inanimate and animate forms and led to a gradual shift from static claims concerning knowledge to evolutionary, dynamic models (Appendix 2 and 3).

Ironically, the present day champions of the semantic web are frequently unaware of this historical context. They continue to assume that words, topics and disciplines are fixed and unchanging, not unlike thinkers prior to the time of Linneaus, who assumed that knowledge and its categories were fixed and static. Until we develop dynamic data structures and databases to address these dynamic dimensions of knowledge, we cannot hope to understand how contemporary categories have evolved, let alone develop frameworks to stimulate their future evolution.

2.1. Ontology to Systematics

In Aristotle's work, the ordering of knowledge was linked with philosophy and specifically with metaphysics. Ontology became the science or study of being. By the early eighteenth century ontology had become "that department of metaphysics that relates to the being or essence of things or to being in the abstract."[47] Classification as an "act of classifying or arranging of classes to common characteristics or affinities"[48] emerged at the turn of the nineteenth century.[49] Classification sometimes had the meaning of "assignment to the proper class," implying that these classes reflected universal laws of nature. Shortly afterwards, De Candolle (1813) developed the idea of taxonomy as "classification, especially in its relation to its general laws or principles."[50] By 1888, this had led to systematics as a "subject or study of systems, especially classification."[51] (cf. Appendix 4). Since then, fundamental work on the nature of definitions, on relations and on knowledge organization have transformed traditional notions of meaning. A survey of this history of definitions of definition and relations will help us to understand some of the major advances of knowledge organisation of the past century. We shall then show how the space-time horizon can be used to further these insights before showing how these efforts entail a much richer understanding of semantics (i.e. meaning) than envisaged in present versions and visions of the semantic web.

3. Definitions

To understand more fully the parameters of meaning, now known as semantics, we need to examine the sources of meaning in definitions and relations. At first sight, the problem appears trivial: to find the meaning one simply looks at its definition. On closer inspection, definition itself has a long history and continues to evolve. As noted earlier, Plato and Aristotle introduced basic principles of definition. Definition, in logic became the "action of defining or stating exactly what a thing is or a word means."[52] Note that, at this stage, definition could refer to a thing or to a word, but entailed no method whereby the relationship of a word to a thing or an object was clearly fixed.

In mediaeval scholasticism, the schoolmen claimed that: "A word stands for a thing by means of thoughts/concepts" (*Vox significat rem mediantibus conceptibus)*.[53] A word (*vox*) now mediated between a concept (*conceptus*) and an object (*res*) in a triadic relationship (figure 13). In mediaeval (as in classical) logic, definition of a word was closely connected with the definition of terms, three of which in combination (major, minor and middle term) formed a syllogism.[54] Thus the triadic relationship in the mediaeval definition of words was hardly a co-incidence.

The mediaeval definition-triangle may appear as convincing as it is compact: a concept in the mind is mediated by a word to link with an object. But since the mind of every person is different and is not defined in this process, what initially poses as a logical claim is actually deeply rooted in implicit psychological dimensions. Using this triangle there is no way of determining how or the extent to which the thought of person A is different than the thought of person B with respect to a word for an object.

Meanwhile, the Middle Ages also introduced the idea of dictionaries. In English, the 13th-century *Dictionarius* of John of Garland is the first recorded use of the term to mean word list.[55] Robert Cawdrey's *A Table Alphabeticall* (1604) is generally accepted as the first English dictionary.[56] At the time dictionary, onomasticon and thesaurus tended to be synonymous. Through the advent of etymology (1725), time entered the study of language just decades before it entered into the study of conceptions of nature.[57]

By the late eighteenth century, the obvious answer to overcoming problems of definition seemed to lie in the creation of comprehensive dictionaries and thesauri. There was an elusive dream that if only we could collect all the usages and arrive at the same definition, then we would all know precisely what was meant and ambiguity would disappear. This led to a series of monumental dictionaries for the major languages of the world, Grimm's for German, Larousse for French and the Oxford Dictionary for English, which remain of fundamental importance today.

Even so, the results were less neat than one might have hoped. Important words often have five, ten or even more meanings. Then there are many kinds of dictionaries: e.g. specialist dictionaries for given fields; technical dictionaries; regional and local dictionaries. These challenges led to work on two fronts: a) in semiotics and linguistics; b) terminology (cf. section 4 below).

3.1. Semiotics and Linguistics

In the fields of semiotics and linguistics, thinkers returned to the mediaeval definition triangle. Curiously enough, although the names of the sides changed slightly, the basic mediaeval triangle continued to dominate their approaches throughout the 20th century. For instance, the philosopher and semiotician, Charles Peirce, saw a threefold[58] relation between a) a Representamen: the form which the sign takes (not necessarily material); b) an Interpretant: not an interpreter but rather the sense made of the sign; and c) an Object: to which the sign refers.[59] This version has been taken over almost directly in Italian semiotics.[60]

Elsewhere, in the semiotics of Peirce, this became the semiotic triangle in which the terms and their position changed slightly but the approach remained the same. In Peirce's scheme, the mediaeval concept (*conceptus*) remained the same but moved from the lower right to the top. Word (*vox*) became symbol and thing (*res*) became an object (figures 9-10). In De Saussure, this became the triangle of signification with a Sign (e.g. a signifier), concept (or signified), and a thing referred to C (*significatum* or referent, figure 11).[61] In Ogden and Richards' seminal *Meaning of Meaning* (1923), this construction

> became the triangle of reference[62] and the terms and positions were again altered slightly to become: thought or reference, referent and symbol respectively (our figure 12). In Lerat, this became Sign (*terme*), Concept (*notion*) and Object (*objet*, our figure 13). The triangle of meaning was alternatively called a semiotic triangle or a semantic triangle. Other names for the ingredients of the triangle also exist, namely Signs (terms, tags); Concepts (descriptions, definitions, connotations, intensions) and Significata (referents, denotations, extensions, objects).[63]

The French tradition of Lerat relates this triangle to a standard description of notion, object, term, as developed in ISO 1087 (1990). According to this view, the Saussurian tradition has put an end to the notion of nomenclature in the simple sense and, following the hypothesis of Sapir-Whorf, one accepts the assumption that each language slices and organises reality in a different manner.[64] By implication, there can be no meaningful reduction to only one natural language.

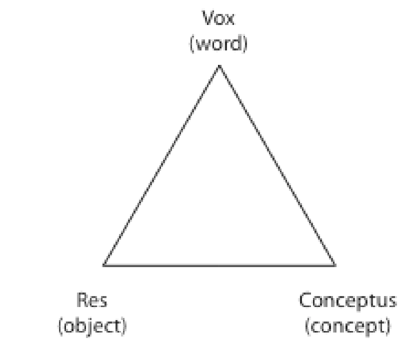

Figure 9

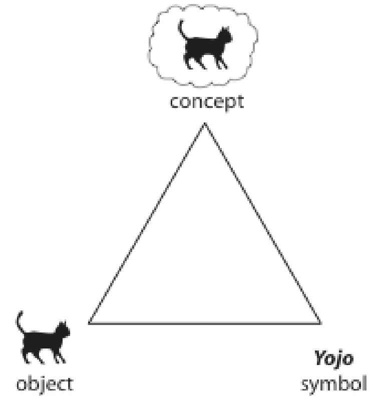

Figure 10

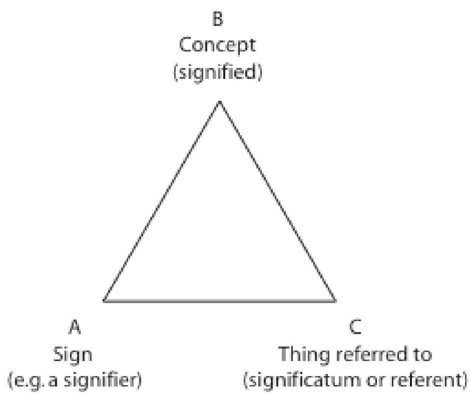

Figure 11

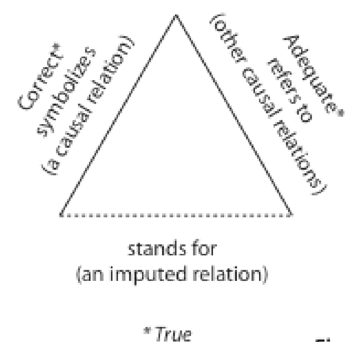

Figure 12

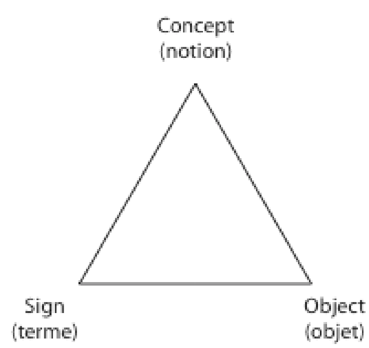

Figure 13

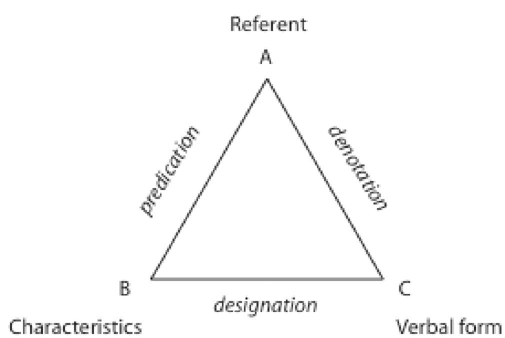

Figure 14

Figures 9. Meaning triangle from Mediaeval logic; 1o) Semiotic triangle in Peirce; 11) Triangle of reference in Ogden; 12) Triangle of signification in De Saussure; 13) Lerat (ISO 1087)[65] and 14) Dahlberg's concept triangle. (Diagrams N. Baerten).

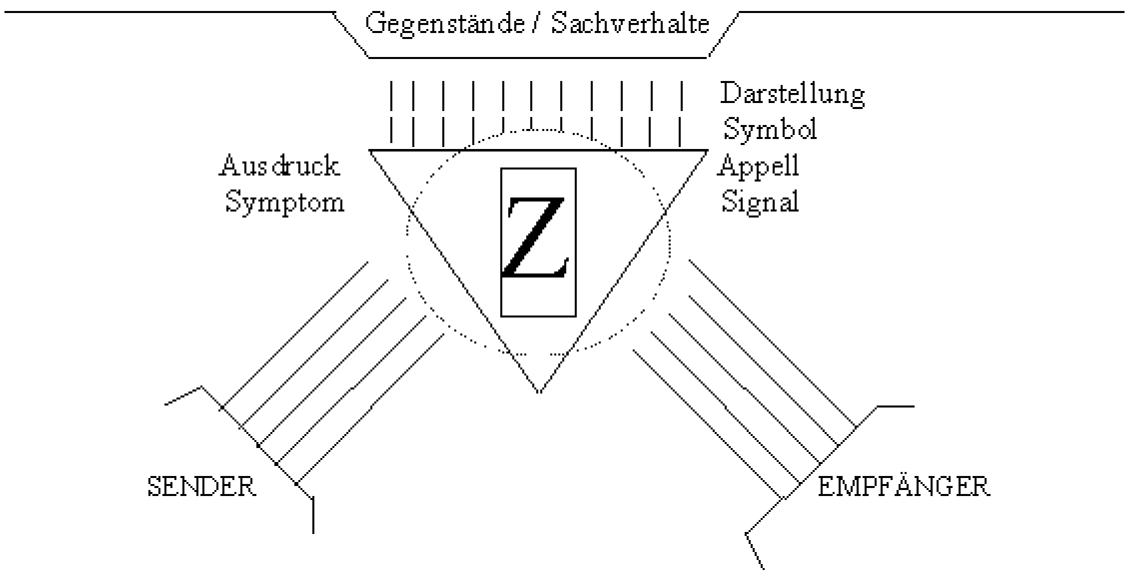

Figure 15. Organon model from Karl Bühler, *Sprachtheorie*, Jena, 1934, p. 28. Unabridged reprint, 1982, G. Fischer (UTB), Stuttgart.[66]

4. **Words versus Concepts (Natural Language versusTerminology)**

Not all linguists accepted De Saussure's assumptions and claims about language. In Germany, Karl Bühler directly challenged his approach by drawing attention to the role of deixis[67] (known in philosophy as indexicality) in language, namely the role played by pointing at objects (cf. ostensive definition, p. 19 below). Bühler argued that a linguistic sign is a) a Symptom, insomuch as it expresses the interiority of the sender; b) a Signal, insomuch as it calls on the receiver, and c) a Symbol, insomuch as it refers to objects and subjects of reality.[68]

This led him to claim that language had three distinct functions, namely: expression, call, and representation.[69] While Bühler's approach recognized the role of psychology in all communication, it went beyond the Anglo-Saxon and French traditions by insisting that meaning was also intimately connected to direct links with the reality of the physical world.

Meanwhile, in Austria, the fundamental work of Wüster[70] on terminology, inspired further work in Germany by Diemer[71] and Dahlberg,[72] who claimed that such triangles could also be understood ontologically. Whereas the starting point of the linguists had been words in general, the starting points of Wüster, Diemer and Dahberg, were concepts: i.e. denoted technical terms. In the English language realm one did not know concepts and equalized them later as technical terms. But terms are only one part of a concept as will be shown in the next paragraph. While Dahlberg's triangle (figure 14) appears very similar to those discussed above, in fact, it introduced four significant differences.

First, whereas Peirce and his followers had started from a thought, which was psychological and thus not open to objective scrutiny, Dahlberg's point of departure was an item of reference, called „the referent“ and a concept (of such a referent which can be anything, an object, a property, an activity, a topic, something abstract, even something not existing) comes into being, if the necessary statements on a referent have been made, yielding its essential characteristics which are synthesized – so to speak – into a verbal form, a name, a technical term, a code. Thus referent, characteristics and name or term are the formal elements of a concept, whereas the material elements are the stated characteristics, the contents of a concept. Thus Dahlberg called a concept a “knowledge unit” – since the statements on the referent show what is known about it and accordingly, called its characteristics “knowledge elements.”

Since in philosophy one discerns (at least) three kinds of definitions, namely the ostensive, the nominal and the real definition, Dahlberg shows that by using her concept triangle one can clearly show, that an ostensive definition uses only the points A and C, i.e. the referent A is denoted by the term C ostensively, i.e. by pointing to it. A nominal definition[73] comes into being, if one omits the referent A and explains the term C only by giving descriptive characteristics without reference to A. However, the real definition comprises all the formal and material elements of a concept, which means that one can effectively work in knowledge organization only with this latter form of a definition.[74]

Third, Dahlberg shows that by the generation of a concept in the way described above, at the same time a definition of a concept is established. And since a referent A can include e.g. either a multitude or some species or a single, individual item, one would not only generate different kinds of concepts, but also its respective different kinds of definitions. (See also Fig. 37 in the notes in which the relationships of A, B and C with regard to All, Some or a Single referent is demonstrated diagrammatically). [75]

Fourth, as will be seen in the next section, Dahlberg showed that different concept relationships can generate corresponding kinds of definitions.[76] This transforms the scope of what a definition is and implies a fundamentally new approach to the future of dictionaries.

5. Relations

As noted earlier relation was one of Aristotle’s accidents but he used the term in a restricted sense to mean comparison: e.g. bigger than, smaller than etc. The *Oxford English Dictionary* (OED) provides a more complex definition that clearly builds on Aristotle, defining relation as a: “feature or attribute if things which is involved in considering them in comparison or contrast with each other; the particular way in which one thing is thought of in connexion with another, any connexion, correspondence or association which can be conceived as naturally existing between things.”

In English, relation also has many other meanings including “the action of relating in words.” In the logical tradition and subsequently in the computing world, relation became one of the five semantic primitives[77] (cf. figure 3). Meanwhile in the field of knowledge organization as developed by Dahlberg there are three main classes of relations or relationships: a) formal (also called relation in general); b) form-categorical and c) material concept relationships.

5.1. Formal Relationships

In first order logic, relation is the fifth semantic primitive. In Dahlberg's approach a formal relationship is the class that defines the other four basic logical categories of Identity, Inclusion, Intersection, Exclusion. Formal relationships provide the abstract categories under which other relations occur.

5.2. **Form-Categorical Relationships**

Form-Categorial relations entail statements involving Aristotle's ten categories (substance plus nine accidents).[78] These relations at the level of characteristics correspond in terms of abstract form to the formal or logical identity relation.

5.3. Material Concept Relationships

Questions of Why? dominated Aristotelian metaphysics. What? questions dominated Aristotle's philosophy and logic. This led studies of quiddity and of material relations/ relationships, namely, abstraction, partition, opposition and function, each of which has their parallels in formal relationships as inclusion (co-reference), exclusion (negation) and intersection (conjunction) respectively (figure 6).

5.3.1. Generic or Abstraction Relations

Abstraction relations are of basic interest for our purposes because they are attempts to classify knowledge at different levels of abstraction: e.g. water, air, land in order to subdivide animals according to animals in the sea (fish), on land and in the air (birds), and to subdivide these in turn into different kinds such as eagle and sparrows.

5.3.2. Partition Relationships

The basic distinction between abstraction and partition has its roots in classical logic in the concepts of division (*divisio*) and partition (*partitio*). The many different names given to abstraction and partition by specialists in different professions (figure 16) is a tribute to their widespread importance.[79] What Wüster[80]and Dahlberg[81] called Generic/Abstraction and Partition, Perreault called Type/Kind and Whole/Part; Shreider and[82] Bean[83] called Hyponomy/hyperonymy and Meronomy. Pribbenow, refers to both meronymy and mereology. Following Tversky,[84] she sees this as the general heading with two classes, namely, taxonomy (i.e. *divisio*) and partonomy (i.e. *partitio*).[85] Meanwhile, Smith[86] and Mylopolous[87] referred to them as Generalisation and Aggregation. Such differences also confirm the problems of specialization that lead to redundant termino-logy and underlines the need for a more systematic, interdisciplinary approach to knowledge organization.

Divisio	Partitio	Logic
Generic/Abstraction	Partition	Wüster, Dahlberg
Tree structure	Beam Structure	“ “
Type/Kind	Whole/Part	Perreault
Hyponomy/hyperonymy	Meronomy	Shreider, Bean
Taxonomy	Partonomy	Tversky, Pribbenow
Generalisation	Aggregation	Smith, Mylopolous
Hierarchical	Hierarchical	Library Science/Info. Science
Broader/Narrower	Broader/Narrower	Library Science/Info. Science
is a/has a	is a part/has a part	Computer Science
(Inheritance: Parent-Child)	(Inheritance: Parent-Child)	Computer Science

Figure 16. Two basic relations introduced from classical logic and their variant names in different disciplines and professions.

Meanwhile, partition, which identifies the parts of a body, a plant[88] or an object, became a basis for all the descriptive sciences (botany, biology, life sciences and earth sciences) and also for many aspects of dictionary definitions: e.g. a man has a head, two arms and two legs etc. In medicine, this partitive approach is now considered to be a basis for semantic networks.[89]

5.3.3. Opposition or Complementary Relations

In its narrowest sense the opposition relation is the equivalent of negation at the logical level. In its broader sense, the opposition relation becomes a complementary relation with a series of six other terms, ranging in their precision and thus resisting clear definition (cf. figure 17). The first, contradictory, is effectively a synonym for opposition and as such is again the equivalent of exclusion or negation at the logical level. Contrariety is nearly the same but, as the example clean-dirty shows, ambiguity enters via knowing, or more precisely, not knowing, the precise parameters or degrees which define where clean stops and dirty begins. Duality is a clearer either-or situation, but as the example Northpole-Southpole shows, duality can be negation of identity without entailing negation of the other’s existence. Complementarity extends this negation of identity without entailing negation of existence, beyond either/or, as in above,

Exclusion		Intersection	
Negation		Conjunction	
Contradictory	(harmony-disharmony)	Complementarity	(above, middle, below, etc.)
Contrariety	(clean, dirty)	Analogy	(model-reality)
Duality	(Northpole-Southpole)	Homology	(arm of man- wing of bird)

Figure 17. Categories relating to exclusion and intersection.

	Being	+	Actions	Question
Level 1	Who?		did	What?
	Substance	+	Accidents	
	Entities	+	Activities	
	Subject	+	Intransitive Verbs	+Predicate
	Nouns	+	Transitive Verbs	+ Object
Level 2		+	Purpose	Why?
		+	Conditions	How?
		+	Time	When?
		+	Place	Where?
		+	Persons	Who?
		+	Objects	What?

Figure 18. A first and second level of material function or syntax relations.

below, middle etc. Analogy and homology bring into play comparisons while leaving open the criteria for degree: e.g. how similar, to what degree, by which criteria etc. Nonetheless, the final three of these terms entail intersection or conjunction at the abstract level. In some senses these relations are the most fascinating because they introduce potentials for unexpected comparisons and insights. On the other hand, until parameters of exclusion and intersection are more carefully defined, they elude quantification.

5.3.4. Functional Relationship or Syntax Relations

Earlier (p. 12) we cited a fundamental insight of Aristotle that words in isolation cannot create affirmations and that positive or negative statements require combinations of such terms in order to achieve statements that can be checked with respect to their truth value. Dahlberg has explored this problem in connection with a fourth material relation of function or syntax: "Whenever two concepts are put together in a syntactic relationship they are said to form a functional relation-ship."[90] At a first level this deals with the questions: Who? did What? and as such entails combinations of substance and accidents (figure 18). These can be of different types: a) entities and activities; b) entities with an intransitive verb + predicate; c) entities with a transitive verb +object. At a second level this also entails purpose, conditions, time, place, persons and objects, thus corresponding to the questions Why?, How?, When?, Where?, Who? and What? In grammatical terms, this entails the addition of adjectives, nouns, subordinate and conditional clauses.[91] In her analysis of the scope of the function or syntax relation, Dahlberg shows that it generates seventeen kinds of questions, which she relates to basic categories and partially also to the kind of questions posed by Lull in his *Great Art* of 1274 (cf. figure 39 in the notes).[92]

The idea that combinations of such questions could be mechanized was introduced by Raymond Lull in his *Great Art* (1274). Perreault[93] has claimed that this approach points directly to the calculating machines of Leibniz in the 17th century, Babbage in the 19th; to the Enigma, Bombe, Colossus and ENIAC machines in the first half of the 20th century and to the distributed supercomputers of today.

What interests us is to note how Lull's idea of systematic questions has yet to be fully adopted. Libraries typically offer access via author catalogues (Who?) and title catalogues (What?). In addition, libraries such as the Herzog August Bibliothek in Wolfenbüttel, offer access chronologically (When?) and via locations of publication (Where?). Search engines such as Artefacts Canada have begun to use such questions for searching.[94] Systematic access using the six basic questions and their variants would greatly expand the scope and the precision of searching. Prototypes for this are being developed in a System for Universal Media Searching (SUMS).[95]

Although syntax in this definition addresses the problem of meaning qua sentences as a whole, it does not yet cope with the meanings of words at the individual level. Clearly the challenge of meaning occurs at numerous levels and needs a multi-leveled approach. We need new ways to visualize such differences.

One of the fundamental implications of Dahlberg's insights is that concepts are not to be equated with words. Concepts and their terms are carefully gathered clusters of words that define their relationships. A very simple example is the concept of water as a fluid which, in chemical terms, is two parts hydrogen and one part oxygen. Here fluid is a so-called broader term. But there are many other approaches to define water as a fluid. It follows that all attempts to attain knowledge through simple "natural language" word counts, may contain much valuable information about practical usage, but cannot solve the challenges of the conceptual approach. Thus, projects such as CYC and Wordnet cannot bring us much closer to rich meaning and understanding.

In the case of cultural objects the situation is more complex still. To take an almost banal example: while the universal concept of beer is relatively easy to define (e.g. according to its ingredients), the particular definition of beer changes radically in different countries, regions and locally from one town to the next. Since these local variations are essentially linked with the unique characteristics of a given town that set it apart from other towns and make it worthwhile as a tourist attraction, a new quest became apparent: how to give access to diversity at the local, regional, national, international and global levels without destroying uniqueness at all the levels.

Hence, whereas the 19th century still dreamed of a single, comprehensive, omni-valent, dictionary that provided universal definition and encompassed all words in a language, the 20th century began with a growing recognition that etymological (i.e. historical), specialist and professional dictionaries, colloquial and slang dictionaries, regional and local dictionaries have their place, and ended with a conviction that the real challenge lay in creating bridges between them through mappings, walkthroughs and other ploys from the meta-data world: bridges between levels of definitions in different languages and dialects. Only thus can the true riches of historical and cultural dimensions be kept intact and fostered.[96]

Kind of Definition	Verb
1. Abstraction	is a
2. Partition	is a part of
3. Opposition	is not
4. Function	is about.

Figure 19. Dahlberg's four kinds of definition that stem from different material relations, and correspond also to basic logical categories (or semantic primitives, cf. figure 3).

What had initially seemed as a quest for a global dictionary and/or a revised edition of the universal encyclopaedia, is emerging as a need for new kinds of Distributed Electronic Dynamic Resources. European IST projects such as *IMASS* have begun to consider some of these challenges.[97] Hence there is a new quest for global networks to link equivalents, synonyms and near matches in a way that foster differences rather than dictate uniform responses. Such insights have contributed to efforts such as *Accès Multilingue au Patrimoine* (AMP), which insist on a need for mapping between conceptual terms in order to maintain subtle differences rather than forcing them into narrow uni-lingual, onto-logical straight-jackets.[98]

6. Relations, Universals and Particulars

All of this has fundamental implications for our understanding of what a definition is. As we have suggested earlier, a naïve definition is in terms of what something *is,* in the sense of its substance. In Dahlberg's approach, definition is potentially expanded into at least four categories[99] (figure 19). Interestingly enough, we have no dictionaries or thesauri with this level of distinctions. To appreciate the implications of this approach it is useful to link Dahlberg's headings, Perreault's relations and the space-time horizon (figures 20-21).

Dahlberg	Entities	Activities	Dimensions
Perreault	Subsumptive	Determinative	Ordinal
	Type/Kind	Active	Conditional
	Whole/Part	Limitative	Comparative
	Subject/Property	Destructive	Positional
	Substance/Accident	Interactive	
		Passive	

Figure 20. Dahlberg's headings, Perreault's basic relators[100] and subheadings (cf. fig. 7).

Subsumptive Relations			
Universals- General	(Not in Space-Time)		
Genus/Species Type/Kind	Whole/Part	Opposition	Function
-----------------------------------	Space-Time Horizon	--	
Particulars-Individuals	(In Space-Time)		
Subject/Property Substance/Accident	(Whole/Part)	Opposition	Function

Figure 21. Perreault's Subsumptive Relations with respect to Universals and Particulars.

Perreault[101] established his schema of different classes of relations as a device for using relationships in classificatory, syntactical expressions especially for the Universal Decimal Classification (UDC). He proposed that all relations can be classed under four headings: general, subsumptive, determinative and ordinal. General relations entail: alternation, conjunction, reciprocal, converse and negative and relate to both the basic logical categories (figure 3) and to what Dahlberg terms the opposition or complementary relation. Of interest at this point are the relations classed under subsumptive, determinative and ordinal (figure 20) and their subdivisions (cf. Appendix 5).

Perreault's distinctions help us to see the age-old debate between Plato's universals and Aristotle's individuals in a new light. In retrospect, Plato was interested in subsumptive, type/kind and whole/part relations, which dealt with universals. By contrast, Aristotle was particularly interested also in subsumptive, subject/property relations relating to particulars and individuals. Plato's universals are not in space-time, whereas Aristotle's particulars, below the space-time horizon, are in space and time. Plato's universals are eternal: Aristotle's particulars are spatio-temporal (figure 21). Plato's universals constitute the world of theory: Aristotle's particulars are in the world of practice. At the level of theory, there are parameters. At the level of practice, there are measurements. Theoretically, "man" is a living being with a range between two feet as a pigmy and eight feet as a proverbial Texan. Practically, one individual is 2'8" whereas another individual is 7'2".

The universal is static and can readily be reduced to mechanistic metaphors. The particular is growing (or decreasing) and is more readily amenable to organic metaphors. To ensure the progress of science, it thus made sense to separate the organic, changing, (subjective) aspects of subjects from the mechanical, unchanging, (objective) elements of objects. Cassirer has documented this chapter in the history of thought in his masterful *Individual and the Cosmos*.[102] It took some centuries to recognize that removing the subjective, also removes the subject, the user, the person towards whom and for whom our inventions are theoretically directed. Hence, simply eliminating subjects does not remove the deeper challenges of subjectivity, a challenge that Polanyi brought back into focus with his basic book on *Personal Knowedge*.

Universal- General	(Not in Space-Time)	
Relations: Subsumptive	Determinative	Ordinal Comparative
Entities Type/Kind (is a) Genus/Species Whole/Part (has a)	(Activities)	(Dimensions)
----------------------------------	Space-Time Horizon	--
Particulars-Individuals	(In Space-Time)	
Subsumptive (Whole/Part) Subject/Property Substance/Accidents	Determinative Active Limitative Destructive Interactive Passive	Ordinal Conditional Comparative Positional

Figure 22. Universals and Particulars in Light of Perreault's Relations.

At the level of universals, all of Aristotle's accidents and some of Perreault's relations apply. For instance, universals have ordinal comparative relations, but not conditional or positional relations (figure 22). The concept of a bird has parameters re: maximum and minimum size, but cannot have a measureable size. Nor does it have a state of excitement or particular position on a tree at any given time in the way that the particular, individual, two-month old robin in my garden does. Concepts above the space-time horizon can be visualized at a level of abstraction different from individuals. They cannot be photographed. Those below the space-time horizon can be photographed. At the level of particulars, all of Aristotle's accidents and Perreault's relations apply. Needed is a reorganization of knowledge that links knowledge at the particular level with corresponding, more general, knowledge at the universal level, and reflects these different kinds of visualisation.

Although Aristotle would very probably have agreed that this is an excellent idea, prior to the advent of high-powered, networked computers the quest to create this number of relations was completely infeasible. The advent of digital media enables a transformation of our relations among entities, properties, activities and dimensions, up and down the different levels of subsumption, to arrive at a re-organisation of knowledge.

Closer study of these classes of relations helps us to understand why there has been such confusion, debate and misunderstanding in the course of the centuries. At the level of an individual one can also speak of whole/part: e.g. John Doe has a head, two arms etc. We need hundreds and sometimes thousands of observations of such whole/parts or components of particulars to understand whole/parts at the level of universals, which in turn is a basis for deciding a generalized or universal type/kind. In other words, there is a clear hierarchy in the subsumptive categories.

Does knowledge then lie primarily in the inductive gathering of individual facts about particulars or does it lie more in the deductive summaries of these lists? The answer is both and yet interestingly enough persons often argue that it is one or the other. As a result some, especially in the Anglo-Saxon tradition, link the whole/part at the individual level directly with the type/kind at the universal level.

Others, especially in the German tradition, distinguish between a particular whole/part, which includes the measurements of a specific individual and a general whole/part, which entails the parameters of a universal concept.[103]Unfortunately, our databases today usually do not distinguish between these different approaches. Needed are methods of database modeling, metadata and knowledge visualization that allow us to see clearly which level of whole/part is under discussion; that allow us to see where we are in the subsumptive list, e.g. vertical y- axis.

Kant spent a lifetime insisting on the primacy of space and time in an attempt to clarify differences between what we can know at various levels. He claimed that ultimately knowledge with certainty is limited to the spatio-temporal domain of particulars. Since then, philosophers including Popper have continued to clarify these distinctions. We can observe 1000 white swans, but that does not prove that there are no black swans in Australia or in exotic parks. Hence, the certain knowledge of particulars can lead us to tentative knowledge of a spectrum at the level of universals.[104] The universals that seemed absolute categories to the Ancients, have reduced themselves to parameters, themselves defined by the extent and limits of our knowledge.

At the macro-level, knowledge of these parameters is often straightforward. In the case of products, it is relatively easy to create parts catalogues that define all the parts of a machine and their relation to one another. Photographing, describing and defining an individual man at the scale of the everyday physical world is fairly simple. At the micro- and nano-level this quest becomes much more elusive (see section 7.2 below).

7. Dynamic Knowledge and Meaning

Our space/time horizon introduces a theoretical framework where universals are not in space/time, whereas particulars are in space/time. We need to remember, however, that this framework itself changes with time as our knowledge of universals and particulars increases or changes. In this sense, Immanuel Kant was right: all our knowledge is in space and time. Hence, later versions will need to go much further, for two fundamental reasons. First, they will need to reflect cultural and historical dimensions of knowledge. Second, they will need to reflect recent developments.

7.1. Cultural and Historical Dimensions of Knowledge

If knowledge were merely a paradigm in the sense of Thomas Kuhn,[105] then the systematic, historical study of a cumulative corpus of knowledge could readily be substituted by (fashionable) themes,[106] or indeed perhaps only fashionable memes would be worthy of study.[107] Such a position would very conveniently absolve experts in artificial intelligence and other new disciplines from the burdens of mastering millennia of human knowledge; burdens which could risk introducing modesty and other inconveniences. Our brief survey of major trends in knowledge collection, organization and classification points to fundamentally different conclusions.

Notwithstanding extinction of some species, destruction through wars, the vagaries of civilizations and changing categories, the cumulative dimension of scientific knowledge is indisputable. The constantly growing species of plants of which we are aware is but one striking case in point (figure 32). The same case could be made equally in the animal or mineral kingdoms. There is a cumulative dimension to the corpus of scientific learning even if occasional shifts in the explanatory framework for that corpus, when described as paradigm shifts, seem disjunctive and non-continuous. In the case of cultural knowledge, this cumulative dimension is even more fundamental as witnessed by the constant growth of libraries and museums.

There is also an extraordinary way in which awareness of biological diversity is integrally linked with cultural diversity (Appendix 4): that different cultures are a key both to awareness of biological diversity and a key to their future, sustainable development. Simply to create databases of our latest views on knowledge cannot answer the challenges facing the planet and its inhabitants. Unless we record and preserve the cultural and historical variations in all their complexity, we cannot understand our past or present, nor shall we have a proper framework to understand the future.

To take a simple example: As we have seen, there were many attempts in the past to visualise the (great) chain of being that linked the lifeless, alive, human and godly. This led to hierarchies from the mineral, through animal and vegetable to the human. In the twentieth century there was new attention to the "being" categories,[108] which extended them to include the products of human effort as *homo faber* and *homo ludens* as these are beings created by man and society. Today some might wish to separate these products from lists of being. However, in order to understand earlier centuries we must maintain a key to their ways of looking at and organising the world. Creating our own modern classification is not enough to understand how, and more significantly why, earlier cultures had very different ways of organsing knowledge.

Thus we need bridging and mapping devices that allow us to move dynamically through different languages, different levels of vocabularies, different chronologies (in the sense of time systems), different cartographical methods and policies (such that we can see how maps of a country such as Poland not only change with time but also differ from those of Russia or Germany for the same area). Such dynamic lists of knowledge will allow us to trace changes of interpretation over time, have new insights and help us to discover new patterns in knowledge.

7.2. Recent Developments

There is a second fundamental reason why such dynamic models of knowledge are necessary. The ability to define objects changes with their scale. It is easy to define a man as having a head, two arms and two legs. However, at the micro-level, it is much more difficult to observe how many hairs Joe Doe has, how many red blood cells etc. At the nano-level and the atomic-level, boundaries are constantly changing, and the very idea of defining and counting each particular cell is usually no longer useful.

In Antiquity, there was a clear distinction between the Godly- Human-Alive-Lifeless. During the Renaissance, as Cassirer has shown, it made sense to distinguish clearly between subject and object. This distinction produced the idea of objective knowledge that led to many scientific and other insights. It also introduced seeming dichotomies between man and his world, between man in relation to machines, and between man and his knowledge. For a while it appeared that these challenges could simply be met with yet another simple technological "fix".

A younger generation is beginning to recognize that much more fundamental solutions are needed: abandoning or at least complementing our mechanistic metaphors for Human-Computer-Interaction (HCI) with organic metaphors, approaches and interactions.[109] How these new organic insights can be integrated into our interfaces with machines, hardware, software and with knowledge itself is an enormous challenge for the next generation and is certain to bring many new insights.

If, however, we were subsequently to switch to such a new set of metaphors and completely abandon our earlier models as if they were merely an outdated paradigm, then we would merely be throwing away many dimensions of the cumulative insights of the past centuries. If evolution is embracing not replacing, then the challenge is both to develop new sets of metaphors and maintain the insights brought by previous sets.

The big picture thus confirms both a remarkable continuity of ideas and also the surprising extent to which the media that we use to approach and to understand the world, define how we organize, and even how we define, knowledge. In retrospect, Aristotle's enormous leap forward in recording details of particulars and individuals only became possible when oral culture shifted to hand-written culture. As Giesecke[110] has shown, another leap forward came with the advent of printing. This again fundamentally changed how the Renaissance defined, ordered and shared its knowledge.

Each of these earlier innovations implied replacement. Hence the shift from oral to written culture led ultimately, as Ong has argued, to a *Decline of Dialogue*.[111] The shift from written to print culture, as McLuhan showed,[112] brought a new emphasis on linear, analytic thinking.[113] The shift to digital media is much more than another new technology that will eventually replace what came before. It offers a new key to translating any medium into any other medium interchangeably. Hence, we can now take an oral or a printed work and translate them into digital form, but we can equally take a digital expression and translate it back into printed, written or oral form. For the first time in history, we have a medium that allows us to move into new modes of expression and also allows us to reconstruct earlier modes of communication, thereby recreating the different perceptions of these earlier methods. This is one of the underlying reasons why reconstructions are rapidly becoming a new industry.

There has always been a paradox that persons further away in time from events, often know much more about them. Hence, thanks to the encyclopaedic efforts of Pliny, Vitruvius and later the Alexandrian school, the Romans had a better survey of Greek culture than the Greeks themselves. In many ways, Renaissance humanists, who profited from both the Arabic contributions and more rigorous tools of historiography, had a better knowledge of the Greeks than the Romans.

Today over 2500 years after the events, the cumulative effects of studies in history, archaeology, philology, geography and other disciplines has led to a detailed knowledge never possible at the time for Socrates, Plato or Aristotle. As a case in point, John Traill[114] (Victoria College, Toronto), has collected more information about names of persons in Athens, than any Athenian in Antiquity. The Perseus project led by Gregory Crane[115] even if it does not always reflect the frontiers of research in the field, makes accessible even to non-specialists a wider range of information about the Greek world than Aristotle or Plato had at their disposal in the Platonic Academy. This new vision of the Greeks ranges from their colonies in Spain at Ampurias, through Sicily and the coasts of Turkey and Syria to include the shores of the Black Sea.

There are still problems of recognizing such contributions in the academic world.[116] We are still judging the contributions of the present using methods familiar from the past. Yet the future clearly lies in such new methods.[117] The real challenge is to go far beyond simple access to knowledge of the past and use new digital media to keep alive awareness of different historical and cultural modes of perception, different ways of experience, different ways of thinking, visualizing not just facts but rather how such facts relate to different belief systems, different ways of knowing, mindsets, *mentalités*, world-views, and *Weltanschauungen*.

There are additional reasons for taking up in a new way the encyclopaedic quest that go far beyond obvious arguments concerning the advancement of knowledge. In taking such an historical, cultural path, we become aware specifically how cultures class, organise and arrange differently the physical world, the man-made world, persons, interactions, just about everything that exists. We have a practical means of seeing different world-views, a new tool for fostering and increasing our sense of the other, a new path towards tolerance.

It is a topic of the day to dismiss everyone who looks at the world differently than ourselves with terms such as “terrorist” or “enemy of the people.” There is an ongoing, more subtle and broader danger about being troubled by and dismissive of the “foreign,” the “strange” or simply the “other;” by the person with a different language, dialect, clothes, appearance. But to dismiss them is hardly the way to tolerance, understanding and deep-seated mutual respect. We need new ways to nurture and foster respect for diversity.

Once upon a time, Europe lived under the illusion that it was the centre of multiple empires, whereby it could carve up the world. We are waking up to a world where Europe is less than 5% of the world's population. Unless we find new ways to share understanding and respect, we shall be reduced to an insignificant minority in a world that is angry about our past, or worse, impatient with us for having no serious advice in the present and for being without visions for the future.

8. Semantics

In the foregoing sections we have traced developments in definition and relation and suggested that this has major implications for the future of dictionaries, thesauri and knowledge organization. In addition, we outlined ways in which the introduction of a space-time horizon can bring further clarity into our understanding of universals and particulars. At this point it is useful to survey briefly key developments in semantics over the past centuries in order to assess where we stand today.

The quest to understand the meaning of words is probably as old as language, for without meaning there can be little understanding and even less communication. As noted earlier (section 3), in the field of logic, the meaning of words was traditionally linked directly with the definition of definition.[118] Only gradually did a quest for the study of meaning become linked with a more general quest to understand the meaning of signs. Some scholars trace the origins of semiotics back to the early 17th century.[119] Other have traced this quest to understand signs back to Vico's *New Science* (1725)[120] but this is debated.[121] It was not until the second quarter of the 19th century that sematology as the "doctrine of the use of signs (especially words) in relation to thought and knowledge" emerged as an independent subject.[122]For instance, Smart in his *Outline of Sematology* (1831) noted: "If we might call the whole of instruction which acquaints us with τά φΰσέιά by the name of Physiology and that which teaches us τά πρακτικά, Practicology, all instruction for the use of τά σηματα or the signs of our knowledge might be called sematology."[123]

A half century later, A. H. Sayce, in his *Introduction to the Science of Language* (1880), referred to "the physiology and sematology of speech (phonology and semasiology)," as if sematology and semasiology were effectively synonyms. Meanwhile, there were related efforts such as those of Victoria, Lady Welby, who aimed at a science of significs. By 1934, Karl Bühler saw sematology as the basis for "a general theory of symbols,"[124] which he saw as opposed to the semiology of De Saussure.[125] Although sematology produced a certain amount of study,[126] it was overshadowed by its near synonym, semasiology.[127]

Meanwhile, Bloomfield (1895), had introduced the word, semantics, as "relating to signification or meaning."[128] Michel Bréal (1897) published a major book (*Essai de sémantique. Science des significations*),[129] which was translated into English by Mrs H.

Semantics	Science that studies the content (meaning) side of linguistic signs
Semiotics	Science of general properties of sign systems
Lexicology	Science that studies vocabulary of language also called Lexical Semantics
Lexicography	Science of dictionaries and their creation
Semasiology	Branch of semantics that seeks meaning departing from expression side of language; Development and changes of the meanings of words.
Onomasiology	Branch of semantics which departs from a meaning side of language and asks what expressions exist in other languages.

Figure 23. Semantics and related sciences in the early 20^{th} century.[130]

Cust in 1900. The Athenaeum (1901) noted that "as applied to language, psychology is not easily distinguishable from semiotics and semasiology."[131] Even so, semantics soon blossomed as part of a new complex of sciences (figure 23) that included semiotics, lexicology, lexicography, semasiology and onomasiology (cf. onomasticon[132] and onomastics[133] which are much older) and has subsequently led to more specialized fields such as cognitive diachronic semasiology.[134]

In retrospect the fascination with semantics and semiotics in the early decades of the 20th century was part of a more complex landscape of semiotic trends (figure 24),[135] which had an implicit and sometimes explicit common goal of understanding symbols and symbolism. Ogden and Richards' famous *Meaning of Meaning* (1923) had as its subtitle: *A Study of the Influence of Language upon Thought and the Science of Symbolism*. Interestingly enough that same year saw the first volume of Cassirer's monumental *Philosophy of Symbolic Forms* (1923, 1924, 1931) which had as its subtitle: *Prologomena to a future Philosophy of Culture*.[136]

As noted above, Bühler's sematology had the same goal of producing a science of symbols, and is the more interesting because his notions of sender and receiver in the 1930s, foreshadow Shannon's[137] work on information theory and Wiener's[138] cybernetics. The past fifty years have seen many more contributions to semantics[139] with respect to linguistics, logic, philosophy, psychology, and information theory.[140] Yet, paradoxically the quest to achieve automated forms of communication especially in the second half of the twentieth century also led to a great simplification of the problems and serious dumbing-down with respect to solutions.

In the 1940s, Claude Shannon, who worked with Vannevar Bush on the ENIAC (Electronic Numerical Integrator and Computer), chose Boolean logic[141] as his point of departure. Boolean logic reduced logic to choices between three logical operators: *and*, *or* and *not*. In terms of the semantic primitives these operators dealt effectively with Exclusion, simplistically with Inclusion and only in a very limited way with Intersection (cf. figure 6). In terms of basic questions this provided some treatment of Who? and What?, ignoring entirely Where?, When?, How? and Why?

Structuralism	Jakobson
Functionalism	Mathesius and Mukarovský
Philosophy of Symbolic Forms	Cassirer
Umwelt Research	von Uexküll
Structural Description	Carnap
Sematology	Bühler
Significs	Mannoury
Glossematics	Hjelmslev

Figure 24. Basic semiotic trends in Europe (1920s -1930s) according to Roland Posner

In the 1950s, Curry and Feys developed typed combinatory logic.[142] This introduced a distinction between three levels of language: 1) Phenotype, which describes natural language as order of words; 2) Genotype, which expresses grammatical invariants and structures and 3) the Cognitive level which deals with lexical predicates as represented by semantic cognitive schemes. This linked cognitive science with the study of meaning and semantics.[143]It also separated perceptual and conceptual dimensions.[144] At the same time, it focussed so much on mental dimensions that a recent survey of trends could ask: Does representation need Reality?[145] This poses a further challenge of remembering that our models need to explain the physical world and to bridge physical and mental worlds.[146]

In the 1980s, the influential work of Langacker established the foundations of a new cognitive grammar.[147] This introduced a distinction between nominal predications to designate things (i.e. nouns) and relational predications used for states (a-temporal relations) and processes (adjectives, adverbs, prepositions and verbs). In terms of basic questions this established a distinction between Who? and What? (nouns) and relations entailing Where?, When?, How? and Why? (adjectives, adverbs, prepositions and verbs). On the positive side this prompted new attention to relations using verbs: the emerging field of troponymy. On the other hand, it obscured the very clear relations which had been established between division and partition (figure 16).

Since the 1980s traditional distinctions have been even further eroded. For instance, Eduard Hovy, [148]one of the authors of the influential, Word Net recently noted (2002):

> We define an ontology rather loosely as a set of terms, associated with definitions in natural language (say English) and, if possible, using formal relations and constraints, about some domain of interest, used in their work by humans, data bases and computer programs. We view a set of semantic relations organized into collections and perhaps related in a generalization hierarchy as a special instance of an ontology.[149]

These definitions are important because they establish new links between ontology and semantics that help to account for the meteoric rise of these two concepts in the past decade. Christiane Felbaum (2002), also linked with Wordnet, provides an even more general notion of semantic relations: "If one examines the lexicalized concepts in relation to one another, it becomes clear that they differ in systematic ways that are characterizable in terms of similarities and contrasts. These consistent differentiations among concepts are what we call *semantic relations*." [150] Interpreted narrowly this definition would mean that semantics has nothing to do with who or what a thing is, what it means. Rather, semantic relations would be limited to differentiations in terms of similarities and contrasts.[151]

Meanwhile those in Library and information science have focussed on equivalence (use/used for); hierarchical (broader term/narrower term) and associative or affinitive relations (related terms). In this context, Why? questions (cause-effect) become linked specifically to associative relations.[152]

The net result of these developments of the past decades is that an enormous corpus of work prior to 1950 has effectively been forgotten or deliberately ignored by the pioneers of the semantic web. We noted earlier that even John Sowa, a highly respected figure in the artificial intelligence and programming community in an article on "Ontology, Metadata, and Semiotics"[153] refers to five semantic primitives (figure 3), four of which, relate directly back to the premises of Aristotelian logic. Indeed, as a result of our survey of definitions and relations (sections 3-6) we are now in a position to provide an update to Ogden and Richard's meaning of meaning, especially concerning efforts towards a semantic web and semantic networks.

8.1. Relational Databases

In light of the above it is clear that the entity relationship model[154] as originally introduced by Peter P. Chen (1976)[155] lacked the complexity of the examples outlined above. Some would claim that this was deliberate, the assumption being that detailed distinctions could subsequently be fitted in at the modeling level. Even so, many early versions[156] of the entity-relationship model were limited to entities and activities, with inheritance in terms of parent-child, with no distinction between abstraction (*divisio*) and partition (*partitio*) as introduced by classical logic (figure 16) and thus no distinction between intransitive (is) and transitive verbs (has).[157]

Fortunately, the past two decades have seen enormous advances through the advent of the Natural Language Information Analysis Method (NIAM) and Object Role Modelling (ORM), whereby there has been a gradual integration or at least bridging of what once seemed opposed data models, namely, conceptual and logical (e.g. relational, object-relational, hierarchical) data models.[158] Even so we still need a model or implementation whereby the different, (vertical) levels of material relations, i.e. subsumption and (horizontal) levels of formal relations, i.e. determinative and ordinal are more systematically linked with respect to the space-time horizon.

8.2. Semantic Web and Semantic Networks[159]

In theory, one might have expected that these challenges would have been solved by the Internet. In practice, the Internet, which began in the late 1960s as a response to military concerns with continued communications in times of disaster, was transformed in the early 1990s by the evolution of the World Wide Web as a means for sharing first scientific and increasingly all kinds of knowledge (Tim Berners Lee and Robert Cailliau). Within a decade the web exploded from a small community of scientists and scholars to over 200 million persons. Since 2000, notwithstanding rhetoric of dot.com busts, there have been more than 480 million additional users. Aside from obvious challenges of scale, this introduced new challenges: how to distinguish between reliable knowledge of a small scientific and scholarly community in the context of a large qualitative range and vast quantitative amounts of information produced by persons ranging from simple enthusiasts to sinister individuals and groups with both clear and hidden agendas.

By 1997, Tim Berners Lee had outlined the need for a semantic web or web of trust, where there was not just access to information, but also access to different layers of knowledge. The idea was noble. Unfortunately, few technologists were aware that the term semantic is just over a century old and that it entails very different agendas, ranging from very narrow definitions in factions of the AI community to one that potentially embraces all human knowledge and experience.

Some technologists especially in the field of artificial intelligence wish to restrict the definition of semantics[160] to the "meaning of instructions, commands and transactions" as used by machines. This potentially takes us back to the level of abstract form (logic). While this approach is theoretically extremely precise, the quote from Wiener at the outset of this paper confirms that in these circles the term semantic is often rather elastic in its meaning.

Some proponents of the semantic web wish to focus specifically on transactions. Business consultants and analysts with an eye on profits in the next quarter are undoubtedly right about the economic potentials of automated, on-line transactions. It already functions in the case of ordering books at Amazon or other items at E-Bay. Ironically, after more than two decades, the methods of Electronic Data Interchange (EDI) have still not become a standard.

On-line transactions assume that money moves while persons remain in the same place. By contrast, tourism assumes that persons move in order to make money move. If we recall that 12% of the world's economy ($3.5 trillion annually)[161] is now tourism, then the economic potentials of systems that improve access to our cultural diversity in such a way that they also stimulate our desire to discover those differences in person, and make both persons and money move and interact are clearly far greater than simple transactions of on-line billing.

Semantic, in the sense of ARPA's Interspace project,[162] is something quite different again. Their latest efforts in the context of Medspace,[163] to create a semantic approach to the whole of Medline, apply to medicine aspects of Perreault's relations, notably subsumptive, type/kind and whole/part.[164]

If we stand back and look at transactions in terms of Dahlberg's original (Ur) categories we quickly see that transactions represent a tiny aspect of activities and ignore most aspects of entities, properties and dimensions. Formal logic relations and subsumptive relations also cover very small bits of the big picture. For the most part the semantic web as it is treated today is merely a bandwagon for technologists re-inventing the wheel with a collection of buzzwords, without qualms about overlooking that these problems of meaning have been addressed seriously by thinkers for the past 2,500 years.

Prior to the late 19th century the quest for meaning, now called semantics,[165] would have been called a quest for syntax. As we have shown (section 5.3.4), syntax, in the sense of formal relations accounts for the richness and complexity of human language. In light of the above, it is perfectly possible to speak of syntactic (re: structure as in grammar) and semantic (re: meaning as in grammar or logic) interoperability. It is even possible to speak of mapping syntactic dependencies onto semantic relations,[166] but great care is needed to distinguish whether the terms are being used in the sense of grammarians, librarians, computer scientists, or in some other sense.

The good news is that there is an immense amount of activity being devoted to these topics that goes far beyond the scope of a single paper. Of central importance are the contributions within the International Society of Knowledge Organisation (ISKO)[167] founded by Dr. Dahlberg; the American Society for Information Science and Technology (ASIS&t),[168] especially their Special Interest Group on Classification Research (SIG-CR) and, of course, the International Federation of Library Associations and Institutions (IFLA).[169] Two individuals connected with these communities, Carol A. Bean and Rebecca Green, have recently edited two important books, which provide an excellent survey of recent developments with respect to relationships and their semantics.[170] This work deserves to be studied more closely by the semantic web community.

The big picture, as we have suggested earlier, is about much more than simply translating existing resources from analog into digital form. It requires a rethinking and restructuring of what has been done so far in the realm of dictionaries and thesauri. This can begin at a very practical level. Many controlled vocabularies such as the *Inventaire générale des monuments et des richesses artistiques de la France* have been developed but are not generally available. Multilingual access to such resources would be an excellent first step.

Subsequently, we need new distributed repositories to distinguish between ostensive, nominal and real definitions and to distinguish between different kinds of definitions re: substance (is a), accidents (has a), subsumptive relations (e.g. is a species etc, is a part of); opposition (is not); and functional (especially determinative and ordinal) relations (is about). We need to combine universal, subsumptive relations (type/kind, whole/part) with particular, subsumptive relations (subject/property, substance /accidents). Such relations need to be aligned with the space-time horizon such that we can distinguish between general, quantitative parameters of universals (e.g. a bird of species x has a wing span between 10-15 cm) above the space/time horizon and quantitative dimensions of particulars below the space/time horizon (e.g. the sparrow in the garden is 11.3 cm.).

A next step will be to map between different versions of these universal, subsumptive relations: e.g. an American classification or thesaurus and a Chinese, Indian or European one. Preliminary versions of such attempts will inevitably resemble virtual reference rooms, with digital equivalents of classification systems, dictionaries, encyclopaedias, book and library catalogues.[171] Gradually these can evolve into a Distributed European Electronic Resource (DEER) with three basic components: a) virtual reference rooms; b) virtual libraries as distributed repositories and c) a forum for collaborative research and creativity. Such a DEER can lead to more ambitious efforts on a global scale in the form of a World Distributed Electronic Resource (WONDER).

9. Practical Consequences

A number of practical consequences have already been outlined or implied in the previous three sections (6-8). Potentially, these consequences have serious implications for the semantic web wedding cake as it now stands (figure 2). Quite understandably, the World Wide Web (WWW) community has focussed on the web. As a result the cornerstones of the semantic web are Uniform Resource Identifiers (URIs) and Unicode (the bottom layer of the wedding cake). On top of this are layers to create self-describing documents, above, which are data layers for ontology vocabulary and logic and finally rules for proof and trust. The good news is that this produces an excellent self-contained system. With respect to the needs of culture, the bad news is that, aside from a small percentage of born digital objects, the vast majority of culture is outside this closed electronic system.

A glib solution would be to limit the semantic web strictly to digital objects, in which case only cultural objects, which have been digitised and digitally-born cultural objects would be part of the system. Needed, however, is something that takes the system beyond this simple self-referentiality.

One approach would be to refine the concept of URIs in order to distinguish between those which entail 1) strictly born-digital materials and those which entail references to and/or claims about 2) particular physical objects that have analog originals in the physical world; 3) particular non-physical, intangible objects, that have originally been documented in analog form (e.g. music, dance), and 4) universal objects or concepts, which again have originally been documented in analog form.

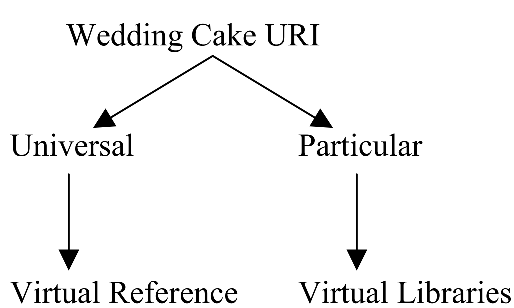

Figure 25. The wedding cake's URI vis à vis universals and particulars (cf. figure 2).

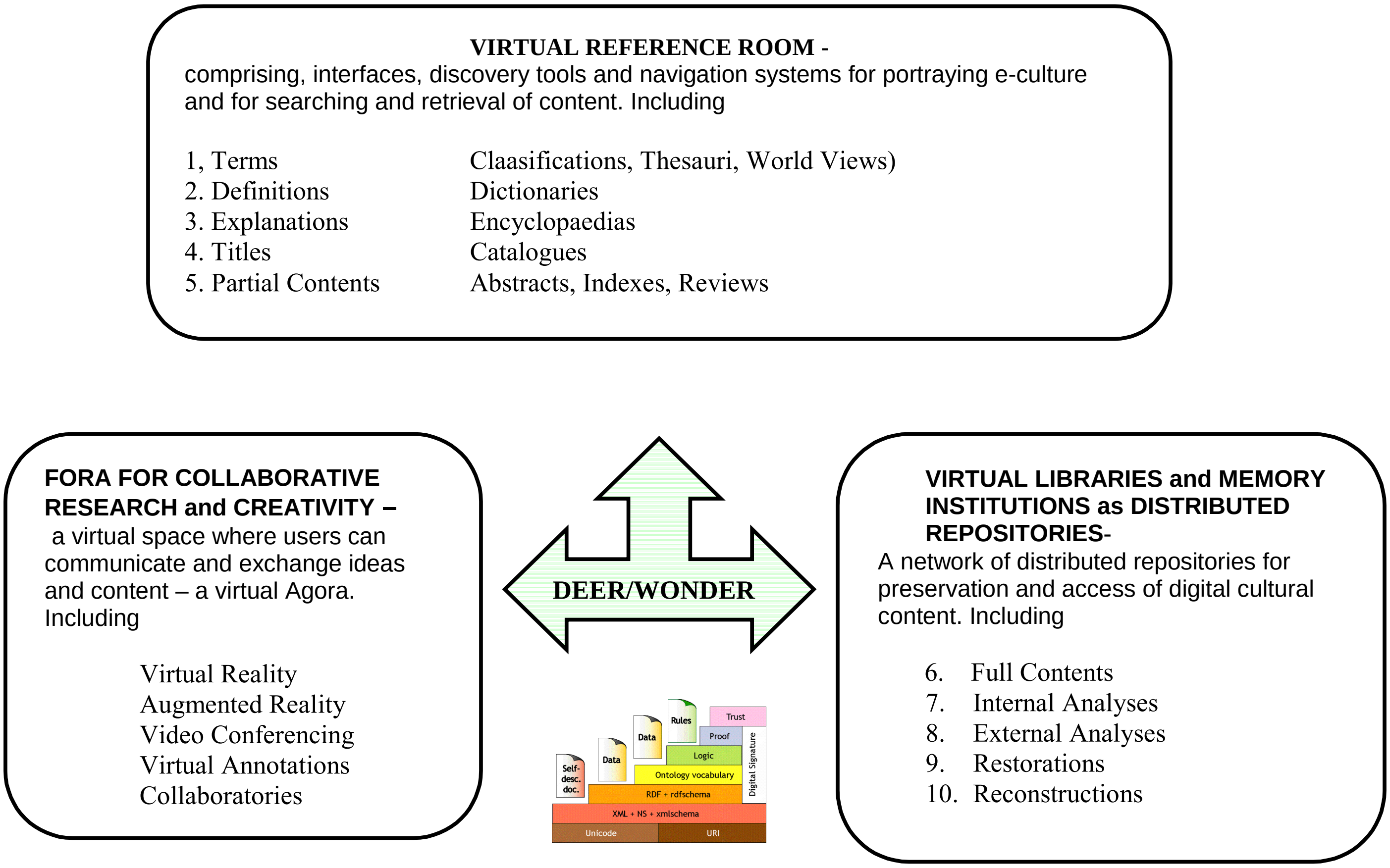

Figure 26. Main elements of an initial Distributed European Electronic Resource (DEER), [172] which offers a model for a future World Distributed Electronic repository (WONDER).

Those in category 1 would be treated as they are being treated today. Those in categories 2-4 would need to be linked with the real world.[173] In addition, all objects in categories 2 and 3 could be linked with a unique object that had a series of subsumptive, determinative and ordinal relations. In like manner, universals in category 4 could be linked to a smaller range of these relations. These universals can then be linked with virtual reference rooms, and the particulars can be linked directly to virtual libraries (figures 25-26, cf. figure 22).

The virtual reference room will show how this universal is related to terms (in classification systems, thesauri and world-views); definitions (in dictionaries); explanations (in encyclopaedias); titles (in library catalogues, book catalogues and bibliographies) and partial contents (in abstracts, indexes and reviews (e.g. IBZ, *Intenationale Bibliographie der Zeitschriftenliteratur).* In the long term, the virtual reference room can supplant the ontology vocabulary layer of the wedding cake: the one enormous difference being that the virtual reference room provides multilingual access to ontologies, which reflect different cultures at a given time and trace their evolution over time.

This link between the wedding cake and a virtual reference room increases access to reference materials and has much wider consequences on at least three fronts. First, as we have noted, the semantic wedding cake uses logic as its basis and is thus limited to Who? and What? concerning existence, identity etc. (cf. figure 3). Hence, today's semantic web follows the limitations imposed on Western thinking when the logic section of the medieaval *trivium* triumphed over grammar and rhetoric (Appendix 1). The virtual reference room expands access to knowledge via a full range of questions including: Who?, What? Where?, When? How? And Why?. This expands semantics (meaning) beyond existence (who or what a thing is and has) to include why, how, where and when a thing is.

Second, whereas todays' semantic web focusses on static definitions, our approach includes different types of definition: distinctions between words and concepts (between natural language and terminology); a more systematic treatment of relations and the need for dynamic meaning.

Third, since today's semantic web focuses solely on logic, it is limited strictly to today's answers: today's world view. The link with a virtual reference allows an expanded number of questions and answers to be seen in terms of different world-views. To return to the example of cartography mentioned earlier (section7.1), today's semantic web assumes that there can be only one "objective" map of Poland. Links with a virtual reference room, allow us to deal with Polish, Russian, and German maps of the same territories that differ considerably at any given time and also change over time.[174]

That which applies to cartography applies to words and concepts generally. To take a relevant, contemporary example: it is instructive to recall that copyright, which is now so emphasized by the United States was almost systematically denied by that same country less than a century ago. The semantic web must do more than give access to today's definitions of copyright. It must show us how such concepts change radically in different places and times. To do so it must create data structures and databases that allow us to see relations between facts, claims, and world-views (including philosophical, theological, political and ideological systems).

This virtual reference room serves as an introduction to a virtual library in the form of distributed repositories, which contains not only primary literature in the form of full texts, but also secondary literature in the form of internal analyses, external analyses, restorations and reconstructions. In terms of the web this implies an increasing distinction between primary (literature) sites which simply contain "content" in the form of digital texts, paintings etc. and those which are secondary (literature) sites, in the sense that they provide annotations, commentaries and interpretations of the original material.

These distinctions again have wider consequences for the semantic wedding cake, because they imply a shift in its basic orientation and goals. As we keep noting, the commitment to logic leads today's semantic web to focus solely on what can be proven logically. This has extremely useful consequences for business: it is necessary to have proof of the identity of the person receiving goods in order to have legitimate claims that they pay for those goods. However, to reduce the web to this would be to reduce it to a new version of bills and bank statements: a mechanical web for machine transactions.

If the World Wide Web is go beyond transactions and simple messaging systems (e-mails, chat rooms, etc.[175]), and evolve into a web for human communication then considerably more is needed. We need tools to prove[176] and areas to distinguish between a) what needs to be proved (science, business); b) what needs to be carefully supported and defended with evidence and reasons (enduring knowledge, law) and c) what does not require proof (personal knowledge).

We need spaces that reflect Pascal's insight that "the heart has its reasons, which reason does not know" ("*Le coeur a ses raisons que la Raison ne connait pas*") or La Rochefoucault's aphorism: "Who lives without folly is not as wise as he thinks" ("*Qui vît sans folie n'est pas si sage qu'il croit"*). In so doing, we expand enormously the scope of the semantic web from the mechanical realm of machines to the organic realms of life and humanity. In so doing, we expand the scope of semantic from a strict logical meaning (i.e. identity, inclusion, exclusion, etc.), to the realm of the meaningful, which is central to the human condition.

With respect to enduring knowledge, by following through the distinctions between universals and particulars as described in figure 22, it becomes possible to see how much could be known about an object, which can then be compared to what is known. In short, this approach points to templates, whereby we can begin to discern lacunae in existing knowledge. This approach thus becomes an inadvertent aid with respect to the logic, proof and trust layers of the cake. Claims about an object where many of the basic characteristics are missing, will be less trustworthy than those where all these characteristics are known and their sources documented.

In the case of categories 2-4, through a simple proviso that these links between URIs and objects should link back to the originals on which they are based one introduces a further aid with respect to aspects of the logic layer and trust layer of the wedding cake. A simple example with help make this clear. A web site that refers to Leonardo da Vinci's *Mona Lisa* in the Louvre should provide a direct link to the Louvre's digital version of that painting. By so doing one solves in large part the existence and identity dimensions of the logic layer.[177]

Creators of websites will of course be at liberty to refer to other copies and versions, legitimate or pirate, but in the absence of a direct link their claims will be idle. This direct electronic link will effectively function in much the same way that a pedigree does in the world of professional breeders. Without a pedigree, without a proof of a direct link, claims of identity will be unclear and thus also at a lower level of trust.

If the web is only about information on the web, then there is a great challenge in determining the logic (existence, identity, co-reference, relation, conjunction, negation); proof and trustworthiness of items. As the web becomes increasingly about the physical world, then it becomes essential to develop unequivocal links with that physical world. This can occur thorough built in sensors and/or through various degrees and levels of remote sensing: e.g. a video camera which checks whether the logical existence a painting (Mona Lisa is in Room x in the Louvre) still holds true at a given hour of a specific day (something below the time/space horizon).

If we ignore the number of layers of the wedding cake and stand back to ask about fundamental characteristics of the World Wide Web (WWW) in its present state, three basic functions stand out. First, there is the identity and (self-) description of "objects," which can be subdivided into a) objective facts and b) subjective interpretations of those facts. Second, there are pointers to that knowledge in the form of metadata and ontologies (classification systems, thesauri). Third, there are tools for annotating (e.g. W3's *Annotea*), which are about adding comments and potentially new knowledge to the existing corpus.

Implicit in this process is a gradual evolution of these three functions. The identity and description of digital objects needs to be aligned with trends towards digital libraries and virtual memory institutions as distributed repositories to assure preservation and access to enduring knowledge. The ontology efforts of the wedding cake need to be aligned with trends towards a virtual reference room. The annotation and commentary dimensions need to be expanded into fora for collaborative research and creativity. As these three evolve they will absorb some layers of the wedding cake. Meanwhile, the essential features of the cake that remain will serve as yeast in linking the three worlds of reference, description and new description which we have identified as fundamental for a future Distributed European Electronic Resource (DEER) and a long term World Distributed Electronic Resource (WONDER, figure 26).

10. Conclusions

The quest for truth and meaning is as old as civilisation itself. In Western civilisation, this quest experienced a serious step forward through the debate that emerged between Plato's theoretical concept of universals versus Aristotle's practical particulars or individuals. The advent of writing that came into fashion at the time of Plato and Aristotle, introduced concepts of substance, accidents and causes that helped define to the contours of Western knowledge for the next millennia.

The centuries immediately after Plato and Aristotle established priorities that focussed on language and mathematics and emerged as the *trivium* (grammar, dialectic and rhetoric) and *quadrivium* (geometry, arithmetic, astronomy and music) to combine as the seven liberal arts. These eventually formed the undergraduate curriculum of the mediaeval university. The revival of Aristotle culminated with the *Summas* of Saint Thomas Aquinas in Paris. From this vision of Aristotle revived emerged theology, law and medicine as post-graduate subjects and many of the basic disciplines as we still know them today.

On the positive side this tradition of dialectic (logic), established distinctions between abstraction (*divisio*) and partition (*partitio*), which have subsequently evolved into Perreault's subsumptive relations. Other efforts in logic also increased understanding of form(al) relations, while work in grammar led to insights into material relations qua syntax or function.

On the negative side, these advances brought fundamental shifts in the kinds of questions asked. The rise of the *quadrivium*, which led to early modern science, brought a shift and narrowing of questions from Why? to How? The rise of *trivium,* with a gradual triumph of dialectic (logic) over grammar and rhetoric, led to a focus on Who? and What? Hence, advances in knowledge narrowed the scope of meaning, from the realms of cause and purpose (Why?) to the realms of existence (Who?, What?) and function (How?). To state the case dramatically and paradoxically: the limitations of today's semantic web are indirectly consequences of historical shifts in knowledge organisation, particularly those in the period 1250-1650.

These limitations do not pose a problem in the field of business where the logical categories of semantic primitives (figure 3) are very useful. As long as one deals with simple transactions, then logic is enough. So the strength of the present day semantic web is that it focuses on present day problems. The weakness of today's semantic web is that it does not offer an historical framework that would make it useful for culture. Semantics needs to be seen in the context of a series of related sciences (figure 23).

This paper claims that to make the semantic web useful for the cultural realm, five issues need to be addressed: 1) changing world views (such as the shift from substance to function); 2) inclusion of different types of definition; 3) distinctions between words and concepts (i.e. between natural language and terminology), 4) new links between classes of relations and 5) dynamic meaning. Earlier encyclopaedic efforts have focused on a history of answers. Underlying this there is a history of questions which potentially entails an expansion of the range of questions to include Who?, What?, Where?, When?, How? and Why? and their systematic combinations that can be used for new methods of access.

Plato and Aristotle's basic categories, aligned with Perreault's general, subsumptive, determinative and ordinal relations, and the space-time horizon, clarify long-standing debates with respect to universals and particulars and open new horizons for future knowledge organisation.

There is a need for networked, distributed, dynamic, multilingual, historical and cultural access to knowledge. There is a need for systems that take us through different kinds of relations; that distinguish between whole/part at both the universal and the particular levels; that allow us to see how definitions of terms change spatio-temporally (local, regional, national, international). Needed are new knowledge visualization tools to make this visible through three-dimensional and multi-dimensional knowledge spaces: to visualize clearly whether we are in the mineral, vegetable, animal, or human/societal realm. This will enable us to explore other ways of perceiving; different ways of knowing, different mindsets and world-views.

At WWW 2003 (Budapest), Jim Hendler, explained that the semantic web offers complete solutions to all the problems that we never knew we had. As we have shown, scholars have spent the past two and half millennia identifying real problems entailed with meaning and significance, distinctions between words and concepts, problems of multiple languages. It would be wise to expand our quest for a semantic web by answering such challenges. If so the semantic web will tackle central concerns of humanity rather than incidental questions of hypothetical scheduling which any good secretary solves on a daily basis.

Digital media[178] thus invite a new, cumulative access to cultural heritage with respect to dynamic knowledge, new overviews and understanding of how perceptions, theories and world-views differ, how meanings change temporally and spatially and introduce further chapters in the evolution of knowledge. A semantic web that integrates these challenges would take us towards a Distributed European Electronic Resource (DEER),[179] with three basic components: a) virtual reference rooms; b) virtual libraries in the form of distributed repositories; c) a forum for collaborative research and creativity[180] and gradually the same on a world scale (WONDER).

When computers were invented, their purpose was computing in the sense of number-crunching. This goal expanded to include texts, images, media, and multi-media, as computers became memory devices for content. As always there are dangers that the tools designed to help us, become an end in themselves: merely providing solutions for the problems, which they create. However, as we have shown there are also other possibilities for semantic computers and the semantic web: to view content through mindsets and world-views different than our own; to look at known content in unknown ways; to see synthetic patterns of meaning: not just as random memory devices, but as tools for interpretation: to expand our horizons from narrow logical categories to the entire range of meaningful human experience.

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Appendix 1. Changing World Views

Language	**Trivium**	
Words	Grammar	Structure of Language
	Dialectic (Logic)	Meaning of Language
	Rhetoric	Effects of Language
Mathematics	**Quadrivium**	
Numbers	Arithmetic	Discrete Quantity
Figures	Geometry	Continuous Quantity
	Music	Applied Discrete Quantity
	Astronomy	Applied Continuous Quantity

Figure 27. Three (Language) Arts (Trivium) and Four (Mathematical) "Sciences" (Quadrivum) comprising the Seven Liberal Arts.[181]

A 1.1 Language and Mathematics

As Havelock[182] and others have made us aware, the shift from an oral culture of the pre-Socratics[183] to a written culture at the time of Plato, changed in fundamental ways the relation of thoughts, spoken and written words; the relation of words and numbers and even definitions of knowledge itself. According to the *Bible,* the "word" (*logos*) was linked with powers of the Divine from the time of creation. Thereafter, this creative *logos* as typically linked with the spoken and later with the written word (which continued to be read out loud until at least the fourth century). The spoken word in this sense was the domain of communicators such as a shaman, high priest, prophet, bard and epic poet. As a result, the study of the structure of words in language as interpretation of words,[184] now known as grammar, was intimately connected with study of effects of the spoken word in language, now known as rhetoric. With the advent of the written word, *logos* also became the domain of the professions of philosopher and the scholar, especially with respect to Dialectic, or Logic, which focussed on analysis, dissection and specialization.

By contrast, Grammar and Rhetoric, which were concerned with interpretation, focussed on synthesis and integration. Marshall McLuhan in a wide-ranging doctoral dissertation traced the history of this tension between grammar and dialectic from Antiquity through to the seventeenth century in order to show how the *trivium* of grammar, dialectic and rhetoric changed dramatically over the centuries.[185]

Eric McLuhan[186] has argued that dialectic, as the analytical, silent word, brought a shift in the definition of formal cause to mean a blueprint: i.e. an emphasis on a static, rational, *dispositio* to the detriment and eventual exclusion of the irrational, fluid and creative aspects of *inventio, elocutio* and *decorum* traditionally entailed in epic, oral versions of words (*logos*).[187] In all this, the champions of the silent word, the philosophers and dialecticians, gradually silenced the voices of grammarians and rhetoricians. In the process the champions of the silent, non-secret and subsequently public arts, increasingly minimized the importance of magic and other secret arts. Ultimately all three subjects of the trivium were reduced in status to become merely the trivial arts in the face of mathematics and the sciences.

These simple shifts of disciplines had profound consequences on both questions and semantics (meaning). In Aristotle's time when philosophy focused on the four causes, semantics, the meaning of things entailed all six kinds of questions but emphasized Why? questions. One would have expected this to continue with the rise of the *trivium* (grammar, logic and rhetoric). In practice, as we have noted, the logicians were often pitted against the grammarians and rhetoricians and ultimately gained the upper hand. The triumph of logic meant that problems of truth became limited to Who? and What? questions (existence, identity, co-reference, relation, conjunction and negation). The gain was the emergence of a small area of reality where one could determine truth. The loss was a) that Where? When? How? and Why? questions faded into the background and b) that semantics and meaning became limited almost exclusively to Who? and What? Exceptional philosophers fought these limitations. Kant spent a lifetime trying to re-instate questions of When? And Where? (time and space). Yet in a sense Western philosophy has never recovered from the shift in disciplines that led to the triumph of logic. A fundamental challenge for the semantic web is to extend the scope of semantics (meaning) from Who? and What? to the full range of questions including: Where? When? How? and Why?

Some have argued that the origins of numbers and arithmetic were intimately connected with the advent of the alphabet in the third millennium B.C.[188] In any case, the advent of the written alphabet in the 5th Century B.C. brought new prominence to number and new emphasis on Aristotle's category of quantity. Aristotle and his successors distinguished between discrete quantity (arithmetic) and continuous quantity (geometry) as well as their applied forms, music and astronomy. These four subjects became known as the *quadrivium.* The combination of the *trivium* and *quadrivium* became known as the seven liberal arts (figure 27). Subjects such as geography (Where?) and chronology (When?) remained auxiliary sciences.

Plato's Academy in Athens remained an important source for Western learning for a millennium. The rise of Christianity from the first century onwards and especially after the conversion of Constantine (c.312 A.D.)[189] saw increasing emphasis on Plato's approach with respect to the metaphysics of universals. The neo-Platonist, Plotinus, changed the position of the Academy from scepticism to a new religious view.[190]

Aristotle had identified four kinds of being, namely, lifeless, alive, human and godly. The neo-Platonists were concerned with identifying the steps in this hierarchy between substance and via material, animate, sensitive and rational levels to the human. Here Plotinus played an important role. His student Porphyry (3rd century A.D) in his commentary on Aristotle's *Categories*, created the so-called *Tree of Porphyry*, a classification system based on the dichotomy of classes, which John Sowa called the first semantic network, in the sense of a diagrammatic set of links (figures 28a-b).[191] Porphyry's successors, Iamblichus, Proclus and Pseudo-Dionysius developed these views.

Porphyry and the neo-Platonists combined Aristotle's basic ideas of a) classification (genus, species, individuals); b) categories and c) assumptions that man was at the centre of creation. This combination lent itself admirably to the goals of the Christian Church. A constraint of this approach was that it did not immediately foster study of how genus, species and individual applied to other levels of being.

A1.2 Chain of Being to Disciplines

Lovejoy has masterfully told the story of how the neo-Platonic tradition led to the idea of a *Great Chain of Being*.[192] With the closing of the Platonic Academy (529 AD) [193] by the Emperor Justinian, the Platonic dominance slowly faded. Even so hierarchies of being continued to play a central role for at least another millennium. One of the most intriguing of these attempts was Raymond Lull (c. 1235-c.1316), a Franciscan friar, who adapted Porphyry's tree into a mechanical method for generating questions and answers in his *Great Art* (*Ars magna*, 1274).[194] We have noted elsewhere (section 7) how Lull's attempt to classify all questions pertaining to knowledge remains of interest today.

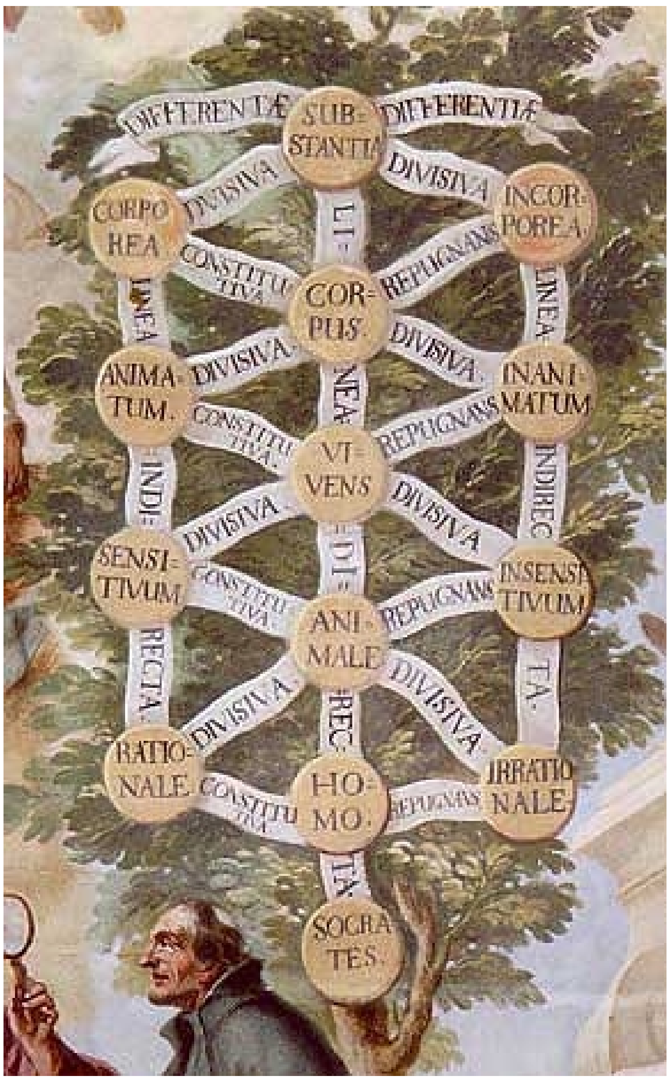
The revival of classical learning and especially Aristotle began sporadically in the Carolingian era (800+) and gained increasing momentum with the initiatives of Abbot Suger (Saint Denis, c.1142) and Abbot Peter the Venerable (Cluny), who inspired programmes of translations of the classics and major texts.[195] This introduced a new chapter in the European consciousness, whereby one studied even the ideas of those to whom one was opposed: e.g. the Koran.[196] This mindset increased the scope of learning.

The rediscovery of the Aristotelian heritage made clear that what had seemed as an either/or choice between universals and particulars was actually a challenge of how one relates the two. Thus it was that reconciling universals and particulars became a burning question of the High Middle Ages and played a major part in discussion from the time of Hugh of Saint Victor and Abelard through to Thomas Aquinas. Meanwhile, Christian thinkers such as Saint Augustine had developed parallels between the Book of God (*Bible*) and the Book of Nature:

> It is the divine page that you must listen to; it is the book of the universe that you must observe. The pages of Scripture can only be read by those who know how to read and write, while everyone, even the illiterate, can read the book of the universe.[197]

Thus nature was for the illiterate what the Bible was for the literate. In the sixth century, Pope Gregory the Great made another comparison, that pictures were for the illiterate what the Bible was for the literate.[198] In the course of the next millennium both nature and visual images, and increasingly visual images of nature, became domains of the literate and cornerstones to a new scientific literacy. Ironically, as general literacy increased and more persons had access to the Bible, it was Nature in its new scientific forms that became the new domain of the scientifically literate.

Supreme Genus		Substance				
Differentiae	Material			Immaterial		
Subordinate Genera			Body			Spirit
Differentiae	Animate				Inanimate	
Subordinate Genera			Living			Mineral
Differentiae	Sensitive				Insensitive	
Proximate genera			Animal			Plant
Differentiae	Rational				Irrational	
Species		Human			Beast	
Individuals		Socrates Plato Aristotle				



Figures 28a-28b. The tree of Porphyry in the version of Peter of Spain (1239), [199] and in a fresco of the library at Schussenried, near Ulm, Germany.[200] Sowa has called Porphyry's tree the first semantic web.

1. Nature	(*Speculum naturale*)
2. History	(*Speculum historiale*)
3. Instruction	(*Speculum doctrinale*)
4. (Moral)	(*Speculum morale*)

Figure 29. The three parts of Vincent of Beauvais' *Speculum Maius* and the apocryphal fourth part.[201]

The comparison between the Book of Scripture and the Book of Nature became much more important in the twelfth and thirteenth centuries through authors such as Hugh of St. Victor (1096-1141),[202] who distinguished between three stages: thought (with which we see God in nature), meditation (with which we see God within ourselves), and contemplation (with which we see God as if face to face),[203] and Saint Bonaventure (1221-1274),[204] ideas which were developed in the natural theology of Ramon Sibuda (fl. 1430s), which inspired Montaigne's *Apology of Raymond Sebond*, Galileo's famous metaphor that the Book of Nature was written in the language of mathematics[205] and culminated in the *Natural Theology* of Paley in the 19th century.

In the thirteenth century, these ideas were developed by both the Dominicans and the Franciscans. The Dominican, Vincent of Beauvais (c.1190-1264),[206] made a compendium of all knowledge at the time in his *Greatest Mirror* (*Speculum maius,* figure 29). Although still very much written with a religious goal, the first book contained a compendium of the natural world in "thirty-two books and 3718 chapters," and dealt with "theology, psychology, physiology, cosmography, physics, botany, zoology, mineralogy, agriculture."[207] His younger contemporaries Albert the Great (1206-1280), and Thomas Aquinas (c.1225-1274), continued this quest for a synthesis of all known knowledge.

Meanwhile, Franciscans such as Robert Grosseteste,[208] one of the founders of Oxford university, focused on the importance of experience and experiment in natural philosophy, ideas which his student, Roger Bacon took further. At the time, two major approaches to knowledge were emerging. One, championed by some Franciscans, focussed on inner spiritualism, claiming that knowledge was faith and prepared the way for an Augustinian revival after 1270 that included Plotinian and neo-Platonic strands.

A second approach, championed by the Dominican, Albert the Great and then his student, Thomas Aquinas, resulted in a summation or *Summa* of all knowledge in 100 volumes. In retrospect, the essence of these results can be reduced to the idea that the way to truth lies not only in theory or practice, but in a combination of both.[209] Even so, the thrust of Aquinas' work emphasized an Aristotelianism that relied on logic and tended to equate knowledge with reason.

Pope Clement IV (Viterbo) wanted to find a middle path between the Platonism of the Franciscans and Aristotelianism of the Dominicans.[210] In 1265,[211] he commissioned Roger Bacon to write the *Greatest Work* (*Opus Maius)*, which gave an epistemological

Lifeless (Inanimate)	Alive (Animate)	Human	Godly
Mineral	Vegetable, Animal	Human	Divine
Natural Philosophy	Medicine	Law	Theology
Mineralogy	Botany, Biology		Humanities
Earth Sciences	Life Sciences	Arts	Theology, Religion

Figure 30. Aristotle's four categories of being and basic disciplines of knowledge.

as well as a theological basis for a new emphasis on visual veracity through visual representation. Whereas Bacon's predecessors had seen the visible as merely a stepping-stone towards the invisible, Bacon claimed that the visible played a crucial role in this understanding. Indeed, he claimed, that an exact knowledge of scientific phenomena was pre-requisite for an understanding of the spiritual sense that lay buried within. This led to a new coupling between theoretical quantity and practical measurement.

In the Greek approach, geometry (continuous quantity) and arithmetic (discrete quantity) remained independent subjects. One of the consequences of the approach outlined by Bacon and his contemporaries was the rise of a practical geometry that linked geometrical forms with measured arithmetical quantities in both surveying and astronomy. In the short term these activities remained largely pragmatic. But by the sixteenth century as the metaphysical frameworks of Aristotle and Ptolemy were fully recovered, and required new orders of precise instrumentation that led to the development of universal measuring devices such as the proportional compass and the sector, this led to a new synthesis of theory and practice, a gradual shift from the Why? to the How? and the origins of early modern science.

From the eleventh through the sixteenth centuries, the focus of learning also shifted as universities in a modern sense emerged in Bologna, Paris, Padua, Oxford and spread throughout Europe. The liberal arts became the basis for undergraduate education, while law (Bologna), medicine (Padua) and theology (Paris) became the key subjects in post-graduate studies.

Increasingly, this focus on the godly and the human expanded to include the alive and the lifeless under the heading of natural philosophy, which subsequently evolved into modern scientific and other disciplines (figure 30). These disciplines are of interest for us because they were starting points for many of the early classification systems of book publishers and libraries and remain the basis for major systems such as the Library of Congress and Dewey Systems today. Samurin[212] has traced these developments in his monumental work on the history of classification systems.

A1.3 Astronomy and Physics

Of all the disciplines in the seven liberal arts, astronomy played a special role. Initially it served as the practical application of continuous quantity, i.e. geometry. Already in Babylonian times, as the chief method for determining events such as eclipses and equinoxes, it had a role as the first of the predictive sciences. Plato's *Timaeus* confirms the close links between astronomy and cosmology. It is said that Plato commissioned Euclid to write his *Elements* in order to provide these cosmological ideas with a proper mathematical basis. This helps explain why the subsequent, apocryphal books of Euclid focussed on description and construction of the five Platonic solids, which later became a major theme in Renaissance science and art through linear perspective.

Study of the heavens was seen as a key to understanding the earth. Accordingly, Ptolemy (fl. 150 AD) became author of key works on astronomy (*Almagest*) and geography, which led to a tradition of creating terrestrial and celestial orbs in tandem. While the Greek approach emphasized the importance of observation in creating models of the universe, it led to a method of saving appearances.[213] The Arabic tradition introduced new concerns for measurement, instruments and observations but it was not until the advent of the telescope and the efforts of Tycho Brahe at the turn of the 17th century that these observations reached a precision that allowed Kepler and Galileo to find confirmation for what Copernicus had proposed in 1543. [214]

The nexus of scientists surrounding Brahe, Kepler and Galileo was of crucial importance because these same persons building on Mediaeval Arabic and Latin traditions,[215] developed the new instruments for surveying the earth that led to trigonometry and logarithms; and the instruments whereby physics and mechanics became the basis for a new world view. By the eighteenth century one tended to contrast the predictive sciences (astronomy, physics) and the descriptive sciences (biology, botany etc). Physics, which in the Aristotelian tradition had been linked with organic metaphors, emerged as the basis of what became the mechanical sciences.

The contributions of Kepler and Galileo brought a shift from the Ptolemaic to the Copernican worldview. Kuhn described this as a paradigm shift as if there were a discontinuity between the two systems. This is true with respect to the systems explaining the phenomena, but not qua the phenomena themselves. A change in the framework did not destroy the continuity and cumulative gathering of reliable observations. Copernicus, Kepler and Galileo could not have achieved their insights without the knowledge that the Ptolemaic tradition had accumulated. We need new systems, which help us to trace a) the cumulative nature of a scientific corpus of facts, while at the same time identifying b) key moments when a new explanation brings a disjuncture in how these facts are seen as relating to each other.

Today's semantic web focuses on facts and assumes that the contemporary world-view of Western science is all that counts. A semantic web for culture needs to trace the evolution of different world views in order to help us understand how the questions we ask and the facts that emerge are profoundly influenced by these world views. Facts are not enough. We need to understand what Aby Warburg called Orientation in terms of world-views, *Weltanschauungen*, cosmologies and cosmogonies.

Appendix 2. From Inanimate Being to Mineralogy and Chemistry

In Antiquity, Theophrastus (372-287 B.C.) and Pliny (77 A.D.) classified minerals mainly in terms of practical uses. Geber (721 - 803) proposed a classification of minerals based on the external characters and on some physical properties such as fusibility, malleability and fracture. Physical classification was developed by Avicenna (980-1037), Agricola (1494-1555), and greatly developed in the early nineteenth century by Werner and Mohs and Huay (1801). Weiss (1780-1856) introduced the seven crystal systems (1815) and Mitscherlich discovered isomorphy (1819) and polymorphy (1824). Berzelius (1819) proposed a chemical classification, which was taken much further by Dana[216] in his classification; Rose, who produced a chemical-morphological mineral system; E.S. Dana (1892) and by von Groth.

After 1913, when the first structures of minerals were determined, the structural criterion for classification was taken into account. This chemical-plus-structural classification was applied to individual branches and eventually to the domain of minerals by H. Strunz (1941), which remains one of the basic classifications today (figure 31). J. Lima-de-Faria (1983) proposed a structural classification of minerals, which has led to structural systematics and five main categories of structures: 1) atomic; 2) group; 3) chain, 4) sheet and 5) framework according to their dimensionality (cf. Appendix 1).

The development of these breakthroughs in crystallography and chemistry through Dalton, Gay-Lussac, Avogadro and Mendeleev in the 1860s and 1870s[217] went hand in hand with the breakthroughs in physics that led to the classification of the elements and the development of the periodic table.[218] As a result, chemistry also shifted from a strictly physical subject into atomic levels whereby it became closely linked with the study of gases, and also developed its own classification systems.[219] There are now specialized classifications for organic chemistry.[220]

I Elements
II Sulfides
III Halogenides
IV Oxides and Hydroxides
V Nitrates, Carbonates and Borates
VI Sulfates, Chromates, Molybdates and Tungstates
VII Phosphates, Arsenates and Vanadates
VIII Silicates
- Tectosilicates
- Phyllosilicates
- Inosilicates
- Cyklosilicates
- Sorosilicates
- Nesosilicates
- Unclassified Silicates

IX Organic Compounds

Figure 31. Basic categories of the Strunz *Classification of Minerals*.[221]

Appendix 3. History of Mineral Classification Systems by the Commission on Classification of Minerals. See: http://www.dst.unipi.it/ima/commissi/CCM2.html

"It is well known that the classification of minerals has changed throughout the ages the criterion of classification following the development of the mineralogical science. The criterion was first based on practical purposes, then on physical properties, later on chemical properties. Mineral classification today is largely structural, when the relation and hierarchy between minerals are based on structure similarity.

The ancient classification of minerals was mainly based on their practical uses, minerals being classified as gemstones, pigments, ores, etc., according to Theophrastos (372-287 B.C.) and to Plinius (77 A.D.). In the middle ages Geber (Jabir Ibn Hayyaan, 721 - 803) proposed a classification of minerals based on the external characters and on some physical properties such as fusibility, maleability and fracture. This physical classification was developed by Avicenna (Ibn Sina, 980-1037), Agricola (1494-1555) and A.G.Werner (1749-1817), published by his student, L. A. Emmerling (1799). This system was substantially refined by F. Mohs (1773-1839) as Natural-History System of Mineralogy (Dresden, 1820), and used in the first editions of the System of Mineralogy by J.D. Dana (since 1837). With Werner the physical classification attained its maturity, and was generally adopted at the end of the XVIII century. However, it became far too complicated. For instance, Werner mentioned 54 varieties for colour. A.F.Cronstedt (1722-1765) seems to be the first to have outlined a classification whereby the chemical properties were taken first, followed by the physical properties. R. J. Hauy (1743-1822), in Traité de Minéralogie (1801), presented a mineral classification based on the nature of metals or, as he would say now, the nature of cations. With the development of chemistry the chemical properties became more and more important, and J.J.Berzelius (1779-1848) in 1819 proposed a chemical classification of minerals. He recognized that minerals with the same non-metal (anion or anionic group) had similar chemical properties and resembled one another far more than minerals with a common metal. He considered minerals as salts of anions and anionic complexes: F-, Cl-, Br-, I-, O2-, S2-, Se2-, Te2-, NO3-, CO32-, BO33-, SO42-, PO43-, SiO44-, BO43-, that is to say, as chlorides, sulphates, silicates, etc., and not as minerals of zinc, copper, etc. (1814, 1824). At this time Christian Samuel Weiss (1780-1856) introduced the seven crystal systems (1815) and Mitscherlich discovered isomorphy (1819) and polymorphy (1824). J.M.Dana, the founder of Dana System of Mineralogy, strongly contributed to the development of the chemical approach (1850, 1854, 3-rd and 4-th editions). With this knowledge, Gustav Rose (1798-1873) combined chemistry, isomorphy and morphology to produce a chemical-morphological mineral system: I - Elements, II - Sulfides, III - Halides, and IV - Oxygen compounds, divided into simple and complex oxides, as carbonates, phosphates, silicates, borates, sulfates. The highest standard of this classification was achieved in the System of Mineralogy by E. S. Dana (1892) and in five editions of Tabellarische Übersicht der Mineralien nach ihrer Kristallographisch-chemischen Beziehungen (1874, 1882, …1921) by P. v. Groth (1843-1927), that made this classification widely accepted. After 1913, when the first structures of minerals were determined the structural criterium for classification was taken into account. The first classifications of this type, which take in consideration the distribution of bonds in a structure, are that of silicates proposed by Machatschki (1928), Naray-Szabo (1930) and developed by Bragg (1930). This chemical-plus-structural classification has been applied to many other branches of mineralogy such as fluoraluminates (Pabst, 1950), aluminosilicates (Liebau, 1956), silicates and other minerals with tetrahedral complexes (Zoltai, 1960), phosphates (Liebau, 1966; Corbridge, 1971), sulfosalts (Makovicky, 1981, 1993), borates (Strunz, 1997).H. Strunz introduced a chemical-structural classification of the entire domain of minerals (Mineralogische Tabellen, 1941), followed by A.S.Povarennykh with a modified classification (1966 in Russian, 1972 in English). The chemical-structural classification of H.Strunz has gone through a number of editions, and is currently in the process of being refined in the light of recent crystal-structure determinations. In the current system, minerals are divided into 10 major compositional classes (1) elements, 2) sulfides, 3) halides, 4) oxides, 5) nitrates, carbonates, 6) borates, 7) sulfates, 8) phosphates, 9) silicates, 10) organic compounds) which are subdivided into divisions, families and groups on the basis of chemical composition and crystal structure. The paragenetic classification (Kostov, 1975) is based not only on chemical and structural pecularities of minerals, but also on the geochemical similarities of their main cations as well as on their morphology. The structural classification of minerals was first proposed by J. Lima-de-Faria in 1983. It corresponds to the application of the general structural classification of inorganic compounds (Lima-de-Faria & Figueiredo, 1976) to minerals, which are an integral part of them. The most general approach to the structural systematics is based on the analysis of the strength distribution in crystal structures and of the directional character of the bonds. There are atoms that are more tightly bounded, and these assemblages are called structural units. They are considered as the main basis for the structural classification of minerals. Thus there are five main categories of structures: atomic or close-packed, group, chain, sheet and framework according to their dimensionality. This approach to the analysis of the crystal structures was approved by IUC Commission on Crystallographic Nomenclature (Lima-de-Faria et al., 1990). Hawthorn in 1984 and 1985 also proposed a structural classification of minerals based on the polymerization of coordination polyhedra. Lima-de-Faria, in 1994, applied the structural classification to the most common minerals (about 500 minerals organized in 230 structure types). Detailed structural classification of silicates was elaborated by F.Liebau (1985).

References on the subject:

- Systematics of Crystal Structures and Crystallochemical Classification of Minerals: In: Advanced Mineralogy V.1 (Marfunin A.S., ed.), Springer Verlag, Berlin,1994.p.147-167.
- Lima-de-Faria J. Structural classification of mineral, an Introduction. Kluwer Acad., 1994, 346 p.
- Strunz H. Chemical-structural mineral classification. Principles and summary of system. Neues Jahrbuch fur Mineralogie, Monatshefte, 1996, H.10, 435-445."

Appendix 4. From Animate Being to Taxonomy

In Antiquity, after Aristotle, Theophrastus (371-286 BC) has been called the most important botanist;[222] Pliny surveyed the known world in his *Natural History*, Dioscorides (c. 40-90), provided objective descriptions of 600 plants,[223] which continued to be known in the Middle Ages, and sparked renewed studies in the Renaissance.

In the sixteenth and early seventeenth centuries there was a sharp rise in the discovery of new species (figure 32), partly because of the rise of printing, partly through the rise of botanical gardens at universities beginning with Padua in 1543. This massive rise in new species continued in the 1600s and especially in the 1700s as explorers became ever more systematic in their exploration of the earth. Linnaeus had no less than nineteen students on the voyages of Captain Cook and other explorers.[224]

Beginning with his *System of Nature* (1735), Carl Linnaeus[225] introduced a fundamental contribution to the development of modern taxonomy through a binomial naming system and by including a number of categories above the traditional genus and species as introduced by Aristotle and developed by Neo-Platonists such as Porphyry (figure 33). Linnaeus' system was initially static, but he gradually abandoned this idea that species were fixed and invariable.

The late 1700s saw the rise of more systematic collections at royal gardens in France (*Potager du Roi*),[226] and in England (Kew Gardens,[227] which now contains over seven million reference specimens.[228] Jussieu (1707-1836) established the major subdivisions of the plant kingdom, while Cuvier (1769-1832) established major embranchments, now known as phyla, for the animal kingdom.[229] The 18th century also saw the rise of natural systems of classification by Adamson, Jussieu, and in the nineteenth century by Bentham and Hooker working at Kew.[230] Linnaeus had consciously created an artificial system of classification. These advances introduced the idea that classifications of the world were classing nature and reality itself.

Year	Author	Number of Species
320-285 BC	Theophrastus	500
40-80 AD	Dioscorides	600[1]
1532	Otto Brunfels	800
1551	Adam Lonicer	879
1552	Hieronymus Bock	240
1552:	Rembertus Dodonaeus	884
1586	Jacques Dalechamp	3,000+
1623	Caspar Bauhin	6,000+
2003	Kew Gardens	13,733+[1]

Figure 32. Ancient authors and key moments in publication of new species after 1500.[231]

Kingdom: ***Animalia***
Phylum: ***Chordata***
Subphylum: ***Vertebrata***
Class: ***Mammalia***
Subclass: ***Theria***
Infraclass: ***Eutheria***
Order: ***Primates***
Suborder: ***Anthropoidea***
Superfamily: ***Hominoidea***
Family: ***Hominidae***
Genus: ***Homo sapiens***
Species:

Figure 33. Levels in Linnaeus' classification of humans[232] (Cf. Porphyry in figures 28 a-b).

The early twentieth century saw a fundamental advance in the life sciences of botany and biology through D'Arcy Wentworth Thompson's *Growth and Form* (1917) wherein he demonstrated that form and structure were intimately connected with function. For instance, since weight cubes as volume doubles, there are natural limits to the amount that a legged animal can grow and still support itself. At an anecdotal level this explained why elephants cannot jump proportionately further than grasshoppers. At a fundamental level it confirmed that scale is not arbitrary: it plays a central role in determining function. These insights created a bridge between the predictive sciences, and descriptive sciences (*beschreibende Wissenschaften*), and technical sciences.[233]

The nineteenth century, introduced the idea of evolution (cf. section 5), through the ideas a) that species have their own histories (phylogeny) and b) that species have variable populations (rather than ideal types as Aristotle claimed). The earliest systems were timeless in the sense that they assumed classification was something static. In Britain, Sir John Hunter (1728-1793) stressed the relationship between structure and function in all kinds of living creatures and fostered the study of comparative anatomy through his collection.[234] Meanwhile, on the continent, the study of fossils and embryos led via scientists such as Treviranus (1776-1837) and Tiedemann (1781-1861) to a science of ontogeny. Karl Ernst von Baer (1792-1876), after studying Comparative Anatomy and Ontogeny with Dollinger at Würzburg, directly examined the physiological and anatomical development of embryos and fetuses in many different species of mammals, birds, fishes, and invertebrates in his *History of the Evolution of Animals* (1828, 1837).[235] Through the work of von Baer, phylogeny emerged as "the genesis and evolution of the phylum or racial evolution of an animal or plant type (as distinguished from ontogenesis, the evolution of the individual)".[236] These ideas of phylogeny were further developed by Ernst Haeckel in his *General Morphology* (1866), which Darwin (1872) cited, referring to phylogeny as "the laws of descent of all organic beings."[237]

Von Baer went on to compare the development of an individual with the development of a species. These insights were remembered as von Baer's law, whereby "ontogeny is the recapitulation of phylogeny,"[238] and were restated more explicitly and forcefully by Ernst Haeckel (1866).[239] The latter 19^{th} and the early 20^{th} centuries applied these ideas naïvely to the development of cultures and civilizations and then went on to apply them mistakenly and tragically to racial questions. While the extreme comparisons of phylogeny-ontology have since been challenged they have introduced an important temporal dimension into models of development. Haeckel's ideas, for instance, served as a starting point for Piaget's developmental psychology and genetic epistemology.

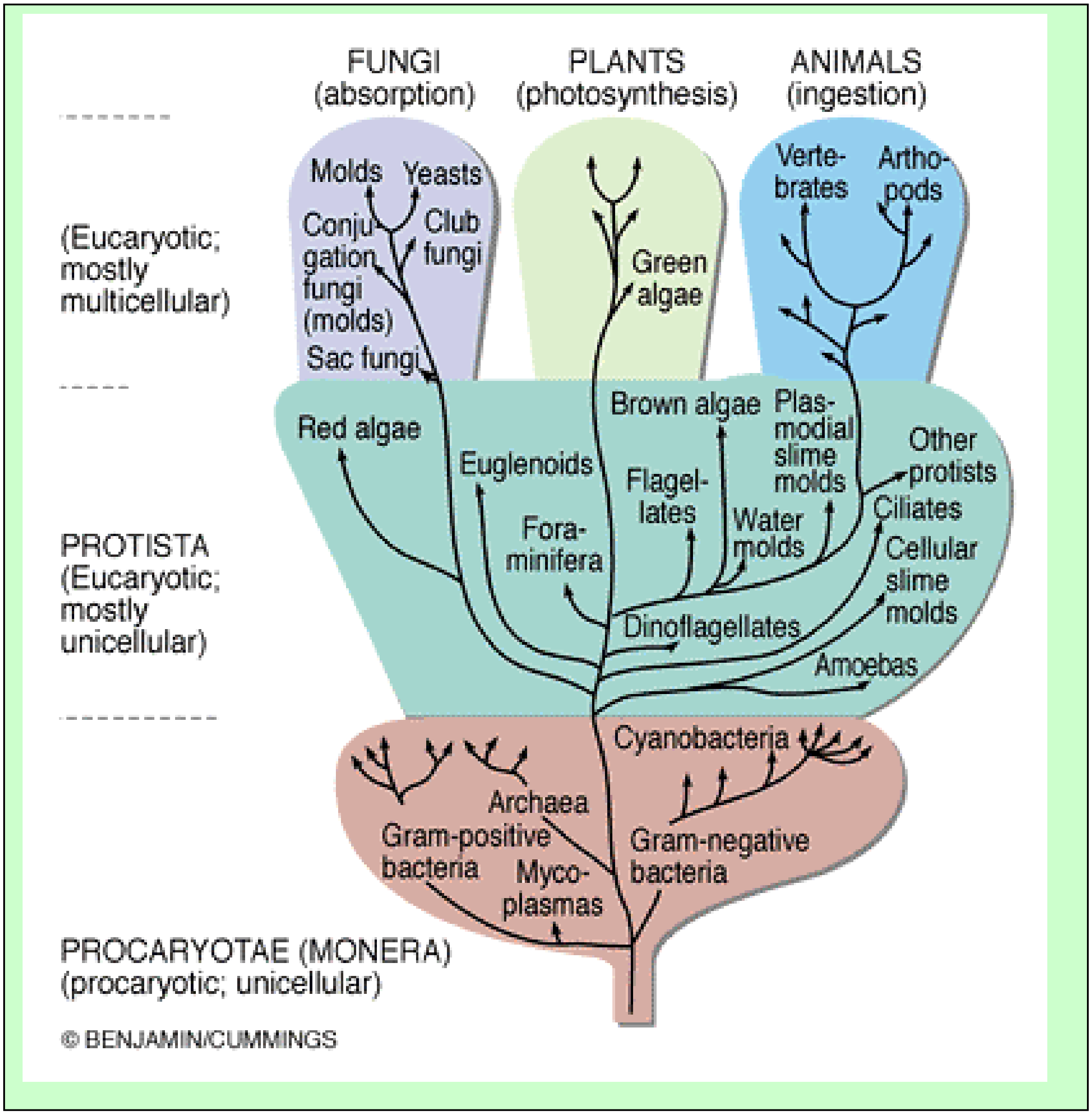
Engler and Prantl's *Natural Plant Families* (1887-1915) further developed such evolutionary ideas. Their assumption that simple equals primitive meant that one started with primitive and evolved towards the complex. This remained a standard work until about 1980.[240] Subsequent evidence from the study of fossils as well as anatomy suggested that the reverse could also be true: "that many seemingly simple structures evolved from more complex structures via reductions."[241] This led to a general reorganisation of the discipline as taxonomy and systematics emerged as independent fields.[242] There are now conferences on the history of classification,[243] databases for taxonomists;[244] there is a world taxonomist database,[245] and global taxonomy initiative.[246] At the same time, the traditional term, ontology, was introduced by computer scientists as another name for what was previously termed "classification" in the sense of "classification system." Now it became relativized to such a degree that a search for multiple ontologies in December 2003 yielded over 42,000 hits in Google.

Once one abandoned the assumption that classification was merely passive recording of an existing static order, classification emerged as a science, which had to define its own methods. Hereby, the scope of classification expanded from definition of individual classes to include relations between these classes: a study of substance *and* function.

Aristotle and Linnaeus attempted to classify living things in terms of two kingdoms, namely plants and animals. Ernst Haeckel (1834-1919) added the protist kingdom (1866) and also introduced the monera kingdom, although these were not immediately accepted by the entire community.

Herbert F. Copeland (1902-1968) championed the protist Kingdom (*protistica*) for all the nucleated microorganisms. Robert H. Whitaker (1959)[247] suggested that fungi should be raised to the level of kingdom and proposed (1969)[248] that the two kingdoms should be expanded to five, as namely: Monerans, Protists, Fungi, Plants and Animals (figure 34).[249] The development of DNA analysis in the 1980s led some to propose a six-kingdom model (figure 35). In the past generation, this had led to new systems by Cronquist[250] and Takhtajan[251]; fields such cladistics (Hennig),[252] the rise of systematics, which has been called expressing relationships,[253] molecular systematics[254] (Palmer),[255] and biosystematics.[256]

In the course of the past centuries it has become increasingly clear that there are a series of criteria for deciding these developments, including homology,[257] analogy, parallelism, and convergence.[258] Hierarchy is now a topic in itself.[259] Study of similarity now occurs on a number of different fronts including: morphological (structures using homology, analogy), cellular, biochemical, genetic, chromosomal and embryological.[260] Other problems with definition of species have also been recognized. At least 22 definitions of species have been identified,[261] which in turn has led to a taxonomy of species definitions.[262] Work in ethno-biology and the study of folk systematics has revealed that



Figures 34-35. View of the five kingdoms of life according to Benjamin Cummings and

Kingdom	**When Evolved**	**Structure**	**Photosynthesis**
Prokaryotes:-			
Bacteria	3 to 4 billion years ago	Unicellular	Sometimes
Archaea	3 to 4 billion years ago	Unicellular	No
Eukaryotes:-			
Protista	1.5 billion years ago	Unicellular	Sometimes
Fungi	1 billion years ago	Unicellular or Multicellular	No
Animalia	700 million years ago	Multicellular	No

of the six kingdoms of life according to G. Ramel.[263]

so-called primitive people develop classifications of species, which are much closer qua results to the latest scientific methods than was previously assumed. In many cases local cultures have identified complexities not recoded by standard science.

Interestingly and paradoxically, research into biodiversity has provided new rationales and incentives for cultural diversity.[264] Hence, the study of ways to classify nature is taking us back to study more closely the different cultures, which allow us to classify nature in different ways. Implicit in this realization, is that simply making computerized lists of the latest scientific versions of our classifications is not enough. We need to record alternatives in other cultures, both minor and major, if we are to develop something more than a one-eyed view of diversity. Moreover, we need to study historical changes and developments in systems of classification systems. We need etymologies not just for single words and concepts but also for the way we class ideas.

All this points to a fundamental shift in how we think about software architectures for the semantic web. In the fields of artificial intelligence, cognitive science and computer science there are many debates about the ontological robustness of a given frame of reference or world view. Some argue that it is simply a question of defining the constraints of a domain or deciding whether it is objective or subjective. Our review of historical knowledge systems confirms that there is a rather different challenge: how to create world-views that evolve and interact with one another.

If the first half of the 20th century saw the rapid development of atomic and quantum theory, the second half of the century saw the unraveling of DNA (cf. Watson and Crick, 1953)[265] and more recently the advent of nano-level studies, which continue to transform our understanding of the physical and life sciences. DNA studies are, for instance, now affecting the classification of birds.[266]

We have already noted how developments in physics and chemistry transformed them from a pre-occupation with the physical world of matter, to a study of immaterial dimensions such as gases, energy, and forces. As a result the mechanization of the world picture, which scholars of the 20th century associated with early modern science, needs revision. Atomic and sub-atomic research has removed the seeming oppositions between material and immaterial, between inanimate and animate. Indeed, where only a century ago mechanical metaphors dominated our views of science, today an incredible growth in the scope and the increasingly central importance of the life sciences means that metaphors of growth, scale, symbiosis are gradually defining our models of all reality.[267]

Natural science, which once reduced nature to a machine (cf. de la Mettrie,[268] Vaucanson[269]), is becoming alive in a new sense. In the process the need for new classification systems that reflect new insights and realities and at the same time allow us to trace the complexities of historical and cultural changes in knowledge is becoming fundamentally important. If we cannot record and conserve cumulatively even our changing views and insights on our world, if we cannot gather our own contributions, what hope is there of recording and conserving the world itself?

Appendix 5. Perreault's Classification of Relations

- Subsumptive
  - Type/Kind
    - Principle/Manifestation
    - Genus/Species
    - Species/Organisation
  - Whole/Part
    - Organism/Organ
    - Composite/Conclusions
    - Matrix/Particles
  - Subject/Property
    - Substance/Accident
    - Possessor/Possession
    - Accompanance

- Determinative
  - Active
    - Productive
    - Causing
    - Originating/Source
  - Limitative
    - Restrictive
    - Orienting, Establishing Frame of Reference, Point of View
    - Destructive
    - Injuring
    - Suppressing, Eliminating
    - Curing
  - Interactive
    - Concordant
    - Differing
    - Contrary
  - Passive
    - Produced
    - Limited
    - Destroyed
- Ordinal
  - Conditional
    - State
    - Attitude
    - Energy
  - Comparative
    - Degree
    - Size
    - Duration

Identical
Similar, Analogous
Dissimilar

Positional

Figurative
Spatial
Temporal
Toward
At
Any

Notes

Given the problem of changing addresses of web sites, the author has provided keywords for searching the site in Google in the event that the present address be changed in future.

[1] Norbert Wiener, *The Human Use of Human Beings,* [1]New York. Houghton Mifflin, 1950; Reprint, New York: Da Capo Press 1988, p. 32.

[2] At this point an interjection is necessary: In school we used to learn that acronyms were rather questionable entities only to be used sparsely and always to be explained before using in a regular text. Technologists and especially computer scientists have always had a reputation for flaunting those rules slightly. In World Wide Web circles the situation much worse: without acronyms one cannot survive. A special dose of patience is thus requested of the reader for the next three pages as we review key developments of the past six years using their terms in order to show why the present solutions leave much to be desired. Thereafter we shall proceed to the main body of this paper to show that the study of meaning, now called semantics, has a very long history, and modern developments, which the champions of the semantic web would do well to discover.

[3] SOAP under World Wide Web Consortium.
See: http://www.w3.org/TR/SOAP/

[4] UDDI.
See: http://www.uddi.org/

[5] WSDL under World Wide Web Consortium.
See: http://www.w3.org/TR/wsdl

[6] The ABC of EDI.
See: http://www.edi.wales.org/feature4.htm#ABC.Cf. http://www.edi-information.com/html/ec_edi_101.html
and the EDIFACT pages.

[7] W3 under architectural blocks.
See: http://www.w3.org/TR/Arch-blocks.gif

[8] RDF and XML Tutorial.
See: http://lsdis.cs.uga.edu/SemWebCourse/RDF.ppt

[9] URI under World Wide Web Consortium.
See: http://www.w3.org/Addressing/. Also sometimes called Universal Resource Indicators or Universal Resource Identifiers (URI).

[10] URI under Larry Masinter.

See: http://larry.masinter.net/.

[11] IETF. Uniform Resource Identifiers (URI) Working Group.
See: http://ftp.ics.uci.edu/pub/ietf/uri/

[12] On-To Knowledge.
See: http://www.ontoknowledge.org/index.shtml

[13] W3C Layer Cake.
See: http://www.w3.org/2001/09/06-ecdl/slide17-0.html.
Cf. http://www.isr.umd.edu/~selberg/Thesis/JournalPaper.pdf

[14] Owl Web Ontology Language. Reference.
See: http://www.w3.org/TR/owl-ref/

[15] In the interests of precision it is useful to quote directly:

> OWL DL (where DL stands for "Description Logic") was designed to support the existing Description Logic business segment and to provide a language subset that has desirable computational properties for reasoning systems. The complete OWL language (called OWL Full to distinguish it from the subsets) relaxes some of the constraints on OWL DL so as to make available features which may be of use to many database and knowledge representation systems, but which violate the constraints of Description Logic reasoners.
>
> NOTE: RDF documents will generally be in OWL Full, unless they are specifically constructed to be in OWL DL or Lite

Owl Web Ontology Language. Reference.
See: http://www.w3.org/TR/owl-ref/

[16] A pragmatic and more cynical reason is because the semantic web had become a buzzword and a fashionable trend whereby a small group of insiders can assure their careers.
For some there is no problem: whereas the web was mostly a web of markup, the semantic web is a web of data. This elegant answer overlooks the fact that data is transmission and not about meaning.
See: http://ilrt.org/people/cmdjb/talks/uob-cs-semweb/ .
This is based on a slide from Tim Berners Lee headed Web of Data.
See: http://www.w3.org/2003/Talks/05-gartner-tbl/slide22-0.html

[17] Sowa (2000) as in notes 27, 145 above.

[18] From discussions at the developers day at WWW 10 (Amsterdam, 2000) it became clear that a number of the developers had no clear idea of the grammatical meanings of subject and object, let alone distinctions between transitive and intransitive verbs. When questions were raised on these points, John Sowa was cited. The matter was then dismissed or rather ignored, except that subject and object have now entered into the introductory texts for the semantic web. Cf. the W3C Primer: Getting into RDF & Semantic Web using N3
See: http://www.w3.org/2000/10/swap/Primer

[19] Sowa's book is generously dedicated to five great knowledge engineers: Aristotle, Leibniz, Kant, Peirce and Whitehead as if nothing had effectively happened since 1920. Peirce and De Saussure are mentioned in passing as the fathers of semiotics with no mention how semiotics and semantics were connected with a series of other disciplines at the time (figure 33). More significantly nothing is said of Bühler's efforts to counter De Saussure through sematology, which has its roots in the eighteenth century, nor of Wüster

who established modern terminology as an independent field, and whose work via Diemer and Dahlberg led to organisations such as the German Society for Classification and the International Society for Knowledge Organization (ISKO). Similarly, contributions in linguistics, library and information science (e.g. Perreault, Bean) and database design (e.g. Mylopoulos, McGuiness) are not mentioned.

Sowa is not alone. The same problem is evident in Mark Stefik's, *Introduction to Knowledge Systems* (1995), has an opening chapter on semantics as the meaning of symbols, and distinguishes eloquently between a numbers of kinds of semantics for programming and representation languages, namely reference semantics, truth semantics, proof semantics, denotational semantics, interface semantics and reasoning control semantics. He further identifies three kind of semantics for natural languages: logical language semantics, action semantics and intensional (sic) semantics. He refers to Hayes (1974) but again makes no reference to any of the key figures in the development of semantics, semiotics, let alone lexicology, lexicography, semasiology and onomasiology (cf. figure 32).

[20] Cf. the author's "Electronic Media and Visual Knowledge," *Knowledge Organisation*, Wurzburg, Vol. 20 (1993), No. 1, pp. 47-54.

[21] Conference in Vienna May 14-16 1997.
See: http://www.univie.ac.at/cognition/conf/ntcs97/

[22] For an historical discussion see: "Visualization and Perspective. Visualizzazione e prospettiva" *Leonardo e l'eta della ragione*, eds. Enrico Bellone e Paolo Rossi, (*Scientia*, Milan, 1982), pp.185-210 (English), pp. 211-224 (Italian).

[23] Reviewer two has kindly noted some classic works in this area, namely: George Lakoff, *Women, Fire and Dangerous Things*, Chicago: University of Chicago Press, 1987; David C. Blair, *Language and Representation in Information Retrieval*, Amsterdam, New York: Elsevier Science Publishers, 1990; Susan Leigh Star, *Sorting Things Out, Classification and its Consequences*, Cambridge Mass..: MIT Press, 1999. Reviewer two also draws attention to the later work of Wittgenstein.

[24] William J. Clancey, "The frame of reference problem in cognitive modeling," In *Proceedings The Eleventh Annual Conference of the Cognitive Science Society*,1989, pp. 107-114, Ann Arbour.
See: http://cogprints.ecs.soton.ac.uk/archive/00000296/

[25] E.g. Debiprasad Chattopadhaya, *History of Science and Technology in Ancient India*, Calcutta: Firma KLM Private Ltd, 1991. Especially volume II: *Formation of the Theoretical Foundations of Natural Science.*

[26] Joseph Needham, *Science and Civilisation in Ancient China*, Cambridge: Cambridge University Press, 1953-. Cf. Science and Civilisation in China Series.
See: http://www.nri.org.uk/scc.htm

[27] Alfred North Whitehead, *Process and Reality*, New York: MacMillan Company, 1929, p. 63:

> The safest general characterization of the European philosophical tradition is that it consists of a series of footnotes to Plato. I do not mean the systematic scheme of thought which scholars have doubtfully extracted from his writings. I allude to the wealth of general ideas scattered through them.

Cited in *The Wit and Wisdom* of Alfred North Whitehead.

See: http://www.alfred.north.whitehead.com/ANW/WitWisdom/witwis2.htm

[28] Ingetraut Dahlberg developed these ideas in many of her publications of which we cite only a few here: *Grundlagen universaler Wissensordnung: Probleme und Möglichkeiten eines universalen Klassifikationssystems des Wissens,* Hrsg. von der Deutschen Gesellschaft für Dokumentation e. V. (DGD), Frankfurt/Main. Pullach bei München: Verlag Dokumentation, 1974, especially pp. 100-167. These ideas are further developed in: "Concept and Definition Theory," *Classification Theory in the Computer Age*, Albany New York, November 1988, pp. 12-24 and in "Conceptual Structures and Systematization," *International Forum on Information and Documentation,* vol. 20, no. 3, July 1995, pp. 9-24.

[29] To be sure Aristotle also asked questions concerning: What?, Who?, Where? When? and How?. But these were subordinate to his interest in Why?

[30] Aristotle, *Metaphysics*, I.3.25-30 (983a); V.2.25, 30 (1013a). From Aristotle, *The Complete Works*, ed. W. D. Ross, Oxford: Clarendon Press.

[31] Some claim that final, formal and efficient causes pertain to universals. See: Eric McLuhan, "On Formal Cause," Unpublished Manuscript, July 2003, due to be published by Fordham University. If one defines material cause in terms of what would be needed as opposed to what is used, then material cause can also be linked to universals.

It is interesting to note how these four causes can be linked to different kinds of questions outlined by Dahlberg, 1995, as in note 24, her figure 11:

Final	For what purpose?
Formal	Why?
Material	By what?
Efficient	By which means?

We shall return to this later.

[32] It is interesting to note that some of the latest work by Deborah McGuiness et al, An Environment for Merging and Testing Large Ontologies is also moving in this direction.

See: ksl.stanford.edu/people/dlm/papers/kr2000-chimaera.ppt

Dahlberg has suggested a variant version of these basic categories in "Conceptual Structures and Systematization," *International Forum on Information and Documentation*, vol. 20, no. 3, July 1995, p. 13, [her] fig. 9:

Entities	principles immaterial objects Material objects
Properties	quantities qualities relations
Activities	operations states processes
Dimensions	time positions

space

[34] These semantic primitives are taken up by Peirce in his semiotics, as noted by John Sowa in Ontology, Metadata and Semiotics.
See: http://users.bestweb.net/~sowa/peirce/ontometa.htm. Peirce claims that there are five semantic primitives: Existence, Coreference, Conjunction, Negation and Relation. As will become clear in this essay, this overlooks that the other semantic primitives are also formal relations.

[35] Aristotle, *Categories*, Translated by E. M. Edghill, Section 1, Part 4.
See: http://www.classicallibrary.org/aristotle/categories/1.htm#4

[36] In the computer world operations are typically called events.

[37] Aristotle's category of substance, which Dahlberg called entities, became linked in Perreault's model with subsumptive relations. What Dahlberg called Activities became determinative relations and her Dimensions became ordinal relations. Of the properties (figure 5, cf. figure 28), quantity shifted to dimensions, and along with quality became part of ordinal relations.
Technically speaking Aristotle had no "activities" or "dimensions." Even so his notion of the four causes (material, efficient, formal and final) were incorporated by Perreault as determinative relations. Aristotle's accident of quantity presaged the notion of dimensions.

[38] In simple terms, the retreat from final causes and quiddity effectively made qualitative properties accidental in a more trivial sense.

[39] Ernst Cassirer, *Substanzbegriff und Funktionsbegriff. Untersuchungen über die Grundlagen der Erkenntniskritik*. Darmstadt 1910.

[40] E. J. Dijksterhuis, *The Mechanization of the World Picture*, Oxford University Press (Oxford, 1961). Original: E.J. Dijksterhuis**,** *De mechanisering van het wereldbeeld*. Amsterdam, Meulenhoff, 1950.

[41] Alexander Koyré, *From the closed world to the infinite universe,* Baltimore. London: Johns Hopkins University Press, 1957.

[42] Stephen Toulmin, *The discovery of time*, Penguin Books: Harmondsworth, 1967.

[43] Through the advent of etymology (1725), time entered the study of language just decades before it entered into the study of conceptions of nature. OED cites Watts Logic (1725) which defines etymology as "tracing a word to its original. To be sure in the Middle Ages, Isidore of Seville had written the *Etymologia* but this was more a fanciful interpretation of the roots of words through association than a proper philological study. For a study of the growing awareness of time in science see Stephen Toulmin, *The Discovery of Time*, op. cit

[44] Another of Stephen Toulmin's books, *The Architecture of Matter* aptly reflects this tradition in its title.

[45] Elements and Atoms: Case Studies in the Development of Chemistry.
See: http://webserver.lemoyne.edu/faculty/giunta/EA/CONTENTS.HTML

[46] The 2003 PACS classification scheme.
See: http://publish.aps.org/eprint/gateway/pacslist

[47] Oxford English Dictionary (henceforth OED). E.g. Bailey, 1721 defined ontology as "an account of being in the abstract." In Perreault's terms this would be subsumptive relations.

[48] OED.

[49] Burke (1790) spoke of classification of citizens, Abernethy (1804) referred to a classification of tumours. OED.
[50] Ibid
[51]OED. *Nature r*eported that "Huxley's classification in 1867 marked an epoch in the systematics of birds." 20 Dec., 1888, 177/2.
[52] OED. As early as 1645 definition was defined as "that which refines the pure essence of things from the circumstance." OED.
[53] Signs and Signification
See: http://www.arts.uwa.edu.au/LingWWW/LIN102/2K3/NotesOld/signs.html.
Cf. James Bernard Murphy, Language Communication Representation in the Semiotic of John Poinsoti, Dartymouth College.
See: http://www.thomist.org/journal/1994/944aMurp.htm.
[54] According to the OED, in Logic a term was defined as:

> Each of the two things or notions which are composed or between which some relation is apprehended or stated, in an act of thought or (more commonly) each of the words or phrases relating those in a verbal statement specifically in relation to a proposition each of the two elements, viz., subject and predicate which are connected by a copula; in relation to a syllogism, the subject or predicate of any of the propositions compositing it, forming one of the three elements (Major term, Minor term, Middle term).

[55] Infoplease under Early English Dictionaries
See: http://www.infoplease.com/ce6/ent/A0857754.html
[56] Ask Yahoo under Who wrote the first dictionary.
See: http://ask.yahoo.com/ask/19990608.html
[57] As noted in note 39, the OED cites Watts Logic (1725), which defines etymology as "tracing a word to its original."
[58] In his semiotics, Peirce also had a binary version of meaning or signification as a relation between two things: a form and an object that form *stands for* or signifies. In the work of Ferdinand de Saussure this binary became a so-called Saussurian relation where a signifier (*signifiant*) stands for a signified (*signifié*). Cf. Signs ans Signification.
See: http://www.arts.uwa.edu.au/LingWWW/LIN102/2K3/NotesOld/signs.html
[59] In this context it was frequently called a semiotic triangle. Cf. David Chandler, Semiotics for Beginners.
See: http://www.aber.ac.uk/media/Documents/S4B/sem02.html#semiotic_triangle
[60]

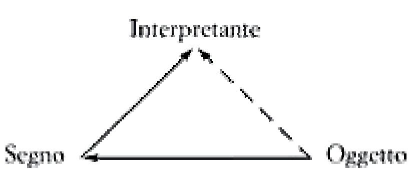


Figure 36. Italian semiotics triangle based on Peirce.
Il triangolo semiotico di Peirce. La Semiosi
See: http://www.gramma.it/semiotica/lezioni/lezione02.html
[61] Course in General Linguistics.
Cf. http://courses.nus.edu.sg/course/elljwp/CIGL.htm

[62] C. K. Ogden and I.A. Richards, *The Meaning of Meaning*, 1923, 8th Ed. New York: Harcourt, Brace & World. Cf. San Diego: Harvest/HBJ Book, 1989, p.11.

Cf. Ogden & Richards's *The Meaning of Meaning* and Its Influence on Burke's Early Thought - A Sketch. See: http://www.missouri.edu/~engjnc/burke/ogden.html

[63] Fred Riggs, *Onomatics and Terminology II. Notes and Bibliography*

See: http://webdata.soc.hawaii.edu/fredr/6-oat7c.htm

[64] As in note 70.

See: http://www.termisti.refer.org/theoweb2.htm

> Aujourd'hui, le champ de la terminologie est nettement investi par des linguistes formés à la démarche saussurienne, laquelle a censément mis fin à la vision de la langue comme une "nomenclature". On pense aujourd'hui que la langue donne une forme à la substance du sens et l'on adhère généralement à l'hypothèse de Sapir-Whorf selon laquelle les locuteurs de chaque langue découpent, organisent la réalité de manière différente. En ce sens, il peut paraître désuet de donner une si grande place au concept (ou notion), sorte d'idée néo-platonicienne érigée au rang de bienfait technique sur lequel fonder la communication interlinguistique.... S'il nous a semblé bon de conserver cette référence, c'est parce que l'approche conceptuelle, quoique criticable, demeure une bonne manière d'introduire la problématique de l'équivalence et des réseaux notionnels, sans pour autant renoncer à une approche descriptive des différences entre les langues.

[65] Cf. Systèmes de notions. L'approache Viennoise.

See: http://www.termisti.refer.org/theoweb2.htm

[66] Organon Modell von Karl Bühler.

See:
http://culturitalia.uibk.ac.at/hispanoteca/Lexikon%20der%20Linguistik/o/organon.htm

[67] Karl. Bühler, *Die Sprachtheorie. Die Darstellungsfunktion der Sprache*, Jena, 1934. For links with *G.W.F. Hegel, Phänomenologie des Geistes*, 1807, Frankfurt, 20 Bde, 1970. p. 84ff.

Cf. Stefan Rabanus (Marburg)

See: http://www.stefan.rabanus.com/seminare/Einf_II/folien/Deixis.pdf

Markus Hundt, Vorlesung: Grammatik und Pragmatik. Deixis bei Karl Bühler.

See: http://rcswww.urz.tu-dresden.de/~kjakob/inhalt/folien_grammatik/material/Folien_ZVII/Deixis_ZVII.doc

Cf. Character II in Nottingham Course:

See: http://www.nottingham.ac.uk/english/teaching/dramdisc/CharacterII.doc

Cf. Gillian Brown," A note on deixis, point of view and the English verbs: depart and leave," Cambridge. See: http://www.rceal.cam.ac.uk/Working%20Papers/brown.pdf.

[68] Organon Modell as in note 66.

See:
http://culturitalia.uibk.ac.at/hispanoteca/Lexikon%20der%20Linguistik/o/organon.htm:

> „Organonmodell der Sprache [griech. *órganon* 'Werkzeug'. - Auch: Dreifundamentenschema, Funktionsschema]. Von K. Bühler (1934) im Rahmen seiner Sprachtheorie entworfenes allgemeines Sprach- bzw. Zeichenmodell, das sich auf Platons Metapher der Sprache als Organon, d. h. als 'Werkzeug', stützt, mittels dessen „einer - dem andern - über die Dinge" etwas mitteilt. Entsprechend diesen

drei Funktionen des sprachlichen Zeichens unterscheidet Bühler drei zeichenkonstituierende Faktoren:

(a) Das sprachliche Zeichen ist „Symptom“, insofern es die „Innerlichkeit des Senders ausdrückt“ (= Ausdrucksfunktion der Sprache

(b) es ist „Signal“, insofern es an den Empfänger appelliert (Appellfunktion der Sprache),

(c) es ist „Symbol“, insofern es sich auf Gegenstände und Sachverhalte der Wirklichkeit bezieht (=Darstellungsfunktion der Sprache).“ [Bußmann, S. 549]

[69] Ibid:

> Bühler spricht von den folgenden drei »semantischen Funktionen des (komplexen) Sprachzeichens. Es ist *Symbol* kraft seiner Zuordnung zu Gegenständen und Sachverhalten, *Symptom* (Anzeichen, Indicium) kraft seiner Abhängigkeit vom Sender, dessen Innerlichkeit es ausdrückt, und *Signal* kraft seines Appels an den Hörer, dessen äußeres oder inneres Verhalten es steuert wie andere Verkehrszeichen.« (Bühler 1934/1978, 28) Bühler fügt unter Bezugnahme auf eine seiner früheren Arbeiten hinzu: »Dreifach ist die Leistung der menschlichen Sprache, Kundgage, Auslösung und Darstellung. Heute bevorzuge ich die Termini: *Ausdruck, Appell* und *Darstellung*« (ebd.).“

[Rolf, Eckard (Hrsg.): *Illokutionäre Kräfte. Grundbegriffe der Illokutionslogik*. Opladen: Westdeutscher Verlag, 1997, S. 124 Anm. 12].

[70] Eugen Wüster, *Einführung in die allgemeine Terminologielehre und terminologische Lexikographie*, New York, Springer, 1979, 2 vol.

Cf. Abrégé de terminologie multilingue. Bibliographie.

See: http://www.termisti.refer.org/theoweb9.htm#W.

Cf. ProCom '98. PROFESSIONAL COMMUNICATION AND KNOWLEDGE TRANSFER. Marking the Centenary of Eugen Wüster's Birth

Vienna, 24-26 August 1998

See: http://linux.infoterm.org/termnet-e/proceedings/procom98.htm.

[71] Cf. *Alvin Diemer and I. Frenzel (eds.),* Philosophie, Frankfurt: Fischer, 1980.

[72] For background on the evolution of thesaurus development in Germany, cf. Ingetraut Dahlberg, “Thesaurusforschung in der Bundesrepublik Deutschland. Die Anfänge des DGD-Komitees für Klassifikations- und Thesaurusforschung.

See: http://www.phil-fak.uni-duesseldorf.de/infowiss/frames/baust/Mandahlb.html

[73] According to the *Encyclopaedia Britannica*, 1978. Another example would be a caryatid defined as “a draped female figure used instead of a column as an architectural support.

[74] Implicitly this means that dictionaries of the future will need to distinguish between the kinds of definitions they contain. If this were done then many of the debates about What? in the Aristotelian sense of “what is” would quickly be diminished. Ideally they would also be able to reflect how different cultures may treat these relations differently.

[75]

Steps in differentiation Steps in construction	All Referents of a given kind	Some Referents of a given kind	Single Referent
A Referential	Genus General Referent	Species Special Referent of a General One	Individual (Individuum) Individual referent of a special one
B Predicational	Essential Characteristics	Essential + Accidental Characteristics	Essential + Accidental" Individualising Characteristics
C Representational	General Terms (Ordinary language)	Special Terms Technical Language	Names/Proper Names
A+B+C	General concepts	Special concepts	Individual Concepts

Figure 37. Dahlberg's (1995, figure 11) generic diagram (generic characteristics and their concepts).

[76] Dahlberg, as in note 24, 1995, pp. 17-18

[77] John F. Sowa, Ontology article, op.cit.
See: http://users.bestweb.net/~sowa/peirce/ontometa.htm

[78] Dahlberg, as in note 24 above.

[79] The above list covers only the most common variants. For instance, Felbaum (in Green, bean, Myaeng, *Semantics of Relationships*, 2002, op. cit.) introduces a specific term troponymy to deal with manner relations in verbs.

[80] Eugen Wüster, *Einführung in die Allgemeine Terminologielehre und Terminologische Lexikographie*, Wien: Springer, 3rd ed. 1991. This results from Wüsters lectures at the *Institut für Sprachwissenschaft der Universität Wien* in 1972 – 74.
See: http://coral.lili.uni-bielefeld.de/EAGLES/WP5/termdeliv97/node65.html
For further references to the work of Wüster see Terminology Forum: Bibliography and Library of the Theory and Practice of Terminology Science.
See: http://www.uwasa.fi/comm/termino/bibtheo.html; cf. http://www.iim.fh-koeln.de/dtp/literatur.html

[81] Dahlberg, as in note 24 above.

[82] The term meronomy is said to have been introduced by the Russian paleobotanist, Sergei Meyen (cf. Alexei A. Sharov, "Analysis of Meyen's Typological Concept of Time." See: http://www.gypsymoth.ento.vt.edu/~sharov/biosem/time/time.html) and developed with his friend, the mathematician, Julius Shreider. Cf. Yuli (Julius) Schreider, On Systems and Models.
See: http://www.gypsymoth.ento.vt.edu/~sharov/biosem/schreidr/schreidr.html).
S.V. Meyen, "Taxonomy and Meronomy," *Methodological Problems in Geological Sciences*, Kiev: Naukova Dumka, 1877 (Orig. in Russian).

[83] Olivier Bodenreider, Carol Bean, “Relationships Among Knowledge Structures: Vocabulary Integration within a subject domain.” In: *Relationships in the Organisation of Knowledge*, Dordrecht: Kluwer, 2001, pp. 81-98.

See: http://etbsun2.nlm.nih.gov:8000/publis-ob-offi/pdf/2001-kluwer-rels-ob-Ft.pdf

Cf.: http://enya.chungnam.ac.kr/board/work/all_abstract.htm

[84] B. Tversky, “Objects, Parts and Categories,” J*ournal of Experimental Psychology: General*, 113, 1984, pp. 169-193. Cf. B. Tversky “Where partonomies and taxonomies meet,” In: S.I. Tsolhatzidis, (ed.), *Meanings and Prototypes: Studies in Linguistic Categorization*, New York: Routledge, 1990. pp. 334-344.

[85] Simone Pribbenow, “Meronymic relationships: From Classical Mereology to Complex Part-Whole Relationships”, *The Semantics of Relationships*, ed. Rebecca Green, Carol A. Bean, Sung Hyon Myaeng, Dordrecht: Kluwer Academic Publishers, 2002, p. 36. She further distinguishes between basic mereology, extensional mereology and classical (extensional) mereology, (pp. 40-43).

[86] John Miles Smith, Diane C. P. Smith, “Database abstractions: aggregation and generalization,” *ACM Transactions on Database Systems (TODS),* Volume 2, Issue 2 (June 1977), pp.105 – 133. See: http://portal.acm.org/citation.cfm?id=320544.320546&dl=GUIDE&dl=ACM&idx=J777&part=periodical&WantType=periodical&title=ACM%20Transactions%20on%20Database%20Systems%20(TODS).

[87] J. Mylopoulos, A. Borgida, M. Jarke, M. Koubarakis, “Telos: Representing Knowledge about Information Systems,” *ACM Transactions on Information Systems*, 8(4), October 1990, pp. 325-362.

[88] Although Linnaeus used anatomical characteristics he relied also on cultural characteristics. His student Blumenbach emphasized the role of anatomic characteristics in classification. Cf. Contexts -- Science -- Physical Anthropology.

See: http://www.english.upenn.edu/~jlynch/Frank/Contexts/physanth.html

[89] Anita Burgun, Olivier Bodenreider, *Methods for exploring the Semantics of the relationships Between Co-Occuring UMLS Concepts*, *Medinfo*, Amsterdam:IOS Press, 2001, pp. 171-175.

See: http://etbsun2.nlm.nih.gov:8000/publis-ob-offi/pdf/2001-medinfo-ab.pdf

[90] Dahlberg, Conceptual Structures, as in note 24 above, p. 12.

[91]

Substance	Accidents = PROPERTIES	Intransitive/Transitive		
Entities	Properties	Activities	Dimensions	Predicate/Object
Material Quantity	Action, Operations		Space	
	Quality	Suffering, Processes	Time	
Relation State	(Presence, Having)		Lage (Position in Dimension)	
a) Entity		+ Activity		
b) Subject		+ Intransitive Verb		+ Predicate
c) Noun		+ TransitiveVerb		+ Object
d) Noun		+Adjective	+ TransitiveVerb	+Adverb+ Object
e)		+ Subordinate Clause	+ Subordinate Clause	
f)		+ Conditional Clause	+ Conditional Clause	

Figure 38. Another view of Aristotle’s categories as the basis for material relations of function or syntax.

[92]

Questions	Categories	Latin Questions
1. What if?	Possibility	utrum?
2. What?	Nature, essence	Quid?
3. From what?	Material stuff, essence	de quo?
4. Why?	Causality, reason	quare?
5. How big?	Quantity, size?	quantum?
6. How good?	Quality	quale?
7. When? Since when?	Time	quando?
8. Where? From where?	Place	ubi?
9. How? In which way?	Modality	
10. By which Means	Instrumentality	
11. By What?	Potentiality, capacity	
12. How generated?	Genesis	
13. By whom?	Originator, producer	
14. With whom?	Accompanied by, together with	
15. For what purpose?	Finality	
16. How occuring	Occurrence, in parallel, in connection	
17. Under which conditions?	Condition	

Figure 39. Dahlberg's list of seventeen questions related to categories and Latin questions found in Raymond Lull's *Ars Magna* (1274).

[93] Perreault, op.cit.

[94] Artefacts Canada uses What?, Where?, Who?, When? and How?.
See: http://daryl.chin.gc.ca/Artefacts/e_MasterLayout.cgi
The Lucent database includes Who? What? Why? and Where?.
See: http://www.lucent.com/minds/infotheory/who.html

[95] See: mmilinux.unimaas.nl under username sums and password summa. One of the fundamental ideas underlying SUMS is that novice users should be guided through these questions starting with Why? and How? to focus the search, then Where? and When? to further define the search? and then proceeding to What? and Who?

[96]As Ingetraut Dahlberg (personal communication) notes:

> The analytical tables of facts (e.g. concepts and classes of concepts) must also contain all the possible concepts (in the form of facets, just as Ranganathan had built his faceted Colon Classification system) by which synthetic patterns of true statements on referents can be constructed. Somewhere in your paper this ought to be said. And here our good Kant with his analytical and synthetic judgments could also be brought into the picture!

[97] I-MASS.
See: www.i-massweb.org/public/workpackages/ project%20presentationvs1.doc
Cf. also MOSES (*MOdular and Scalable Environment for the Semantic web*)
See: http://www.hum.ku.dk/moses/index2.htm.
Then there are the EU Grid projects under Gridstart. Cf. Mark Parsons, IST Grid Research - Inventory, Roadmap and Market Analysis
See: www.gridstart.org/CM_documents/cm_one/plenary/ GRIDSTART%20Roadmap%20&%20Inventory%20-%20M%20Parsons.ppt)
(MOSES) Modular scaleable Management tools for the Knowledge Grid
(GRACE) Distributed Search and Categorization Engine for Grid

(COG) Grid Ontologies of modeling of Data in dispersed locations.
(SELENE) Bridge Between Semantic Web and P2P in E-Learning
(GRASP) Advanced Infrastructure for ASP based on Grid technologies

[98] AMP newsletter under Ministère de la Culture, France.
See: http://www.culture.gouv.fr/culture/mrt/numerisation/fr/f_01.htm.
On this subject see also: Marc van Campenhoudt, *Abrégé de terminologie Multilingue*,
See: http://www.termisti.refer.org/theoweb1.htm#intro
which contains: Marc Van Campenhoudt, *Le Réseau Notionnel Interlinguistique. Réseau notionnel, intelligence artificielle et equivalence en terminologie multilingue: essai de modélisation.* Centre de recherche TERMISTI. Institut supérieur de traducteurs et interprètes, Bruxelles. Communication aux IVes journées scientifiques du réseau L.T.T. Lyon, 25-30 septembre 1995. d'après Van Campenhoudt (1994)
See: http://www.termisti.refer.org/rni.htm.

[99] Others have identified further kinds of definitions. For instance, Reviewer one has kindly drawn attention to Robert Audi, ed., *The Cambridge Dictionary of Philosophy*, New York: Cambridge University Press, 1995. Reviewer one also recommends B. Karpatschof, *Human Activity. Contributions to the Anthroplogical Sicences from a Perspective of Activity Theory*, Copenhagen: Dansk Psychologisk Forlag, 2000. As the reviewer also rightly notes a fuller treatment of this subject would need to discuss the history of concepts (*Begriffsgeschichte*). In this context the reader is advised to consult the *Archiv für Begriffsgeschichte* Founded by Erich Rothacker (now in its 45th volume) and the *Historische Wörterbuch der Philosophie.*
Cf. http://www.ruhr-uni-bochum.de/philosophy/series/archiv.htm.
A more comprehensive study would also need to follow the Lessico Intellettuale Europeo e storia delle Idee an Istituto del Consiglio Nazionale delle Ricerche led by Professor Tullio Gregory (Sapienza, Rome).
Cf. http://www.iliesi.cnr.it/index.htm.
While extremely important the details of these undertakings would take us far beyond the scope of this paper.

[100] Perrault's relators were purely syntactically meant. In the Mediaeval period these would have been called synkategoremata.

[101] J. Perreault, "Categories and Relators", *International Classification*, Frankfurt, vol. 21, no. 4, 1994, pp. 189-198, especially p. 195. Cf. Professor Nancy Williamson (Faculty of Information Studies, University of Toronto) who lists these in a different order under the heading Types of Associative Relationships:

1. Whole-part
2. Field of study and object(s) studied
3. Process and agent or instrument of the process
4. Occupation and person in that occupation
5. Action and product of action
6. Action and its patient
7. Concepts and their properties
8. Concepts related to their origins
9. Concepts linked by causal dependence
10. A thing or action and its counter-agent
11. An action and a property associated with it

12. A concept and its opposite.

102 Ernst Cassirer, *Individuum und Kosmos in der Philosophie der Reinassance;* Leipzig und Berlin, 1927; Reprint: *Individual and the Cosmos in Renaissance Philosophy*, New York; Dover, 2000

103 Saint Thomas Aquinas effectively had this insight in his *Commentary on the Metaphysics of Aristotle*, trans. J. P. Rowan, Chicago: Henry Regnery Company, 1961, Book V, Lesson 2, Paragraph 764.

104 Some would insist that even this is far too optimistic and represents a positivistic view of the 18th or a neo-positivist view of the 19th and early 20th centuries. They would argue that almost everything is so troubled by interpretation and bias, which can only be partly overcome by constructivism, constructionism, and/or deconstructionism, that clarity and knowledge are things of the past. This view has the enormous advantage that one is then free to judge on matters where one is not an expert, indeed even in areas where one effectively knows nothing.

105 Thomas Kuhn, *The Structure of Scientific Revolutions,* Chicago: University of Chicago Press, 1962.

106 Cf. Gerald Holton, *Thematic Origins of Scientific Thought*, Harvard: Harvard University Press, 2nd ed., 1988.

107 Cf. those in the third culture and the edge, e.g. Professors Minsky, Dennett, and Blackmore under Edge.

See: http://www.edge.org/

108 As Dahlberg, 1974, as in note 24, pp. 101-104, has also shown, being characteristics lead on the one hand to material content characteristics and on the other hand to formal being characteristics. The formal determinations of being can be categorized (according to Aristotle's accidents and a proposal by Professor Diemer) as follows (Figure 40):

Being an object

Being a type, a part, a system

Being a carrier

Having properties, having a disposition, a mode, aspects, values, being equipped, having needs

Being a process

Being worked on, having process-moments, having a beginning and an end, Having a

course, having a duration, being in a change

Having a relationship

Having an order, an orientation (spacial, timely), having a determination

(active, passive, dependent, final, interactive) etc.

Such characteristics have been termed by Dahlberg ‚characteristics of form'. They can also constitute Form Concepts."

Figure 40. Being characteristics and their components according to Dahlberg.

Much work has been done on each of these but there are few systems, which allow us to visualize how we go systematically from one to the other. One important example is the Information Coding Classification (ICC) in which the parts of a knowledge field are its subdivisions

Cf. ICC - Information Coding Classification.
See: http://index.bonn.iz-soz.de/~sigel/ISKO/ICC/ICC.html.

[109] See the doctoral thesis of my student, Nik Baerten, *From the Mechanistic to the Organic World-Picture. New Interactions and user Interfaces,* Maastricht, 2004. Baerten associates the organic with forms that are fluid, dynamic, and not bound by the subject-object distinction.

[110] Michael Giesecke, *Der Buchdruck in der frühen Neuzeit. Eine historische Fallstudie über die Durchsetzung neuer Informations- und Kommunikationstechnologien.* Frankfurt/M.: Suhrkamp, 1998.

[111] Walter Ong, *Ramus, Method and the Decay of Dialogue,* Cambridge, MA: Harvard University Press, 1958.

[112] Marshall McLuhan. *The Gutenberg Galaxy: the Making of Typographic Man*, Toronto: University of Toronto Press, 1962.

[113] Using television as an example, McLuhan also made some inspired guesses where the new electronic media were heading. What he could not foresee as someone still living in an analog world, that the implications of digital were far more fundamental.

[114] John S. Traill under U of Toronto Faculty Biographies.
See: http://www.chass.utoronto.ca/classics/bios/jtra.html

[115] Perseus Digital Library
See: http://www.perseus.tufts.edu/

[116] Only a decade ago Harvard University refused to count Professor Crane's electronic work in considering him for tenure. Even today, digital contributions have not yet attained the stature of analog publications.

[117] For a science-fiction view cf. Michael Crichton, *Timeline,* New York: Ballantine books, 1999, pp. 141-142.

[118]Etymology, in its original sense in English (Fraunce, 1588) was linked with the "interpretation of a word." OED.

[119] Namely in the semiotic of John Poinsot 1632.
See: http://www.thomist.org/journal/1994/944aMurp.htm

[120] Jürgen Trabant, *Neuer Wissenschaft von alter Zeichen: Vicos Sematologie*, Frankfurt: Suhrkamp, 1995.

[121] Thomas A Sebeok, "From Vico to Casirer to Langer", *in Giambattista Vico and Anglo-American Science*, ed. Marcel Danesi, Berlin: Mouton de De Gruyter, 1995, pp. 159-170.
Cited in Thomas A Sebeok, "Semiotics and Biological Science, Initial Conditions, Signs Bridges Origins," *Global Semiotics*, Bloomington: Indiana Univeristy Press, 2001, pp. 59-73. Cf. http://www.colbud.hu/main/PubArchive/DP/DP17-Sebeok.pdf.

[122] OED.

[123] Cited in OED. Cf. B. H. Smart**,** *Beginnings of a New School of Metaphysics: Three Essays in One Volume: Outline of Sematology*.---MDCCCXXXI. *Sequel to Sematology*.--MDCCCXXXVII. *An Appendix,* Now First Published. London: John Richardson, 1839. 1st ed. 8vo.

[124] Karl Bühler, *Sprachtheorie*, Jena: Fischer, 1934 p. 34.

[125] For a discussion of this in relation to Gombrich who does not mention Bühler see: Klaus Lepsky, "Art and Language: Ernst H. Gombrich and Karl Bühler's theory of

language' in: Richard Woodfield (ed.), *Gombrich on Art and Psychology,* Manchester: Manchester Univeristy Press, 1996.

See: http://davinci.ntu.ac.uk/gombrich/leonardo/intro.htm

[126] Carl S. L. Collin, A Bibliographical Guide to Sematology, Lund, 1914.

Cf. Herbert Ernst Wiegand, Lieratur zur Lexikologie.

See: http://www.uni-heidelberg.de/institute/fak9/gs/sprache2/hew_lex.htm.

Cf. CR BSL 21, 1918-1919

See: http://perso.club-internet.fr/flo.blanc/SLP/21.html

Josef Reinius, *On Transferred Appelations of Human Beings***, C**hiefly in English and German. Studies in Historical Sematology. I. (all published) Diss. Gbg (Uppsala) 1903.

Jan Wolenski, "From intentionality to formal semantics (From Twardowski to Tarski),"

See: http://www.masda.vxu.se/~per/IVC743/intentionaltarski.pdf

1993b John James Van Nostrand and Sematology: Another neglected figure in American semiotics. In Karen Haworth, John Deely, and Terry Prewitt (editors), *Semiotics 1990*, 224-240. New York: Lanham

[127] For a more recent treatment cf. Section 6.6 Relating syntax and semasiology.

See: http://www.burgoyne.com/pages/bdespain/grammar/gram066.htm#P1

which forms part of: Bruce D. Despain, *A Paraphrastic Grammar of English*, *A Scientific and Logical Approach to the Science of Syntax,* Salt Lake City, 2002.

See: http://www.burgoyne.com/pages/bdespain/grammar/gramtoc.htm

[128] OED cites *American Journal of Philology*, XVI, 1895, p. 412.

[129] Michel Bréal, *Essai de Sémantique. (Science des significations),* Paris
: Hachette,1897.

See: http://www.chass.utoronto.ca/epc/langueXIX/breal/breal_sem.htm

[130] See: http://www.uni-bonn.de/~dbuncic/14ung/semantik.pdf

[131] OED.

[132] OED reminds us that an onomasticon as a "vocabulary or alphabetical list of proper names especially of persons" goes back to the 15th century and that in 1730 Hume referred to: "Thesaurus's, Lexicons, Glossaries, Onomasticons" as if they effectively were synonyms.

[133] OED defines it as "relating to or connected with a name or names so with the naming of something." In 1609 it was used as a synonym for Nomenclators. A comment in the Contemporary review of 1880 suggests that as a science onomastics was not always perceived as having a strong foorting: "the system which rests on onomastic vocabularies of a highly imaginative philosophy."

[134] Andreas Blank, "Words and Concepts in Time: towards Diachronic Cognitive Onomasiology,"Metaphorik:de. Under Metaphorik.de 01/2001 under Research Center for Semiotics RCS under The "Zeitschrift für Semiotik Abstracts".

See: http://www.metaphorik.de/01/blank.htm

[135] Roland Posner, "From Russian formalism to glossematics:European Semioticians between World Wars I and II", *Zeitschrift für Semiotik*, Berlin, vol. 6. no. 4, 1984.

See: http://angli02.kgw.tu-berlin.de/semiotik/english/ZFS/Zfs84_4_e.htm

Professor Tito Orlandi has extremely interesting sites on:

Semantics Semiotics

See: http://rmcisadu.let.uniroma1.it/~orlandi/iasulez/biblio/noth03.html#linsem

Meaning

See: http://rmcisadu.let.uniroma1.it/~orlandi/iasulez/biblio/noth02.html#typsem
Sign
See: http://rmcisadu.let.uniroma1.it/~orlandi/iasulez/biblio/noth01.html#typsem
Symbol
See: http://rmcisadu.let.uniroma1.it/~orlandi/iasulez/biblio/noth05.html#typsem
Cf. Professor Tito Orlandi
See: http://rmcisadu.let.uniroma1.it/~orlandi/

136 Cf. Eine Rezension von Eberhard Fromm. „Prolegomena zu einer künftigen Kulturphilosophie"
See: http://www.berliner-lesezeichen.de/lesezei/blz99_10/text19.htm

137 For context re: Claude Shannon under Lucent Technologies:
See: http://www.lucent.com/minds/infotheory/who.html.
C. E. Shannon, ``A mathematical theory of communication," *Bell System Technical Journal,* vol. 27, pp. 379-423 and 623-656, July and October, 1948.
See: http://cm.bell-labs.com/cm/ms/what/shannonday/paper.html

138 Norbert Wiener, *Cybernetics. Control and Communication in the Animal and the Machine,* New York: John Wiley & Sons, Inc., 1948.

139 One of the essential problems with semantics is that it is a linguistic term and misued in our context. However, since most people do not know anything about the theory of concepts, i.e. knowledge units, they remain with the linguistic understanding. This is excusable and we will not be able to do away with the term „Semantic Web" but we should make it clear that in order to work in the field of knowledge organization we are dealing with concepts, conceptual relationships, concept systems, etc.

140 In Tito Orlandi website:
See: http://rmcisadu.let.uniroma1.it/~orlandi/iasulez/biblio/noth03.html#linsem

1. Linguistic	
2. Logical	
3. General	
4. Philosophical	Semiotics, Language theory
5. Anthropological	Malinowski (1925), Firth Contextualism
	Semiotic anthropology (Ardener, ed. l971, Singer l984).
6. Psychological	Osgood et al. (l957; Osgood l 976)
	Psychosemiology (Krampen l979b)
7. Information Theory MacKay (l 969)	

Figure 41. Categories of Semantics and Related Fields according to Tito Orlandi.

141 Boolean logic diagrams are themselves a simplification of Euler's diagrams. For Euler and Quantified Expressions
See: www.rci.rutgers.edu/.../Deduction/ EulerDiags.html
Cf. Venn Diagram Survey for their relation to Euler Diagrams.
See: http://www.theory.csc.uvic.ca/~cos/venn/VennEulerEJC.html
For relations to set theory,
See: noppa5.pc.helsinki.fi/ koe/boole/boolea.html
For a further discussion cf. the section on diagrams in the *Stanford Encylopaedia of Philosophy*.
See: plato.stanford.edu/ entries/diagrams/

142 H. Curry and R. Feys, Combinatory Logic, Amsterdam: North Holland, 1958.

[143] For a thoughtful essay on this subject cf. Mihailo Antović, "The Position of Semantics within Contemporary Cognitive Science," UDC 81'37:165.19: in: *Facta Universitatis, Series Linguistics and Literature*, vol. 2, no. 10, pp. 415-424.
See: http://facta.junis.ni.ac.yu/facta/lal/lal2003/lal2003-06.pdf
For linguistics and cognitive science
See: http://www.press.uchicago.edu/Subjects/virtual_linguistics.html
[144] S. Pribbenow, "Meronymic relationships", in *Semantics* as in note 8, p. 39.
[145] Conference in Vienna May 14-16 1997.
See: http://www.univie.ac.at/cognition/conf/ntcs97/
[146] For an historical discussion see: "Visualization and Perspective. Visualizzazione e prospettiva" *Leonardo e l'eta della ragione*, eds. Enrico Bellone e Paolo Rossi, (*Scientia*, Milan, 1982), pp.185-210 (English), pp. 211-224 (Italian).
[147] R. W. Langacker, *Foundations of Cognitive Grammar*, Stanford: Stanford University Press, 1987, (Volume 1: *Theoretical Prerequisites*) .
[148] For Further publications
See: http://www.isi.edu/natural-language/people/hovy/publications.html
[149] Eduard Hovy "Comparing Sets of Semantic Relations in Ontologies," *The Semantics of Relationships*, ed. Rebecca Green, Carol A. Bean, Sung Hyon Myaeng, Dordrecht: Kluwer Academic Publishers, 2002, p.92. he adds:
"We view a domain model as an ontology that specializes on a particular domain of interest."
[150] Christiane Felbaum. On the Semantics of Relations, "*The Semantics of Relationships*, ed. Rebecca Green, Carol A. Bean, Sung Hyon Myaeng, Dordrecht: Kluwer Academic Publishers, 2002, p.23.
[151] To be sure there are exceptions to this trend. Jouis (2002) distinguishes between elementary semantic types of entities (Boolean, individualizable, mass, distributive, collective and place); Formation operators for compound types; fundamental static relations and fundamental dynamic relations. Cf. Christophe Jouis, "Logic of Relationships," *The Semantics of Relationships*, ed. Rebecca Green, Carol A. Bean, Sung Hyon Myaeng, Dordrecht: Kluwer Academic Publishers, 2002, especially pp. 129-130.
[152] Christopher Khoo, Syin Chan, Yun Niu, "The Many Facets of the Cause-Effect Relation," *The Semantics of Relationships*, ed. Rebecca Green, Carol A. Bean, Sung Hyon Myaeng, Dordrecht: Kluwer Academic Publishers, 2002, especially pp. 51-70; cf. pp. 46, 55.
[153] Presented at ICCS'2000 in Darmstadt, Germany, on August 14, 2000. Published in B. Ganter & G. W. Mineau, eds., *Conceptual Structures: Logical, Linguistic, and Computational Issues*, Lecture Notes in AI #1867, Springer-Verlag, Berlin, 2000, pp. 55-81.John F. Sowa, Ontology Metadata and Semiotics.
See: http://users.bestweb.net/~sowa/peirce/ontometa.htm.
For a more detailed understanding of his work see: John F. Sowa, *Knowledge Representation: Logical, Philosophical, and Computational Foundations*, Brooks/Cole Publishing Co., Pacific Grove, CA, 2000.
For a fuller bibliography cf. John F. Sowa.
See: http://www.jfsowa.com/pubs/index.htm
[154] Entity Relation Data Modelling.
See: http://www.ils.unc.edu/~denns/inls256sp01/notes/ernotes.html

[155] Peter P. Chen: *The Entity-Relationship Model - Toward a Unified View of Data*. ACM TODS 1(1): 9-36(1976). Sowa has also noted these limitations.Cf., op. cit., p. 423.

[156] Of course as figure 24 makes clear, computer scientists such as John Mylopoulos building on Smith and Smith have long since introduced this level of distinction into their database systems.

[157] Consequently the basic grammatical distinction between a predicate (as in the sentence Henry is a man) and an object (as in the sentence Henry killed the chicken) also disappeared.

In terms of Dahlberg's basic distinctions (cf. figure 7) the original entity-relationship model of Chen focused on entities and thus overlooked most properties, activities and dimensions. Because the model focused only on level one, the entity relationship model was initially able to record only some aspects of questions about Who? is, has, does What? Because it omitted level two it did not deal with purpose, conditions, time, place, persons and objects, and thus did not deal with the questions Why?, How?, When?, Where?, or Who? and What? (with respect to ancillary persons and objects, figure 40b). In grammatical terms, this meant it did not deal with adjectives, nouns, subordinate and conditional clauses as outlined in figure 40d-f. Some proponents of the semantic web have assumed that entity relationships solve the challenges of relationships, syntax and meaning. Clearly it might be helpful if they looked more closely at the long history of knowledge organization that is the subject of this paper.

[158] Tony Halpin, "Object-Role Modelling (ORM/NIAM)," *Handbook on Architecture of Information Systems,* eds. P. Bernus et al., Berlin: Springer Verlag, 1998.

See: http://www.orm.net/pdf/springer.pdf

Cf. also the doctoral thesis of H. Bakker, *Object-oriented modeling of Information Systems, the INCA Conceptual Object Model*, FdAW, Rijskuniversiteit Limburg, Maastricht: Published by Author, 1995.

[159] For standard writings on semantic networks from the Ai viewpoint cf. CSE 676: KNOWLEDGE REPRESENTATION. Fall 2001

See: http://www.cs.buffalo.edu/~rapaport/676/F01/syl.html:

Martins, João Pavão (2001), *Knowledge Representation* (unpublished manuscript), Sects. 6.1-6.2, 6.4-6.8

Quillian, M. Ross (1967), "Word Concepts", B&L: 97-118.

Schank, Roger C., & Rieger, Charles J., III (1974), "Inference and the Computer Understanding of Natural Language", B&L: 119-139.

Woods, William A. (1975), "What's in a Link: Foundations for Semantic Networks", B&L: 217-241.

McDermott, Drew (1976), "Artificial Intelligence Meets Natural Stupidity", in John Haugeland (ed.), *Mind Design: Philosophy, Psychology, Artificial Intelligence* (Cambridge, MA: MIT Press, 1981): 143-160.

[160] The ACM Digital library has 200 references under Semantics of programming languages. Under ACM Portal See:

http://portal.acm.org/results.cfm?query=CCS%3A%22F%2E3%2E2%22&coll=GUIDE&dl=ACM&CFID=12408722&CFTOKEN=21886016

[161] Tours.com under Travel Statistics and Trends.

See: http://www.tours.com/travelstats.php

[162] Interspace Summary.

See: http://www.canis.uiuc.edu/projects/interspace/index.html

[163] Medical Interspace Projects.

See: http://www.canis.uiuc.edu/projects/medspace/index.html

[164] Without careful filters, attempts to include these particular, subsumptive classes directly would contravene patient confidentiality and raise personal privacy concerns. Even so, we can imagine a framework whereby information at the level of particulars – a banal example would be the heart rate and temperature of cancer patients over time – could be gathered, even automatically, to provide knowledge about parameters at the level of universals. In contrast to Plato's universals, which were purely intellectual exercises, these universals would be summations or more precisely generalisations as parameters or limits based on concrete observations of particular, individual, patients.

[165] Cf. Pat Hayes. Under MIT Cognet

See: http://cognet.mit.edu/MITECS/Entry/hayesp.

Re: semantic networks cf. UMBC CMSC771 Spring'00 .

See: http://www.cs.umbc.edu/www/courses/graduate/771/spring00/syllabus.shtml

For an Introduction to these themes see the author's: "Challenges for a Semantic Web," *Semantic Web Workshop 2002. Proceedings of the International Workshop on the Semantic Web 2002 (at the Eleventh International World Wide Web Conference), Hawaii, May 7, 2002,* Honolulu, Hawaii, pp. 16-22. Position paper also published electronically.

See: http://semanticweb2002.aifb.uni-karlsruhe.de/proceedings/Position/veltmann.pdf.

Reprinted in Cultivate Interactive, Issue 7, June 2002

See: http://www.cultivate-int.org/issue7/semanticweb/).

See also the author's: "Syntactic and Semantic Interoperability, New Approaches to Knowledge and the Semantic Web," *New Review of Information Networking*, Cambridge: Taylor Graham, Volume 7, 2001, pp. 159-183.

[166] Pablo Gamallo, Marco Gonzalez, Alexandre Agustini, Gabriel Lopes, and Vera S. de Lima *Abstract, Mapping Syntactic Dependencies onto Semantic Relations*.

See: www-sop.inria.fr/acacia/WORKSHOPS/ECAI2002-OLT/Proceedings/Gamallo.pdf

[167] See for example a very useful article by Uta Priss, "Alternatives to the 'Semantic Web': Multi-Strategy Knowledge Organisation" in: *The Seventh International ISKO Conference*. Granada, Spain, 3-6 July 2002 and the journal *Knowledge Organisation*.

[168] ASIS&t.

See: http://www.asis.org/

[169] IFLA.

See: http://www.ifla.org/. As reviewer three rightly points out, enabling dynamic access to cultural and historical dimensions of knowledge is central to discussions in these organizations concerning: "issues of boundary crossing in time, space, language, and culture, ethics of globalization; cultural hospitality; multilingual and multicultural access to information; metadata etc."

We have not considered a full review of these issues since this would take us far beyond the limitations of the five issues that concern us here. Interested readers are advised to study the books mentioned in the next footnote.

[170] *Relationships in the Organization of Knowledge*, ed. Carol A. Bean, Rebecca Green, Dordrecht: Kluwer Academic Publishers, 2001; *The Semantics of Relationships. An*

Interdisciplinary Perspective, ed. Rebecca Green, Carol A. Bean, Sung Hyon Myaeng, Dordrecht: Kluwer Academic Publishers, 2002. These books also offer an excellent survey of recent literature.

[171] Cf. again the IMASS project mentioned earlier.
See: www.i-massweb.org

[172] Cf. the study by Francesca Monti and Suzanne Keene on the DEER under E-Culture Net. See: http://www.eculturenet.org/FP5/publicPDF/deliverable11a.pdf.

[173] It is instructive that Dr. Robert Kahn, active in the Internet Society and in the U.S. Corporation for National Research Initiatives has similar ideas with respect to the use of Digital Object Identifiers (DOIs). Robert Kahn, Testimony before the Subcommittee on Basic Research of the Committee on Science on the subject of Internet Domain Names
See: http://www.cnri.reston.va.us/testimony.html

[174] It will be noted that this can be done without abandoning the concept of objectivity. One is not saying that claims about maps are fully subjective: simply that more than one claim exists.

[175] E.g. IRCs, MUDS, MUSHs.

[176] If we had to subject every statement of a friend to a logical truth or trust process, it would reflect poorly on our concept of friendship.

[177] This problem is discussed in more detail in the author's: "Four Ways that Digital Communications are Transforming Scholarship: Sources, Names, Claims and Scope." Submitted to INET 2004.

[178] We are often distracted, for instance, by the daily challenges of moving from one operating system, from one format to another, from one file name to another. The scale of this revolution is too easily reduced to quick statistics: that what began as a toy for a handful of "geeks" a few decades ago is now used daily by 10% of the world's population, which means that over 7 million new Internet pages are being added daily.

[179] For a further discussion of this idea see the excellent report by Suzanne Keene and Francesca Monti on the DEER produced for E-Culture Net.
See: http://137.120.135.183/FP5/publicPDF/deliverable11a.pdf.
Cf. http://res2.agr.gc.ca/ecorc/cnc/histo_e.htm

[180] Unless we find new ways to remember what we have done as humans, and new ways to perceive these accomplishments, we risk losing insight into what it is that makes us unique as humans. In which case, the technologies that some now fear would truly become a threat, rather than providing us with new tools to extend our horizons.

[181] In terms of our space-time horizon (cf. figure 4) the initial division would have looked as follows:

Geometry Form
Arithmetic Number
Dialectic Logic
-----------------------------------Space-Time Horizon---
Astronomy
Music
Grammar
Rhetoric

The mediaeval constellation of the seven liberal arts began to bridge this horizon.

One of the strengths and at the same time principal weaknesses of the Greek approach to knowledge was a sharp specialization of the sciences, such that those who studied shape and form (geometry) tended not to study number (arithmetic). One of the great contributions of the Arabs was to begin a reconciliation of form and number, theory and practice, which then led via the late Middle Ages and Renaissance to the synthesis foreseen by Leonardo and carried through by Galileo and his successors.

[182] Eric A. Havelock, *Preface to Plato*, Cambridge, Mass: Harvard University Press, Belknap Press, 1963.

[183] Socrates spoke philosophy but did not write it. Hence the generations of his student Plato and Plato's student Aristotle represented much more than a productive moment in the history of thought.

[184] Both Marshall and Eric McLuhan claim that early grammar also entailed etymology. Notwithstanding the famous work by Isidore of Seville, the term, etymology, in the sense of "tracing of a word to its original" did not enter into English until 1725 (see Oxford English Dictionary).

[185] Marshall Mcluhan, "The Place of Thomas Nashe in the Learning of his Time," *Unpublished PhD.Thesis*, Cambridge University, 1942.

[186] The son of Marshall McLuhan.

[187] Eric Mcluhan, "On Formal Cause," Unpublished Manuscript, July 2003, due to be published by Fordham University.

[188] Denise Schmandt Besserat, 'Before Writing', vol. 1: 'From Counting to Cuneiform,' University of Texas Press, 1992.

Cf. Chapter 4 of John Heise's 'Akkadian language' on the origin and development of cuneiform.

See: http://saturn.sron.nl/~jheise/akkadian/cuneiform.html. .

[189] Eusebius, Chapters XXVII-XXXII in: *Library of Nicene and Post Nicene Fathers*, 2nd series (New York: Christian Literature Co., 1990), *Vol I*, 489-91.

Medieval Sourcebook. Eusebius. The Conversion of Constantine.

See: http://www.fordham.edu/halsall/source/conv-const.html

Cf. 6.The Conversion of Constantine

See: http://isthmia.ohio-state.edu/teg/50501/6.htm

[190] Plotinus 205-270.

See: http://www.island-of-freedom.com/PLOTINUS.HTM

[191] John F. Sowa, *Knowledge Representation. Logical, Philosophical and Computational Foundations*, Pacific Grove: Brooks/Cole, 2000, p. 4. Cf.
The Internet Encylopaedia of Philosophy under Neo-Platonism.

See:
http://www.utm.edu/research/iep/n/neoplato.htm#Part%20II.%20Porphyry%20and%20Iamblichus.

Cf. Northwestern University Library. Classics.

See: http://www.library.northwestern.edu/collections/classics/ for a fresco painting of the Tree of Porphyry: Classification method based on dichotomies, as rendered on the ceiling fresco of the library at Schussenried, near Ulm, Germany. Artist: Franz Georg Herrmann (1757). (Photograph by J. Garrett, October 2000).

[192] Arthur Oncken Lovejoy, *Great Chain of Being: A Study of the History of an Idea*, Boston: Harvard University Press, 1936.

[193] When the Academy closed in Athens seven scholars took its learning to Gundishapur which became a centre of learning where Greco-Roman learning was translated into Arabic. Cf. The Land of Tajiks.
See: http://www.geocities.com/tajikland/History.html. From there a corpus of Greco-Roman knowledge in Arabic moved westwards only to be translated anew into Latin at centres such as Toledo.

[194] For a background on Raymond Lull (Ramon Lullius) cf. 1274 A.D. Raymond Lull's Ars Magna.
See: http://www.maxmon.com/1274ad.htm
For a survey and translation of his Great Art cf. *Ars magna*
See: http://lullianarts.net/Ars-Magna/ars-magna.htm.
Lull has nine levels of being which he calls subjects:

1. God
2. Angels
3. Heaven
4. Man
5. Imaginative
6. Sensitive
7. Vegetative
8. Elementative
9. Instrumentative

Dahlberg (1995, as in note 24), figure 13 makes interesting parallels between her questions and those of Raymond Lull.

[195] Prior to Abbot Suger, the recapture of Toledo by the Christians in 1086 was an important moment in this development. CF. SF Timeline 12th Century.
See: http://www.magicdragon.com/UltimateSF/timeline12.html for a brief summary of chief translators. For a thorough overview see the *Catalogus translationum et commentariorum*, ed. P. O. Kristeller and F. E. Crantz, 4 vols (Washington DC 1960 etc.) and now continued by Virginia Brown.

[196] This translation was carried out by Herman of Carinthia (Herman Dalmatin) and Robert of Chester (Robert of Ketton). Istrianet.org under Herman Dalmatin.
See: http://www.istrians.com/istria/illustri/dalmatin/.

[197] St. Augustine, *Enarrationes in Psalmos*, XLV, 7 (PL 36,518). Cited in G. Tanzella-Nitti, *The Book of Nature and the God of Scientists according to the Encyclical Fides et Ratio*, *Invited talk at the Jubilee for Men and Women from the World of Learning*, Vatican City, May, 23, 2000.
See: http://www.usc.urbe.it/html/php/tanzella/nature.rtf. Eric McLuhan building on the work of his father (as in note 6 above, cf. note 14) has argued that it was the grammarians with their commitment to etymology and interpretation who gradually combined a study of the *Bible* as the Book of God and the natural world as the Book of Nature in which one saw God's creations.

[198] Dorothy Verkerk, *Early Medieval Bible Illumination and the Ashburnham Pentateuch.*
See: http://assets.cambridge.org/0521829178/sample/0521829178WS.pdf

[199] See: http://www.cs.helsinki.fi/u/eahyvone/presentations/Usix2Ontologiat2003-01-26.pdf

[200] See: http://www.library.northwestern.edu/collections/classics/

[201] This is generally accepted as being by another author.
[202] Hugh of Saint Victor in the 12th century was an important exponent of this comparison between the two books.
Cf. The Electronic Labyrinth. The Book of Nature.
See: http://www.iath.virginia.edu/elab/hfl0247.html.
[203] The Columbia Encyclopedia, Sixth Edition. 2001, Hugh of Saint Victor.
See: http://www.bartleby.com/65/hu/HughStVi.html
[204] See the article by Tanzelli-Nitti cited in note 191 above.
[205] Joseph C. Pitt, *Galileo, Human Knowledge, and the Book of Nature: Method Replaces Metaphysics*, Dordrecht: Kluwer Publishers, 1982. The idea that the book of nature is written in alphabet of mathematics had been expressed earlier by Christopher Clavius in his introduction to Euclid's *Elements*.
[206] Cf. the Encylopedia Britannica (1911 ed.) article on Vincent of Beauvais:
See: http://5.1911encyclopedia.org/V/VI/VINCENT_OF_BEAUVAIS.htm
Cf. Vincent of Beauvais, Bibliography.
See: http://www.cs.uu.nl/groups/IK/archives/vincent/bibl/subj/sm_g.htm#home
[207] New Advent. Vincent of Beauvais.
See: http://www.newadvent.org/cathen/15439a.htm
[208] Alistair Crombie, *Robert Grosseteste and the Origins of Experimental Science: 1100-1700*, London-New York: Oxford UP, 1971. While some critics insist that the case is overstated, the growing importance given to the natural world and experience remains an important point. Grosseteste was inspired partly by Arabic knowledge translated by Gundissalinus and others.
[209] In so doing Aquinas was closer in spirit than might first appear to the Franciscan, Grosseteste, a founder of Oxford, who claimed that the bridge between theory and practice lay in the realm of experience and experiment and who Alistair Crombie has credited as being one of the fathers of experimental science.
[210] This has been discussed in more detail in the author's *Literature on Perspective*.
See: http://www.mmi.unimaas.nl/people/Veltman/books/vol3/ch1.htm.
For another interpretation of the role of Albert the Great and Roger Bacon, cf. the Jacques Mauritain Center under The Experimental Sciences -- Albertus Magnus -- Roger Bacon.
See: http://www.nd.edu/Departments/Maritain/etext/staamp3.htm#CULTI
[211] 1265 was also the year Clement IV permitted Thomas Aquinas to begin his *Summa*.
[212] E. I. Samurin, *Geschichte der bibliothekarish-bibliographischen Klassificaktion*, Munich: Verlag Dokumentation, 1977, 2 Vols. Original published in Russian, 1955-1959.
[213] Pierre Duhem, *SOZEIN TA PHAINOMENA, Saving the appearances*, Original French: 1906. English translation: Chicago: University of Chicago Press, 1969.
[214] Pierre Duhem has traced the history of cosmologies in his monumental: *Le Systeme du Monde. Histoire des doctrines cosmologiques de Platon a Copernic*. Paris, 1913-[59]. 8o. 10 volumes.
[215] Pierre Duhem (1861-1916) was one of the first to explore in detail how many of the Renaissance developments in statics and mechanics had their roots in mediaeval philosophy and science. Cf. his: *The evolution of mechanics* Alphen aan den Rijn: Sijthoff, 1980 and *The origins of statics. The sources of physical theory*. Pierre Duhem. translated from the French by Grant F. Leneaux, Victor N. Vagliente, Guy H. Wagener

Dordrecht, London: Kluwer Academic, 1991 (Boston studies in the philosophy of science. v.123).

[216] Dana class.
See: http://webmineral.com/danaclass.shtml

[217] Elements and Atoms: Case Studies in the Development of Chemistry.
See: http://webserver.lemoyne.edu/faculty/giunta/EA/CONTENTS.HTML

[218] Ibid.
See: http://webserver.lemoyne.edu/faculty/giunta/EA/CLASSIFICATION.HTML

[219] E.g Derwent chemical classification.
See: http://thomsonderwent.com/support/dwpiref/reftools/classification/#chem

[220] E.g. IUPAC nomenclature organic chemistry.
See: http://www.acdlabs.com/iupac/nomenclature/
Cf. Organic chemistry resources.
See: http://www.organicworldwide.net/

[221] Strunz Class.
See: http://webmineral.com/strunz.shtml

[222] First Scientific Descriptions.
See: http://www.biologie.uni-hamburg.de/b-online/e01/01a.htm

[223] History of Horticulture. Dioscorides, Pedacius or Pedanios 40-90.
See: http://www.hcs.ohio-state.edu/hort/history/020.html.
Cf. Scienceworld.worfram.com under Dioscorides.
See: http://scienceworld.wolfram.com/biography/Dioscorides.html

[224] Re: Global voyages of Linnaeus' students**:** Rob. E. Fries' "De Linneanska 'Apostlarnas' Resor: Kommentarer Till Enkarta" in Svenska Linné-Sällskapets Arsskrift (Vol. 33–34, 1950–1951). Cf. Order from Chaos. Linaeus Disposes. See: http://huntbot.andrew.cmu.edu/HIBD/Exhibitions/OrderFromChaos/pages/03The%20Linnaean%20inheritance/students.shtml

[225] Linnaeus Link.
See: http://www.nhm.ac.uk/library/linn/

[226] Potager du Roi.
See: http://www.potager-du-roi.fr/. This was also one of the starting points for Lavoisier's work in chemistry.

[227] Royal Botanic Gardens, Kew.
See: http://www.rbgkew.org.uk/index.html

[228] Ibid., Collections, Herbarium Collections.
See: http://www.rbgkew.org.uk/collections/herbcol.html

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[230] See: http://arnica.csustan.edu/boty3700/lectures/history.htm

[231] Based on: K. Sprengel, *Geschichte der Botanik*, 2 Bände. Altenburg und Leipzig: F. A. Brockhaus 1817 under Renaissance.
See: http://www.biologie.uni-hamburg.de/b-online/e01/01d.htm
Cf. Botanik *online* - The Internet Hypertextbook
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[232] Linaean Classification of Humans.
See: http://anthro.palomar.edu/animal/table_humans.htm

[233] *Systematischer Bandkatalog bis 1964/1965: Übersicht über die Systematikgruppen und einige wichtige Untergruppen.*
See: http://novsrv3.ub.tuwien.ac.at/bandkatalog/kurzsystematik.html

[234] Royal College of Surgeons of England under John Hunter.
See: http://www.rcseng.ac.uk/services/museums/history/john_hunter_html

[235] Karl Ernst von Baer.
See: http://www.serpentfd.org/b/vonbaer.html

[236] OED.

[237] OED.

[238] OED. Cites C.W. Salesby in Academy June 394/1.

[239] OED. Cf. 1899, Cf. E. Haeckel, 1899. *Riddle of the Universe at the Close of the Nineteenth Century*:

> I established the opposite view, that this history of the embryo (ontogeny) must be completed by a second, equally valuable, and closely connected branch of thought - the history of race (phylogeny). Both of these branches of evolutionary science, are, in my opinion, in the closest causal connection; this arises from the reciprocal action of the laws of heredity and adaptation... 'ontogenesis is a brief and rapid recapitulation of phylogenesis, determined by the physiological functions of heredity (generation) and adaptation (maintenance).'"

Ernst Haeckel (1834-1919)
See: http://www.ucmp.berkeley.edu/history/haeckel.html

[240] Ibid.

[241] History of Plant Taxonomy.
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[242] Monaco Educational Service. Taxonomy. See:
http://www.personal.psu.edu/faculty/w/x/wxm15/Online/Taxonomy/taxonomy_lec01.htm

[243] Spaces of Classification.
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Cf. a site on basis for classification under Monaco Educational Services under Taxonomy. See:
http://www.personal.psu.edu/faculty/w/x/wxm15/Online/Taxonomy/taxonomy_lec01.htm#Basis%20for%20classification

[244] Datenbanken für Taxonomen und verschiedene Organismengruppen.
Online directories for Experts in Taxonomy and for selected Taxa
See: http://biosys-serv.biologie.uni-ulm.de/expertdatei/databases.html

[245] World Taxonomist Database.
See: http://www.eti.uva.nl/Database/WTD.html

[246] The Global Taxonomy Initiative (GTI)
See: http://www.nhm.ac.uk/science/biodiversity/gti.html

[247] Chapter 10. Classification of Microorganisms Cf.
http://207.233.44.253/wms/reynolmj/lifesciences/lecturenote/mic20/Ch10Classification.pdf

[248] R.H. Whitaker, See: Unlocking the Mysteries. Kingdoms:
Cf. http://www.usoe.k12.ut.us/curr/science/sciber00/7th/classify/sciber/5king1.htm
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See: http://hometown.aol.com/ksmith9526/SciName.htm
[249] See: http://www.usoe.k12.ut.us/curr/science/sciber00/7th/classify/sciber/5king2.htm
[250] Arthur Cronquist, *An Integrated System of Classification of Flowering Plants*, New York: Columbia University Press, 1992.
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[251] Armen Takhtajan, *Evolutionary Trends in Flowering Plants*, New York: Columbia University Press, 1991.
See: http://employees.csbsju.edu/ssaupe/biol308/Course_Materials/classification-evol.htm
[252] Willi Hennig Society.
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[253] Taxonomy. See:
http://www.personal.psu.edu/faculty/w/x/wxm15/Online/Taxonomy/taxonomy_lec01.htm#Basis%20for%20classification
[254] Molecular Systematics and Evolution.
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[255] Jeffrey D. Palmer, Moleculat Evolution.
See: http://www.bio.indiana.edu/facultyresearch/faculty/Palmer.html
[256] J.T. Huber and J.M. Cumming, HISTORY OF THE CANADIAN NATIONAL COLLECTION OF INSECTS, ARACHNIDS AND NEMATODES.
See: http://res2.agr.gc.ca/ecorc/cnc/histo_e.htm
[257] Cf. the homology site.
See: http://www.bio.indiana.edu/courses/S318-brodie/S318/S318lect23-homology&class.html
[258] Principles of Classification.
See: http://anthro.palomar.edu/animal/animal_2.htm
[259] For hierarchies
See: http://biology.fullerton.edu/courses/biol_403/Web/Hierarchies.html
[260] Cf. the work on similarities as a basis of classification adapted by William J. Monaco Educational Service. See:
http://www.personal.psu.edu/faculty/w/x/wxm15/Online/Taxonomy/taxonomy_lec01.htm#Basis%20for%20classification
[261] See: http://biology.queensu.ca/~biol440/Biol440_Lec03_SpeciesDefs.pdf
[262] John S Wilkins, *A Taxonomy of Species Definitions. Or, Porphyry's Metatree.*
Work in progress - version of 13/5/97.
See: http://www.users.bigpond.com/thewilkins/papers/metataxo.htm
[263] This diagram is from G. Ramel at: http://www.earthlife.net/kingdom.html. For an excellent introduction to these different views of kingdoms
See:
http://www.personal.psu.edu/faculty/w/x/wxm15/Online/Taxonomy/taxonomy_lec01.htm
[264] Michael F. Claridge, H. A. Dawah, M. R. Wilson, eds., *Species: The Units of Biodiversity* (*Systematics Association, Systematics Association Symposium on 'the Units of Biodiversity: Species*), Cambridge: Cambridge University Press, 1997 (Systematics

Association Special Volume Series, 54); Jared M. Diamond, "Zoological classification of a primitive people," Science, 151, 1966, pp. 1102-1105. cf. Ethnobiology.
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[265] Watson and Crick describe structure of DNA 1953.
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[266] DNA and Passerine Classification.
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[267] Researchers are increasingly turning to non-mechanical metaphors in design. Cf. Järvi, Outi, "The sign theories of Eugen Wüster and Charles S. Peirce as tools in research of graphical computer user interfaces," *Teoksessa: Terminology Science & Research. Journal of the International Institute for Terminology Research IITF.* Ed. Heribert Picht. International Network for Terminology (TermNet), Wien. 1997, pp. 63-72. The rise of organic metaphors in interface design is the topic of a dissertation by my student Nik Baerten.

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[269] Automata. See: http://www.culture.com.au/brain_proj/CONTENT/NETS_02.HTM