Tools Extending Human and Organizational Cognition: Revolutionary Tools and Cognitive Revolutions

By: Dr William P. Hall

Abstract

This work explores revolutions in human and organizational cognition that have resulted from new technologies and methods for managing the kinds of persistent knowledge that form Karl Popper's (1972) world 3. World 3 knowledge includes the logical contents of books, libraries, computer memories, etc. Persistent or "explicit" knowledge is a major blind spot for many of today's KM practitioners because of their reliance on a much narrower concept of knowledge derived from Michael Polanyi's works. This paper seeks to highlight and fill in that blind spot.

Knowledge workers using different cognitive tools often become so heatedly involved in irrational arguments about which tools are best, that bystanders call such discussions "holy wars". This is symptomatic of historically unprecedented cognitive and technological revolutions that fundamentally change how individuals and organizations interact with the world. To explain what is behind these holy wars, I weave together disparate themes, including epistemology, military affairs, the evolution and heredity of complex systems, and ideas regarding revolutions in human cognition to shed new light on the importance of knowledge in organizations.

Keywords: Karl Popper, Michael Polanyi, Epistemology, Organization Theory, Autopoiesis, Technological Revolution, Personal Knowledge, Organizational Knowledge, Evolution

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Dr Hall began university in 1957 as a physics major, then transitioned to biology through biophysics (neurophysiology). As a biologist, his first interests were in ecosystems and the early evolution of life. His PhD research focused on systematics and the evolution and roles of genetic systems in species formation. He also spent two postdoctoral years studying epistemology and scientific revolutions. His physics and biophysics background exposed him to early generation computers. Dr Hall purchased his first personal computer in 1981, and was fascinated by the rapid evolution of computers and the impact of these new cognitive tools on humanity. Since 1981, Dr Hall was employed in computer literacy, software and banking industries, and since 1990, with one employer in the defence industry where he has held a variety of documentation and knowledge management roles throughout the lifecycle of Australia's largest defence contract. In 2001 Dr Hall started writing a book on technological revolutions on the coevolution of human cognition and tools for extending cognition and encountered a major need to reformulate organization theory and the theory of organizational knowledge. This theoretical framework is built on Karl Popper's evolutionary epistemology and Maturana and Varalea's autopoiesis. See: http://www.hotkey.net.au/~bill.hall.

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Introduction

Today's discipline of organizational knowledge management is built on theoretical foundations that are still quite weak. As highlighted by von Krogh and Roos (1995), McKelvy (1997, 1999, 1999a; McKelvey & Baum 1999), and Tsoukas (2005), there are still major uncertainties over the nature of knowledge at an organizational level and of organizations themselves. In this paper I will present four conceptual themes from epistemology, biology, history and military affairs that provide the basis for a new kind of theoretical foundation for understanding managing individual and organizational knowledge. They also highlight a large gap between popular understandings of knowledge in the discipline and what could be achieved from taking a broadly integrated point of view.

Theme 1 - the nature of knowledge

Gourlay (2004), Haldin-Herrgard (2004), and Tsoukas (2005) review the epistemology of tacit or personal knowledge introduced by Polanyi (1958, 1966). Following introductions into the discipline by Nonaka (1991, 1996, Nonaka & Takeuchi 1995) and Sveiby (1994, 1997, 2000), most KM practitioners seem to heavily base their concepts of knowledge on this thread (Hall 2004, 2004a). Many using Polanyi's epistemology second hand accept a definition that knowledge is justified true belief, but may not know that Polanyi claimed (1958) that judgment of truth must ultimately depend on the individual's (religious) faith and belief.

Firestone and McElroy (2003, 2003a); Blackman et al. (2004), Capurro (2004), Hall (2003, 2005; Hall et al. 2005) trace their epistemologies from Karl Popper's (1972, 1982, 1999) more inclusive theory of knowledge. From 1972 on, Popper treated knowledge as an evolutionary phenomenon tracing from attempts to address problems of living (see Popper 1999). By contrast to Polanyi, Popper argued that knowledge of the world can approach a correspondence with external reality (David 2005) through an evolutionarily process of actively testing tentative solutions to problems in the real world and criticizing the solutions to eliminate errors. Through continuous iteration and criticism to eliminate unsuccessful solutions, internal representations of the world will become increasingly realistic. Popper called this his "general theory of evolution" (1972: pp. 241-245) or his "tetradic schema" (most works post 1972).

Popper (1972) also argued that knowledge can exist persistently and objectively outside of the human brain, and he elaborated an ontology of three metaphysical domains or "worlds" to frame his arguments. World 1 is the dynamic physical world and all that is in it. World 2 encompasses cognition in living things. Living entities exist in world 1 but Popper places the cybernetics of cognition and building subjective knowledge in world 2. Personal "dispositions" and "propensities", together with subjective beliefs, are forms of knowledge in world 2. World 2 knowledge thus corresponds reasonably closely to the entirety of Polanyi's (1958) concept of personal knowledge. Popper goes beyond Polanyi to provide a world 3 for persistent expressions of knowledge as encoded in DNA, computer memories and forms of human knowledge expressed linguistically in books and other made artifacts. Hall (2005) and Hall et al. (2005) review Popper's three worlds in more detail.

In this paper, unless specifically stated otherwise, "knowledge" is used in Popper's broadly defined sense of proposed/tested solutions to problems. Terms "tacit", "implicit" and "explicit" will be used in the senses defined by Nickols (2000), where tacit refers to knowledge that cannot be articulated (expressed linguistically), implicit refers to knowledge that can potentially be articulated, and explicit refers to knowledge that has been expressed and exists in a persistent form outside the living entity. Tacit and implicit knowledge are found in Popper's world 2. Explicit knowledge exists objectively in world 3.

Theme 2 - knowledge is strategic power over environment and competitors

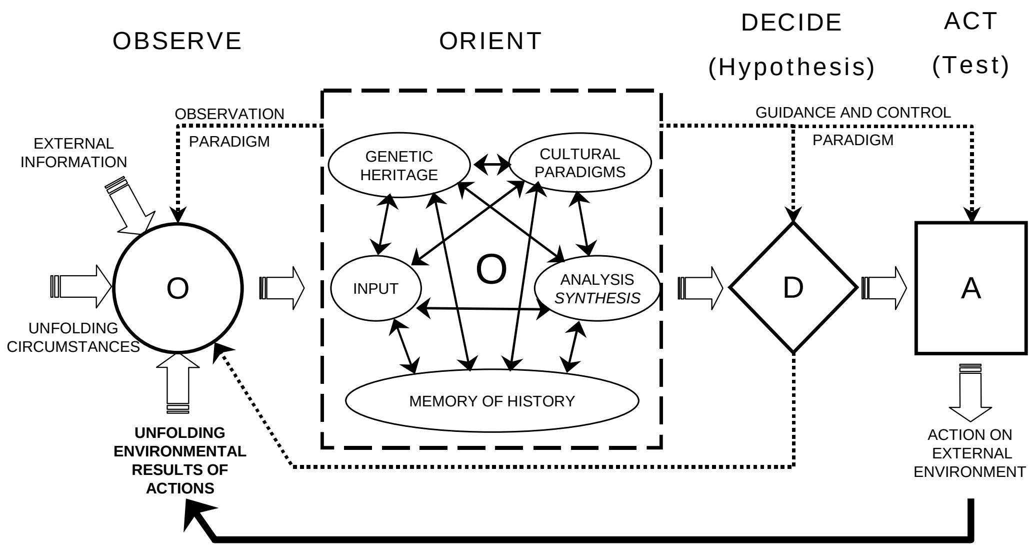

Figure 1. Boyd's OODA loop - Observe, Orient, Decide Act, (Hall 2003; Hall et al. 2005) after Boyd 1996). The loop process is immersed in world 1.

The fundamental problem of life is to build and maintain enough knowledge to survive. Strategic power is the outcome of survival knowledge. The essence of Popper's evolutionary epistemology is represented by John Boyd's (1996) OODA loop concept (Figure 1)[1]. This is a knowledge building process consisting of (O)bservation, (O)rientation, (D)ecision and (A)ction focused on solving the problems of survival and maintenance of power. Boyd observed that entities (i.e., individuals or organizations as the case may be) that were able to complete their OODA loops fastest gained strategic power through their ability to actively change the world before competitors could deploy their answers to what they had observed so the competitor's solutions did not correspond to current reality.

[1] Boyd was a renowned military strategist See http://www.belisarius.com for background on Boyd's life and the importance of his ideas.

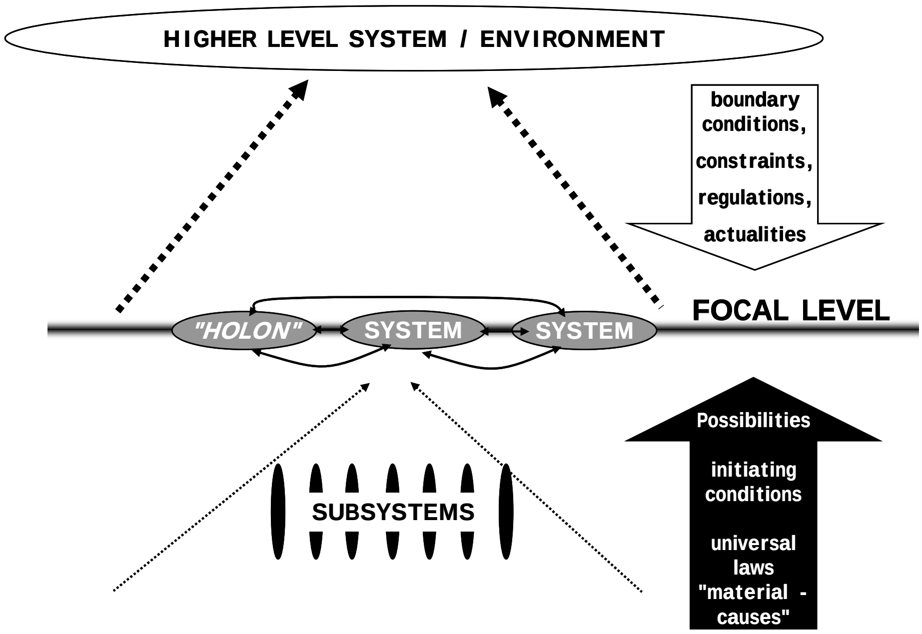

Figure 2. The systems triad in hierarchy of complex dynamic systems (Hall et al., 2005, after Salthe 1985)

Theme 3 - hierchically complex autopoietic systems are knowing entities

The world of living things, including people, is hierarchically complex (Simon 1962). Self regulating dynamic systems, e.g., cells, organisms and organizations, all exist at different levels (or nested "orders") of complexity within the scalar hierarchy. To study a particular system and its interactions with the world, a level of focus needs to be established centered on the system of interest (Salthe 1985, 1993). Any system at a focal level (Figure 2) is comprised of sub-systems whose interactions establish the "laws" of nature that govern the system in question (i.e., the "holon"). However, the actual behavior of systems in a complex hierarchy cannot be computed exactly from properties of the lower level component systems (i.e., complexity is irreducible - Polanyi 1968; Davies 2004). The focal system also exists within an external environment of a higher level super-system that establishes boundary conditions and constraints (i.e., attractors and barriers) that control what happens at the focal level.

By using a microscope, we can see and understand boundaries, behaviors and interactions of the cells that comprise our bodies. However, it is more difficult for us to see and understand the boundaries, behaviors and interactions of individual systems we may help to form at higher level of order in the complex hierarchy (Gould 2002).

Maturana and Varela (Maturana 1970, 2002; Maturana and Varela 1980; Varela et al. 1974) developed the concept of autopoiesis to define properties a complex system must have to be considered living. Varela et al. (1974) list six criteria that I abbreviate here (quoted verbatim by von Krogh and Roos 1995).

- Identifiable (membranes contain or tags identify system components)
- Complex (identifiable components within the boundary)
- Mechanistic (i.e., self-regulating metabolism/cybernetic processes)
- Self-bounded (system boundaries internally determined)
- Self-producing (system intrinsically produces own components)
- Autonomous (self-produced components produce the system).

Systems at any level of complexity can be evaluated against these criteria. Von Krogh and Roos (1995) and Magalhaes (1996, 1998) suggested that organizations might be autopoietic. Hall (2003, 2005) argued that many human economic organizations exhibited all the properties to be considered autopoietic, and hence could be studied as living things. Hall et al. (2005) further developed the argument based on properties at the organizational level of focus in a complex systems hierarchy. Cells, multicellular organisms and organizations meet all requirements to be considered living when examined at their own focal level. Thus, it is proper to consider that types of knowledge will evolve that specifically pertain to entities at each of these focal levels. Maturana and Varela (1980) argued that the cybernetically self-regulating, self-maintaining and self-producing activities of an autopoietic system constituted cognition. By surviving the problems of life, autopoietic systems evolve and build knowledge (Popper 1972).

Applying Popper's evolutionary epistemology, and Nickol's vocabulary, autopoietic systems at any focal level in a complex hierarchy can potentially possess three types of knowledge: tacit, implicit or explicit (ideas I will develop more fully in other papers). The emergence and evolutionary growth of knowledge is a fundamental aspect of autopoietic cognition.

Tacit knowledge (= Popper's "dispositional" knowledge) is inherent in the structure of an autopoietic entity. In living cells knowledge exists in the components of the cell and the instantaneous trajectory of their three dimensional relationships and interactions that leads to continuing survival. In multicellular organisms tacit knowledge exists in the connections and interactions of the cells - especially neurons and their connections in the brain. In organizations tacit knowledge is held in the structure of personal networks formed by members of the organization, electronic networks, computational apparatus, production lines, organizational routines, and the layout and capabilities of the physical plant and equipment—as first described by Nelson and Winter (1982).

Implicit knowledge probably does not exist at the cellular level, in that there are no known pathways by which adaptive responses of an individual organism can be articulated into the explicit heredity of DNA. Implicit knowledge in lower multicellular organisms may be what the organism consciously learns during its life and is able to self-consciously manipulate and criticize. In humans, this is personal knowledge that can potentially be expressed linguistically. From the organizational point of view, some personal knowledge held by an individual relates more to the person's roles in a specific organization than to his/her life and activities independent from the organization. The sum of the implicit knowledge relating to the organization held by its members, is the organizational implicit knowledge.

Explicit knowledge at the cellular level is the naturally selected result of surviving trials of life as encoded in the nucleotide sequences of DNA molecules (Popper 1972). At the organismic level, Popper considers made artifacts such as spider's webs, nests, trails and the like to carry knowledge. Humans make very sophisticated use of world 3 through the linguistic articulation of experience into forms that can then be preserved and disseminated for intersubjective understanding and criticism in the form of discussions, books, papers, etc. Some explicit knowledge produced by humans for organizations they belong to conveys meaning that is important to the functioning of the organizational entity, but has little or no meaning to the individual person in isolation, and could thus be considered to be organizational knowledge rather than personal knowledge. Added to this are explicit forms of knowledge stored in computer memories and disseminated electronically to effect actions (e.g., regulatory instructions in a continuous flow chemical plant, instructions for numerically controlled tools in a robotically controlled assembly line, etc.).

The physical emergence of codified knowledge from dispositional knowledge deserves a discussion in its own right. However, here I can only point to the seminal work of Pattee (1965, 1972, 1995, 1997, 2000, 2001) and Rocha (1997, 1998, 2000;

Rocha and Hordijk 2005) in this area. A fuller treatment would mention several other workers as well.

Theme 4 - cognitive revolutions give humans and organizations new kinds of knowledge

Fossils show that our human lineage diverged a few million years ago as one amongst several similar species of hominids, which, in turn were not that different from other anthropoid apes. From that point the lineage leading to humans has gone through a sequence of "grade shifts" resulting in revolutions in our interactions with the world that have made us the overwhelmingly dominant form of life on Earth. A grade is “a unit of biological improvement from an evolutionary point of view comprising a group of individuals similar in their level of organization.” (Rieger et al. 1976 after Huxley 1958). A grade shift corresponds to a significant change (i.e., a "revolution") in the ecological capabilities of a species allowing it to exploit more or less new ecological niches, or ways of living. Kaplan (2006; Kaplan & Robson 2002) describes the first steps (primarily genetic) in the sequence of grade shifts by which the human lineage evolved away from its primate ancestry.

Following on from the grade shifts described by Kaplan and his colleagues, those grade shifts having the most ecological impact have occurred in the last six to eight thousand years with minimal genetic change and have primarily been changes in the way human knowledge is transmitted, stored and processed. Rather, there has been a sequence of cognitive revolutions associated with the invention of new cognitive tools (Donald 1997; Lock 2000; Naccache 2004). Except for the origins of language, the following grade shifting revolutions have been enabled by the cultural growth and transmission of by language. The new kinds of knowledge transfer have been enabled by the invention of new forms of technology, and have fundamentally changed the nature of humans as ecological species.

Speech and teaching effectively transfers knowledge from one human memory to another evolved perhaps 100,000 - 200,000 years ago. A major enabler for the grade shift of the agricultural revolution was that our ancestors acquired language, allowing a person to efficiently transfer complex knowledge about food, shelter and dangers to his/her offspring and cohorts. The rate of evolutionary change in humanity's ecological adaptations shifted into a much higher gear when a complex heritage of experience regarding the manufacture and use of tools and controlling the environment could be transmitted linguistically and criticized intersubjectively (Carstairs-McCarthy 1999; Bickerton 1998, 2005; Hauser et al. 2002).

Robertson (1998) calculated that the ability to express and transfer knowledge linguistically would increase the volume of content that a person could hold in memory by at least two orders of magnitude compared to what could be remembered without language - or to around 10^9 bits. The memorization of sagas and learning able to be passed from one generation to the next represents the first tentative origins of linguistic expression in Popper's world 3.

Physical counters, tallies, writing and reading to record and transmit knowledge external to human memory are invented >5,000 years ago. The Neolithic (Agricultural) Revolution carried with it a need to develop and maintain a complex social hierarchy with systems for remembering and tracking the ownership and exchange of goods and services (Budja 2004; Watkins 2000; Weisdorf 2005). The earliest archeological records of counting systems are from sites in Mesopotamia, dated some 11,000 years ago (Nissen et al. 1993; Goetzmann 1996). By 5,000 years ago, pictograms expressing more complex ideas were introduced, followed by cuneiform writing and then alphabetic scripts – all pressed into clay or chipped onto stone (Mouck 2000).

World 3 now encompasses persistent artifacts as people record their important ideas in writing (Lock 2000). Robertson (1998) calculates the ability to write things down increased by another two orders of magnitude the content a single person could manage, i.e., to 10^{11} bits.

The development of writing also enabled a totally new kind of life to emerge - that of the human economic organization (Hall 2003, 2005, Hall et al 2005), where the organization could begin to maintain written records (i.e., organizational heredity) in their own rights.

Printing technology and spread of universal literacy transmit knowledge to the masses 550 years ago. The invention in Europe of moveable type and the printing press around 1450 turned the production and replication of text documents into an industrial mass production processes. As printing presses became more efficient over the next 200–300 years and book prices declined, more commoners became literate, and individuals who wanted books could afford to buy more of them. Literate commoners began writing books themselves to record and pass on knowledge they had accumulated and distilled from practical experience with the real world. The increasing volume and utility of knowledge held in widely circulated books undoubtedly played crucial roles in stimulating and facilitating the Scientific and Industrial Revolutions (Eisenstein 1979, 1983).

Given the means to record, accumulate, reproduce and disseminate practical knowledge, people began to collect published information relating to particular subjects. The concept of scholarly and scientific investigation and reporting known as the "Scientific Revolution" followed on from an increasing interest in observing and reporting on natural and realistic phenomena and the awareness of multiple connections between scientific explanations and reality (Fjällbrant 1997).

As printing became increasingly industrialized, the relative cost of books continued to decline until the mid–20th Century when book production was increasingly automated, and literacy became almost a universal human birth right. Robertson (1998) calculates that with humans able to access libraries of recorded information, that the content accessible to a single human brain increased by more than 6 orders of magnitude (or to 10^{17} bits) compared to what could be managed by writing alone. Also, with universal literacy, an ever–increasing proportion of the human heritage has been transmitted down and disseminated across the generations, completely extrinsically to the human genome and the limited life spans of individual memories.

In the evolution of humanity's relationship to our environment, the development of science and technology, and the systems to record and retrieve this kind of knowledge represents a huge grade shift in the relative importance of genetic heredity versus cultural heritage in terms of defining the niche humans, as a biological species, occupy in the world.

Electronic content processing technologies extend cognitive processes beyond the limitations of human brains around 25 years ago. Computerized word processing and the Internet enabled by the microelectronics revolution are vastly important tools for assembling, replicating and distributing ever larger volumes of distilled knowledge. Robertson (1998) estimates that "computers" now allow individual humans to create, access and control 10^{25} bits of information - or 8 orders of magnitude more information than even cheap printing gave people access to. Since Robertson's estimate, this will have increased by another order of magnitude or two increase (Bergman 2000; Lyman and Varian 2003).

As I write this paper in my home study, I have at hand my own reference library of some 3000 books, containing content I can access at will. Through my academic connections, I have physical access (at the cost of hours and $$ for the round trip) to a university library containing millions of cataloged volumes. However, when used intelligently, search tools such as Google provide closely targeted access in milliseconds to retrieve current content to at least billion pages of freely available and indexed information (Gulli & Signorini 2005, Sullivan 2005). Through my library's electronic subscriptions I can access semantically more sophisticated services such as Thompson Scientific's Web of Knowledge[2] that index the "deep web" that may be 800 times the size of the surface web addressed by Google (Lyman and Varian 2003). In minutes, using citation indexing (Garfield 1994) or other tools using classification metadata, I can find and retrieve on demand a highly significant and very closely targeted fraction of the world's scientific, professional and technical literature produced in the last 10 years or so. I am working on a laptop computer with 56 GB storage! where most items I reference (except for books) can be captured, saved and stored for instant retrieval via hotlinks I add to the papers I write. The deep cognitive connections to background materials I make in writing these papers can be retrieved in seconds. These sources of explicitly printed or electronically archived knowledge are as much of my personal knowledge as anything I have not articulated.

Discussion - cognitive revolutions and the rise of the autopoietic organization

Give that our mammalian and primate ancestors are all social; humans must also have been social through their evolution - to form families, tribes and groups led by dominant or charismatic leaders. However, the successive cognitive revolutions of speech, writing, printing and cognitive automation enabled the evolution of increasingly complex and powerful systems to coordinate adaptive emergence at higher levels of organization of ever more complex and self-sustaining social and economic systems (Nissen et al. 1993; Goetzmann 1996; Mouck 2000; Beaudreau 2003) such as religious organizations, governments and firms able to persist for longer than the lifetime of a charismatic leader.

The rise of major religious centers or cities in ancient Mesopotamia appeared to be closely associated with the revolutionary development around the temple of various tools to facilitate trading, such as record keeping, writing, money and codified civil law. A second revolution in the size and complexity of organizational forms occurred in conjunction with the industrial revolution (Beaudreau 2003) enabled by the industrial replication and spread of know-how through printed books, and today, we are in the midst of what will be the greatest grade shift yet (Donald 1997; Contractor 2003) based on the development of computers and computer networking (Monge & Contractor 2003; Contractor et al. forthcoming).

Writing, record keeping and codified regulations provided the basis for accumulating problem solutions pertaining to the self-maintenance and self-production of formal organizations able to persist independently of the membership of any particular individual humans in the organization - thus providing the basis for an organizational cognition that meets all requirements for being considered to be autopoietic. The necessary level of complexity to support autopoietic organization could probably not be achieved without the storage of various forms of explicit knowledge as an organizational memory.

[2] http://scientific.thomson.com/ - Thompson's indexes cover 250 disciplines in the sciences, social sciences, arts and humanities as published in 8,500 leading, peer-reviewed journals, representing about 1.3 million articles and 30-35 million citations a year.

Conclusions

What humans have evolved through the externalization of knowledge is something totally new in the evolutionary and ecological history of planet Earth. The discipline of organizational knowledge management will need to develop a deep understanding of its foundations in organizational biology and evolutionary epistemology before it can be considered to be a genuine science. However, there is progress in a number of diverse disciplines contributing towards this understanding.

Michael Polanyi's (1958) concept that knowledge, as justified true belief - where the determination of "truth" is based on religious faith, and the idea that knowledge is something that can only ever be held in a person's head are very limiting. Contrasted to this limited view, the rich veins of ideas encompassed by the four threads I have summarized above are truly revolutionary and greatly expand the scope of concepts that should be included within the framework of knowledge management. It is no wonder that flame wars often erupt when people with different disciplinary paradigms try to discuss definitions for knowledge (Kuhn 1970, 1983)

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[Note: All links valid as at 3 July 2006]

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