INFORMATION RICH & ATTENTION POOR

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by

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INTRODUCTION

More than three years ago I spoke to the Association of Research Libraries, meeting in Ottawa, on the subject of the changing nature of intellectual authority. My story then can be summarized essentially as follows. We can observe that people today are much less prepared to defer to the experts than they once were. But at the same time we are all being swamped by a glut of information that cries out for authoritative analysis and summary. So there's a dilemma of who to turn to. Increasingly the answer is – to ourselves, of course, as individuals empowered by a World Wide Web that has evolved into a *social* medium. More specifically, it is a medium that supports massively distributed collaboration – exemplified by resources like Google and Wikipedia – that we hope will finally help make sense of it all.

We know that three years later is a virtual eternity in the timescale of Web 2.0. So most of what I said in May of 2006 regarding the role of "crowdsourcing" and Wikipedia, which seemed almost novel at the time, is now far too well-known to repeat. Nonetheless, we are still struggling with the challenge of adapting, our organizations, our business models and our habits of thinking to the new world that information technology has created and that the web exemplifies.

Today, I want to step back and consider from our current perspective the tectonic forces created by information technology over the past four or five decades, and to speculate on some of their deeper implications for the production and consumption of knowledge. The theme – drawing on an observation made 28 years ago by psychologist and computer scientist, Herbert Simon – is that the most fundamental consequence of the *superabundance* of information that has been created by the digital revolution, is a corresponding *scarcity* of attention. In becoming *information rich* we have become *attention poor*.

My objective is to provide a perspective from my own experience which, most recently, has been as what might be called a "broker of intellectual authority". The Council of Canadian Academies – a young organization modeled on the National Research Council of the U.S. National Academies – supports panels of experts who prepare detailed reports on scientific issues that are relevant to important public questions, ranging, for example, from the transmission of the flu virus, to the regulation of nanomaterials, among many other topics. I will also speak from the perspective of the telecommunications industry where, as an executive from 1995 to 2002, I witnessed first hand the emergence of the web as a mainstream medium. Finally, throughout a career in business and government, I have developed the habit, perhaps unfortunately, of thinking like an economist. This is not so much to think in terms of

dollars and cents but, more generally, in terms of the allocation of scarce resources to desired ends, and in terms of the inevitable "opportunity costs" of the choices we make.

I will try to weave together these strands of experience into an integrated narrative that links the fundamental technologies and economics of the web with the new modes of knowledge production and associated intellectual authority that are the result. The thesis, in a nutshell, is this.

- The three underlying digital technologies that have powered the information revolution – computation, data transmission and data storage – have each increased in capability (or decreased in cost per unit of capability) by approximately *10 million times* since the early 1960s.
- This has unleashed a torrential abundance of data and information. But economics teaches that the counterpart of every new abundance is a new scarcity – in this case, the scarcity of human time and attention. This can be roughly quantified. The cost of human attention (approximated, for example, by the average wage) relative to the cost of data manipulation, transmission and storage, has increased roughly 10 million-fold in just over two generations, a change in relative "prices" that is utterly without precedent.
- The corresponding change in *relative* abundance has made us information rich but attention poor. This is *fundamentally* what is driving the evolution of online behavior and culture, with profound implications for the production and consumption of knowledge. The primary consequence is the growing emphasis on speed at the expense of depth.
- Finally, I will speculate as to three of the most significant manifestations, each of which represents a paradigm shift from the world in which my generation was conditioned to some new equilibrium, the nature of which remains far from settled. There is underway:
    - a shift from knowledge that has existed primarily as a "stock" to knowledge that manifests increasingly as a "flow"
    - a shift in the locus of intellectual authority away from the expert and toward the crowd, and
    - a shift in the motivation of learning from "just in case" to "just in time".

SIGNIFICANCE OF THE INFORMATION TECHNOLOGY REVOLUTION

The most transformational technologies are those that enormously amplify capabilities of the human body – for example, as the steam engine amplified the power of our muscles and the automobile, the function of our legs. From this perspective, the technologies of information media began by amplifying *memory*, perhaps first in the form of clay tablets, then evolving via Gutenberg's innovation to the mechanically printed word. The encoding of information on the electromagnetic spectrum, beginning in earnest only in the late 19th century, enabled the amplification of our hearing via the radio; our voice via the telephone;

and eventually our eyes via television. The development of the Internet, and particularly the web, has, in barely one generation, effectively superseded and encompassed all other forms of information representation and transmission. I believe that the web should be thought of, by analogy with the human central nervous system, as a "cyber nervous system" for the planet – essentially a global *mind amplifier* with PCs, cell phones and their telecommunications links playing the metaphorical role of neurons. This cyber nervous system is still in its embryonic stage of evolution but already it is linking together upwards of 1.6 billion people or almost one-quarter of humanity.[1]

The web is so powerful because its underlying hardware technologies – transistors, magnetic domains, lasers and optical fiber – are based on moving around electrons and photons on which are encoded bits of information. Relative to tangible media, the virtually massless electronic and photonic media are incomparably small, fast and cheap. Just how fast, how small and how cheap? Consider the performance of the three key technological functions that make up the World Wide Web.

- *Data manipulation*: Today's fastest supercomputers are capable of performing a few *million billion* arithmetic operations per second – in the jargon, these are called petaflop computers where "peta" is the prefix that signifies 10 raised to the 15^{th} power and "flop" refers to a "floating point operation".[2] This rate of logical processing is incomprehensible. But if, for example, you imagine performing one multiplication per second on a hand held calculator, it would take more than 30 million years to complete the calculation that the latest supercomputers can perform in one second!

- *Data transmission*: Today's state-of-the-art optical fibers use ultra high frequency lasers to encode information on various pure colours of light. Each such colour (or wavelength) can carry about 40 billion bits per second or enough bandwidth to transmit the text of about 5,000 books in one second. Moreover, the single fiber can accommodate several information-laden wavelengths simultaneously.[3]

- *Data storage*: Finally, the state-of-the-art magnetic storage is roughly 4,000 billion bits (or 500 Gigabytes) per square inch, enough to store the text of about half a million books in an element that could easily fit inside a cell phone.[4]

These capabilities are essentially indistinguishable from magic. But what about their economics? The cost of manipulating, or transmitting, or storing a unit of information has been reduced roughly 10-

million-fold over the last 45 years or so*.[5] A change of this magnitude is virtually incomprehensible. It is as if a house that cost half a million dollars in 1964 could be purchased for a nickel today; or if one's life expectancy – say 75 years – were reduced to a mere four minutes, or if the distance to the moon were to shrink to the height of a tall tree. We should therefore not be surprised that a 10-million-fold decrease in the cost of information processing will have profound consequences.

Of particular significance for human behavior is the fact that the cost of information handling, relative to the value of one's time, has also been cut by a factor of roughly 10 million. In the oft-quoted words of Herbert Simon that I referred to at the outset:

> "Information consumes the attention of its recipients. Hence *a wealth of information creates a poverty of attention* and a need to allocate that attention efficiently among the overabundance of information sources that might consume it."[6]

Those prescient words were written when the modern information revolution was barely a decade old, and a quarter-century before the web became a household word. The data I have just been citing enable us to put a rough number on Professor Simon's intuition and to quantify just how scarce human attention has become relative to our superabundance of data and information. This has the following two profound consequences.

The first is that behavior inevitably adapts to conserve the scarce resource – in this case, attention and time – and to "waste" the abundant resource – the production, manipulation and storage of information. Thus, for example, a great deal of the technology's capability has been spent on simplifying interfaces and reducing communications latencies essentially to zero, both of which conserve precious time for users. The same motivation has also spawned a plethora of indexing and searching schemes, of which Google is the iconic example. These are all seeking to be attention optimizers, exploiting the fact that the locus of economic value invariably migrates from areas of abundance to areas of scarcity.

The second major consequence of the collapse of the scarcity value of information is that all of the institutions whose business models have relied on that scarcity have been suddenly placed at great risk. Newspapers, book publishers and sellers of music recorded on CDs all exploited a scarcity that was

* The capability, per unit cost, of information processing hardware ("computer chips") has been roughly doubling every two years since the early 1960s (an empirical regularity known as Moore's Law), while the rate of improvement of transmission and storage technology (again, per unit cost) has improved even more rapidly, but over a somewhat shorter period. For all three basic technologies, there has been roughly a 10-million-fold *decrease* in cost per unit of capability.

linked to the cost and *excludability* of a tangible medium. Meanwhile, radio, television and the wireline phone companies exploited the scarcity of communications bandwidth, giving rise to huge organizations that enjoyed regulated access to that bandwidth. Now virtually all of these scarcities are gone.[†]

The technological drivers of the information revolution have not nearly run their course. The exponentially increasing capability (or decreasing cost) of the current digital technology paradigms are projected to continue for another five to ten years, leading probably to at least a further ten-fold increase in the performance of the hardware.[7] Beyond that, there is a reasonable prospect that nanotechnologies and quantum phenomena may take us well past the limits of the current paradigm. For example, it was recently announced that a novel storage technology using carbon nanotubes may potentially be able to hold digital information without degradation for a *billion* years or more – an innovation that would eliminate the major shortcoming of the digital archive.[8] In fact, today's technology is nowhere near the theoretical physical limits, though there are many engineering and cost hurdles that may slow development after 2015.

We have all noticed, of course, that the exponentially increasing performance of the individual components of today's technology – the raw hardware capability – has not produced the same ratio of improvement in device performance from the perspective of users. This is because software development has not kept up with hardware innovation and a lot of computing power has been deliberately "wasted" in order to simplify the user interface – thus saving time and attention – or otherwise to bulk up with the kind of exotic features that only a geek could love. The upshot is that today's users have not come close to fully exploiting the raw capacity of yesterday's technology, let alone tomorrow's. The bottom line is that, in purely technical terms, the information revolution is still in its early days in terms of the effects it is destined to have on human behavior and society.

ADJUSTMENT TO A WEALTH OF INFORMATION AND A POVERTY OF ATTENTION

The 10 million-fold change in the relative prices of information and attention has already had profound effects on business models and on many aspects of social behavior. I want to restrict my attention, more narrowly, to the impact of the technology on the production and consumption of knowledge, recognizing

[†] When intellectual property is recorded on tangible media, using costly technologies – e.g., as is the case with newspapers, books and CDs – it is relatively easy to limit access only to those prepared to pay the producer's asking price and to exclude others. Analogously, over-the-air bandwidth (i.e., the frequencies on which radio and TV stations traditionally broadcast) is inherently limited by the need to avoid interference among broadcast frequencies and access to these frequencies can be readily policed by licensing authorities. The technology of the web has effectively eliminated all of these traditional scarcities and, at the same time, made it increasingly difficult, for both technical and social reasons, to enforce intellectual property rights that were formerly protected not only by law, but also by the nature of the media over which the IP was distributed.

of course that knowledge is not at all the same thing as "information". By analogy with the standard economic model of production – where a nation's output is considered, in the simplest case, to be a function of capital and labour – we can think metaphorically of the production of knowledge as a function of "information" and "attention", with attention understood to be the set of activities by which information is ultimately transformed into various forms of knowledge.

Information technology – by virtue of its unprecedented impact on the relative prices of information and human attention – is driving a correspondingly profound transformation of knowledge production, the main feature of which is a fundamental shift of emphasis from "depth" to "speed". This is simply because depth, and its associated nuance, requires time and attention to absorb. So as attention has become the dominant scarcity, depth has become less "affordable".[‡] Conversely, with information so abundant, strategies are needed to process it more quickly, lest something of vital interest or importance is missed.

The paradigm shift from depth to speed has many manifestations among which I will focus on three that I believe are of particular importance for the production and consumption of knowledge. These are:

- A shift from knowledge as a "stock" to knowledge as a "flow"
- A shift from the authority of the expert to the "wisdom of the crowd", and
- A shift in the motivation for learning from "just in case" to "just in time"

We are talking here about shifts of *emphasis* rather than the complete abandonment of the old approach in favour of the new. But I would argue that these three movements are already significant and have far from run their course.

The evolution of knowledge as a stock, to knowledge as a flow

In economics, reference is frequently made to the concepts of stock and flow, with "wealth" (a stock) and "income" (a flow) being the most familiar examples. In the case of knowledge, the stock may be thought of as a quasi-permanent repository– e.g., a book, a journal or an entire library – whereas the flow is the process of developing the knowledge before committing it to a more or less permanent form. The old Encyclopedia Britannica was quintessentially a stock; Wikipedia is the paradigmatic example of flow.

[‡] Terms like affordability, price and cost are not used here in their purely monetary connotation, though in many circumstances, time is money. These economic terms have a broader meaning in the context of allocating both scarce and abundant resources among the various options open to us. Thus even unpaid activity has its "price" since by choosing to do any particular thing you foreclose a host of possible alternatives at the same time. Economists call this opportunity cost.

Obviously, no stock of knowledge is absolutely permanent – knowledge depreciates just like any other type of capital. But what electronic information technology has changed profoundly is the *rate* of depreciation. By analogy with the 24-hour news cycle – which was an early consequence of the growing abundance of video bandwidth as cable television substituted for scarce over-the-air frequencies – there is now the equivalent of the 24-hour knowledge cycle – "late-breaking knowledge" as it were. To introduce another metaphor, knowledge is becoming more like a river than a lake, progressively more dominated by the *flow* than by the stock. What is driving this?

Most obvious is the technological fact that the media by which electronic information is presented and manipulated permit it to be changed continuously and virtually costlessly. Information products are therefore in a constant state of evolution for the simple reason that, faced with the option, who would not choose an *up*dated version over an *out*dated version? By the time information products do eventually come to rest, they are very likely to be considered obsolete. In the cutthroat competition for attention, they are no longer "news". As a consequence, there is little time to think and reflect as the flow moves on. This has a subtle and pernicious implication for the production of knowledge. When the effective shelf-life of a document (or any information product) shrinks, fewer resources will be invested in its creation. This is simply because the period during which the product is likely to be read or referenced is too short to repay a large allocation of scarce time and skill in its production. As a result, the market for "depth" is narrowing.

There is a second force at play that greatly amplifies this trend. As the tempo of information generation increases, and attention becomes scarcer, the consumers of information are driven to economize on time by demanding only the essence of the message – from executive summary, to the deck of bullet points, to the elevator pitch or the bumper sticker. Thus the demand for only the condensed summary *combines* with the shrinking shelf-life of knowledge products to reduce the incentive for depth, and therefore to undercut the market for the producers of depth, which have traditionally been individual experts.[§] But as one market has begun to decline, an alternative has begun to emerge.

Expert authority gives way to crowd wisdom

The shift of intellectual authority from the expert to the crowd is nowhere more tellingly illustrated than by Wikipedia, now one of the top ten most popular sites on the Web with roughly 300 thousand volunteer

[§] The term "market" is used here in the generic sense of a system of supply and demand (producers and consumers) of some product. Although often structured around sellers and buyers co-ordinating via monetary transactions, this is not necessarily the case.

contributors every month and almost three million articles in the English version, all accumulated in just eight years.[9] But the phenomenon of publicly-generated knowledge (sometimes called 'peer production' or 'crowdsourcing') is far more widespread and reflects, I believe, the *convergence* of both cultural and technological trends.

The key cultural factor has been the decline of deference to virtually all traditional sources of authority, including expert authority. This is by no means a recent phenomenon since deference to hierarchical authority has been declining for decades. But given the empowering tools of universal education and the Google search engine, we should not be surprised that people increasingly regard *ex cathedra* expert authority with skepticism, of not outright hostility. The paradox is that expert opinion is being sought and cited more than ever. But increasingly, it is individuals themselves who weigh the various authorities and come to their own conclusion. (Just ask doctors about their web-savvy patients.)

This cultural trend has been enormously enhanced by the capability of the web to mobilize both the "wisdom" of the crowd as well as the shallower and baser instincts of the crowd. In fact, the collective behavior, whether intelligent or stupid, that is being manifested through crowdsourcing and various schemes for rating and automatically filtering online content is arguably the *only* way to keep up with the overload of information on the web – another instance of the adjustment to the relative scarcity of attention. The upshot, in the context of knowledge generation, is that thousands of heads working in parallel are, in an environment of information superabundance, perhaps better than one, even if that one is an expert. Or so the theory goes.

But will it work? The fact that hundreds of thousands of people – many of whom are quite expert in their own right – are prepared to volunteer their time to create or edit Wikipedia articles, even without the ego benefit of acknowledged authorship, has confounded a lot of cynics. Many suggested the model would be unsustainable, but this has so far not turned out to be the case. Studies have shown that contributors are most often motivated by membership in a *community*, which has proven to be a potent organizing principle on the web.[10] What makes the movement powerful in intellectual terms is that the technology of the web makes it so easy for even amateurs to access the corpus of human knowledge. But while hundreds of thousands of web-empowered volunteers are able to very efficiently dedicate small slices of their discretionary time, the traditional experts – professors, journalists, authors and filmmakers – need to be compensated for their effort since expertise is what they have to sell. Unfortunately for them, this has

become a much harder sell because the ethic of "free" rules the economics of so much web content.[**11] Finally, for the reasons argued earlier, the value of traditional expert authority is itself being diluted by the new incentive structure created by information technology that militates against what is deep and nuanced in favour of what is fast and stripped down.

The result of the convergent cultural and technological trends is the growing disintermediation of experts and gatekeepers of virtually all kinds. The irony is that experts have been the source of most of the nuggets of knowledge that the "crowd" now draws upon in rather parasitic fashion – for example, news and political bloggers depend heavily on a relatively small number of sources of professional journalism, just as many Wikipedia articles assimilate existing scholarship. In other words, the system works because it is able to "mine" intellectual capital. This suggests that the "cult of the amateur" we are witnessing today will ultimately be self-limiting and will require continuous fresh infusions of the more traditional forms of expert knowledge. It is really a question of what form the new equilibrium will ultimately take and that remains very much an open issue.

In this regard, there are many examples that draw on Wikipedian principles but seek to hybridize expert knowledge with crowd wisdom – for example, Scholarpedia, the Encyclopedia of Earth, and Citizendium. While these particular hybrids may not survive, they are part of a necessary discovery process which must eventually find the best ways to blend the depth of the expert with the breadth of the crowd. This has already become the subject of major academic investigation in groups like MIT's Centre for Collective Intelligence and the Centre for Open Innovation at Berkeley.

The shift in learning from "just in case" to "just in time"

When virtually all of the world's codified knowledge is instantly at your fingertips, why should you spend increasingly scarce attention loading up your own mind "just in case" you may someday need this particular fact or concept? Far better, one might argue, to learn how to access *efficiently* what you need, when you need it. Of course, that logic puts a great premium on teaching efficient access to online knowledge. It also seems obvious that the strategy depends on building up, through systematic education,

[**] The notion that content on the web should be free reflects in part the anarchic origins of the medium, the cultural trace of which is still very much present. The more mainstream attitude probably reflects expectations created by our traditional exposure to ad-supported radio and TV. There is also some basic economics at play. Web technology permits information to be transmitted and stored at essentially zero marginal (i.e., incremental) cost, and in competitive markets, price is driven down toward marginal cost – or in this case, to essentially zero. Information products are also "non-rival" in the sense that my consumption does not take away from yours – e.g., the fact that I download and listen to a song does not interfere with your ability to do the same. The catch, of course, is that many creators of (high quality) content, or of the means to organize and disseminate content, still need somehow to be paid. So there are inherent limits to "free", even on the web.

a sufficient *internalized* structure of concepts in order to link with the external store of knowledge. This is the greatest challenge and opportunity facing educators in the 21st century.

One can only speculate as to the ultimate implications for future knowledge generation of the just-in-time habit – which is to say, more goal-directed and automatically filtered *searching* and less casual *browsing*. (The web browser, ironically, is for most people, anything but!) It seems inevitable that the just-in-time approach engenders a certain myopia; a narrowing of peripheral intellectual vision and thus a reduction of the serendipity that has been the source of most radical innovation.

What is apparently being eroded is the deep, integrative mode of knowledge generation that can only come from the "10 000 hours" of individual intellectual focus and sweat – a process that mysteriously gives rise to the insights that occur, often quite suddenly, to the well-prepared mind. We appear to be seeing fewer of the great synthetic innovations associated with names like Newton, Shakespeare, Bach, Einstein, Picasso or Watson and Crick. In particular, new scientific knowledge is being generated in narrower and narrower domains and is almost always the result of phenomenally refined observation technology combined with unprecedented data processing capability.

So we decry the increasing compartmentalization of knowledge – knowing more and more about less and less – while awaiting the great syntheses that someday may be achieved by millions of linked minds, all with fingertip access to the world's codified knowledge but with a vast spectrum of different perspectives. The hyperlinked and socially-networked structure of the web is perhaps making the metaphor of the global "cyber nervous system" into a reality – still primitive, but with potential for a far more integrated collective intelligence than we can imagine today.

Those who are still skeptical – and I confess to a certain skepticism myself – might recall that Plato, in the *Phaedrus*, suggested that *writing* would "create forgetfulness in the minds of those who learn to use it" and would create "the show of wisdom without the reality."[12] This is a striking example of a particular kind of generation gap in which masters of an established paradigm can only see the shortcomings, and not the potential, of the truly novel.

I might open a parenthesis here and speculate – and I would emphasize the word *speculate* – on the implications of the shift in the dominant medium in which codified knowledge is presented – that is, the shift from linear print on a page to hyperlinked multimedia information on a screen. It is well established that the shift has consequences in respect of pure perception. Those of us who have been raised on books

tend, for example, to be better proofreaders but I suspect that our powers of visual pattern recognition are, on average, inferior to those who have been raised on screens. Certainly, we are far less adept at media multitasking.

The implications for habits of thinking are much more speculative but it has been suggested that the linear structure of print induces a more linear pattern of thought – a pattern well-suited to the logic of "cause" giving rise to "effect" – in other words, to the step by step reductionist methods of science and engineering. By contrast, the electronic screen, with its lack of linear constraint, its ephemeral scintilla, and its hyperlinked multimedia content, perhaps portends a very different logical paradigm. How this may condition the habits of thought of the so-called "digital natives" – who, after all, are about to become both the custodians and creators of human knowledge – is one of the deepest and most significant questions facing our species. This is a case where, most certainly, *the medium is the message*, but unfortunately there is no Marshall McLuhan to decode it for us!

IN CONCLUSION

So what does all this mean for individuals and organizations engaged in the production and dissemination of "knowledge"? Commenting recently on the future of journalism in the world of Web 2.0, the media guru, Clay Shirky, put it this way:

> "The hard truth about the future of journalism is that nobody knows for sure what will happen; the current system is so brittle, and the alternatives are so speculative, that there is no hope for a simple and orderly transition from State A to State B. Chaos is our lot; the best we can do is identify the various forces at work shaping various possible futures."[13]

We can substitute "libraries" or "academies", or any number of institutions for "journalism" and Clay Shirky's wise words apply just as well. We are all in *terra incognita*. But there is no turning back, and in fact the landscape can only become more unfamiliar as information technology continues its exponential power trip and today's generations of "digital natives" form a progressively larger fraction of the population.

The truth is that societies – and particularly the experts of the day – have never been able to imagine where major technological innovations will ultimately lead. Marconi imagined that his radio was primarily for ship to shore communication; personal computers began as glorified typewriters; and the brilliant engineers at AT&T in the 1980s were somehow unable to imagine a mass consumer market for

portable phones! In the context of the traditional library, for example, librarians adapted to the online world first by simply migrating onto the electronic medium everything they used to do by hand and in print. Only then did they recognize that the new medium – like every new medium or technology – has a logic and rhythm all its own; in effect its own unique landscape that must be both *discovered* and *created*.

The challenge implied by what I have been describing is to adapt, and then to evolve, to a world in which:

- there continues to be an exponential increase in the supply of information handling capability relative to the supply of human attention – a ratio that has already undergone a 10 million-fold change in a little more than two generations;
- the peer-produced knowledge of the crowd – some of it wise, much of it not – will continue to supplant the intellectual authority of experts whose own mode of production will, moreover, increasingly conform to the rhythm of the web; and
- the flow of knowledge will thus increasingly dominate the stock of knowledge as the shelf-life of knowledge products shrinks and as those products themselves morph into multimedia, hyperlinked objects in cyberspace.

The epochal challenge facing the creators and stewards of humanity's codified knowledge is to guide us all in *developing* and *using* the tools needed to navigate an electronic information landscape in which both the supply of information and the competition for human attention are destined to grow without limit.

Notes on Sources:

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[1] Internet penetration in North America is already nearly 75%, while in Africa it is still less than 6% of the population. (Data downloaded 20/07/09 from www.internetworldstats.com)
[2] *FLOPS*; Wikipedia; downloaded 7/07/09
[3] *Wavelength-division Multiplexing*; Wikipedia, downloaded 21/07/09
[4] *Western Digital launches 2TB hard drive (27/01/09)*; ZDNet.co.uk
[5] *Moore's Law*, Wikipedia; downloaded 12/07/09
[6] H. Simon, *Computers, Communications and the Public Interest* (pp. 40-41); Martin Greenberger, ed., The John Hopkins Press, 1971
[7] *Moore's Law*, Wikipedia; downloaded 12/07/09
[8] *A Billion Year Ultra-Dense Memory Chip*; Berkeley Lab News Center; 31/06/09
[9] *Wikipedia: Size of Wikipedia*; downloaded 21/07/09
[10] See *FREE* (reference 11 below), p. 187, citing a survey in 2007 by Andy Oram of O'Reilly Media
[11] Chris Anderson, *FREE: The Future of a Radical Price*; 2009
[12] The quotations are from *Phaedrus* and are cited by Michael Lesk: *How Much Information is There in the World?* (www.lesk.com/mlesk/ksg97/ksg.html)
[13] *Not an Upgrade – an Upheaval*, by Clay Shirky; 13/07/09, (www.cato-unbound.org)