Some Thoughts on *Human Nature*:
A Discussion of Human Strengths and Weaknesses

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Abstract

This paper attempts to explore the behavioral characteristics of human beings from a point of view that is not based on inter-human comparisons, but on an examination of the intrinsic physical, biological, intellectual, emotional, and social characteristics of this species. It is argued that the experience-based nature of the human cognitive system greatly reduces our ability to adapt to changes in our environment, exploit opportunities, and create new knowledge. A fundamental biological survival instinct drives the human being to seek a level of certainty and security that is irreconcilable with a continuously changing and largely unpredictable environment. The symptoms of this distinctly human struggle manifest themselves in a strong resistance to change and an emotional aversion to experimentation and risk taking.

The author postulates that the merging of biology and technology will allow the human species to accelerate progress along its evolutionary path in preparation for a series of emerging environmental challenges. These challenges are most likely to be related to rapid world population growth in the context of finite natural resources. It is argued that the merging of biology with technology may be a prerequisite for providing human beings with the necessary intellectual capabilities to both mitigate the abuse and maximize the use of planet Earth.

This paper focuses on the need for technology to supplement and enhance the intellectual capabilities of human beings, and not on the technological prospects themselves. The latter can be found in the literature (Kurzweil 1999, Brockman 2002, Kelly 1994, Brooks 2002, Richards 2002).

Introduction: Will Technology and Biology Merge?

One could argue that among all attributes it is the intellectual capabilities that have allowed human beings to gain superiority over all animal species on planet Earth. These intellectual capabilities have allowed human beings to adapt to their environment, protect themselves from predators, and ensure the availability of an adequate supply of food and water under all but the most extreme circumstances. Furthermore, these intellectual capabilities have evolved from very primitive beginnings into much more sophisticated and specialized skills (e.g., observation, planning, coordination, and problem solving), over the relatively short period of a few thousand years.

The purpose of this paper is to explore the strengths and limitations of human beings within the context of an evolving information society. The principal enabling characteristics of this society are revolutionary advances in computer, bio-electronic, and communication technology. By utilizing these technological advances a single person is able to achieve today what entire organizations struggled to accomplish only 20 years ago. However, at the same time, these new opportunities are placing unprecedented pressure on the individual to perform at a significantly higher level of expectations. Clearly, the rapidly emerging emphasis on the potential contributions of each person, expressed in the adoption of knowledge management principles by organizations and a flurry of new laws in many Western countries aimed at protecting the rights of individuals (e.g., privacy, security and consumer protection laws), are symptomatic of this new awareness of the value of the individual.

How will the human intellectual capabilities that have served us so well in the past measure up in this new era of unprecedented opportunities and corresponding expectations? To what extent will the emotional pressure generated by significantly heightened expectations impact the useful application of our intellectual capabilities? In short, will we human beings rise to the occasion and accomplish an evolutionary leap that can keep pace with the revolutionary advances in technology?

Kurzweil (1999, Brockman 2002) argues rather convincingly that technology and biology will merge over the next millennium to significantly accelerate human evolution. Recent developments in subcutaneous sensors and prosthetics (Finn 1997), bio-engineered materials (Kelly 1994), brain scanning (Kiernan 1998, Hübener et al. 1997, Powledge 1997), DNA therapy (Time 1998), and unraveling of the human genome (DOE 2000), appear to be only the beginning of bio-electronic advances that promise profound extensions to the quality, productivity and longevity of human life. In Kurzweil's words (Brockman 2002) "… We are entering a new era. I call it the Singularity. It's a merger between human intelligence and machine intelligence …"

The Digital Transformation

Over the past 30 years the principal advances in digital technology have been related to the miniaturization of electronic components, increases in the power of computer hardware, and the connectivity provided by communication systems. While these advances have been dramatic in terms of continuous increases in computational speed, memory, storage capacity, and decreases in cost, the intellectual utilization and exploitation of these capabilities has been less than startling. The latter is the province of the software that executes on the hardware and allows human users to accomplish tasks.

It can be argued that our human view of computer software has been shortsighted in respect to two popular notions: that data and information are essentially synonymous terms; and, that computer intelligence is largely a misnomer because computers are machines. Neither of these notions is accurate. While we human beings are able to convert data (i.e., numbers and words without relationships) automatically into information due to the experience (i.e., context) that is held in our cognitive system, computers do not have the equivalent of a human cognitive system and therefore store data simply as the numbers and words that are entered into the computer. For a computer to interpret data it requires an information structure that provides at least some level of context. This can be accomplished utilizing an ontology of objects with characteristics and relationships (Pohl 2001). In this way it is possible to create a virtual version of real world situations in computer software.

For example, let us assume that we wish to represent a component of a building such as a conference room in the computer. Until recently, in a ***data-centric*** software environment, we would have treated the conference room as a three-dimensional geometric entity that can be described in terms of points (i.e., x-y-z coordinates), lines, or surfaces. While this may be satisfactory for displaying different internal views of the building space and even generating animated 'walk-through' sequences, it does not provide a basis for the computer to reason about any aspect of the space, such as that a conference room must have a door for it to be usable. To provide the computer with such a reasoning capability the particular entity, in this case the conference room, must be represented in the computer as an information structure that constitutes the context of a building. This can be achieved quite easily by storing in the computer the word building and associating this word with some characteristics such as: physical object; made of material; has height, width and length; consists of one or more floors; has spaces on floors; and so on. Then further defining spaces with characteristics such as: enclosed by walls, floor and ceiling; with wall having at least one opening referred to as a door; and so on.

In such an ***information-centric*** software environment the same conference room would be presented to and stored in the computer as part of the 'building' information structure (i.e., ontology) in the following manner:

Computer user:	I would like to represent a component of a 'building'.
Computer software:	Loads its stored 'building' ontology into memory. Asks user "What kind of a 'building' component?"
Computer user:	A 'space' of type 'conference'.
Computer software:	For how many persons?
Computer user:	Up to 16 persons.
Computer software:	Suggested space size is: 16 ft (length), 14 ft (width), 8 ft (height). Suggested furniture: 6 ft by 3 ft table, 16 chairs, screen, white board. Other features: There must be at least one door.

As can be seen from the interaction between the user and the computer software, by virtue of the information structure the computer has some understanding of the meaning of a building within the context of its characteristics and the relationships of its components (i.e., floors, spaces, walls, openings, and furniture). This endows the computer software with the ability to collaborate and assist the user by reasoning about the relationships between the data entered by the user and the context contained in the simple information representation provided by the 'building' ontology.

Now that the computer software has reasoning capabilities does that equate to intelligence? From a human point of view, hardly. However, one could ask: Is human intelligence the only form of intelligence? Arguably there are different kinds of intelligence and also levels of intelligence. The lowest level of intelligence is remembering. Certainly, computers have the ability to remember, in fact, one could argue that they surpass humans quite easily in this area. Reasoning is a higher level of intelligence. As has been shown by the previous example of the 'conference room', computer software can be designed with reasoning capabilities as long as there exists an underlying information structure that provides context. Learning is an even higher level of intelligence, yet elementary learning capabilities have been demonstrated in computer software for several decades (Forsyth 1989, Clancey et al. 1994). It would therefore appear that although computers are electronic machines they can function with some level of intelligence.

Humans are Situated in Their Environment

It is perhaps interesting to note that we human beings have little to compare ourselves to apart from other human beings and lower forms of life. Whenever we assess our capabilities we do so in comparison with our colleagues. Arguably, this gives us a very biased view of ourselves and makes us vulnerable to a self-centered interpretation of our environment in general and more specifically the events that occur within that environment. In short, we have a tendency to believe that everything revolves around us.

Clearly, we are situated in our environment not only in terms of our physical existence but also in terms of our psychological needs and understanding of ourselves. We depend on our surroundings for both our mental and physical well being and stability. Consequently, we view with a great deal of anxiety and discomfort anything that threatens to separate us from our environment or comes between us and our familiar surroundings.

This extreme form of ***situatedness*** is a direct outcome of the evolutionary core of our existence. The notion of evolution presupposes an incremental development process within an environment that represents both the stimulation for evolution and the context within which that evolution takes place. It follows, firstly, that the stimulation must always precede the incremental evolution that invariably follows. In this respect we human beings are naturally reactive, rather than proactive. Secondly, while we voluntarily and involuntarily continuously adapt to our environment, through this evolutionary adaptation process we also influence and therefore change our environment. Thirdly, our evolution is a rather slow process. We would certainly expect this to be the case in a biological sense. The agents of evolution such as mutation, imitation, exploration, and credit assignment, must work through countless steps of trial and error and depend on a multitude of events to achieve even the smallest biological change (Pohl 1999).

In comparison to biological evolution our brain and cognitive system is capable of adapting to change at a somewhat faster rate. Whereas biological evolution proceeds over time periods measured in millenniums, the evolution of our perception and understanding of the environment in which we exist tends to extend over generational time periods. However, while our cognitive evolution is of orders faster than our biological evolution it is still quite slow in comparison with the rate of change that can occur in our environment.

Human Resistance to Change

In the short term, the experience-based nature of our cognitive system creates a general resistance to change. The latter is exacerbated by a very strong survival instinct. Driven by the desire to survive at all costs we hang onto our past experience as an insurance. In this respect much of the confidence that we have in being able to meet the challenges of the future rest on our performance in having met the challenges of the past (i.e., our success in solving past problems). We cling onto the false belief that the methods we have used successfully in the past will be successful in the future, even though the conditions may have changed. As a corollary, from an emotional viewpoint we are inclined to perceive (at least subconsciously) any venture into new and unknown territory as a devaluation of our existing (i.e., past) experience.

This absolute faith in and adherence to our experience manifests itself in several human behavioral characteristics that could be termed weaknesses. First among these weaknesses is a strong aversion to change. Typically, we change only subject to evidence that failure to change will threaten our current existence in a significant way. An example is the rather slow transition from data-centric to information-centric computer software. Although the digital computer was originally conceived as a very fast computational machine capable of reducing the time required for the solution of large numbers of mathematical equations from days to seconds, it soon emerged as a data storage and processing facility. This was mainly due to the need for record keeping accelerated by the growth of commerce and industry driven by major improvements in the ability to travel and communicate over long distances. As a result new opportunities for interaction, leading to cooperation, and eventually collaboration, presented themselves. As the intensity of these activities and the tempo of daily life increased so also did the competition among the human players. However, it did not occur to these players for at least two decades that the functions of the computer could extend beyond the rote storage and processing of data to the representation of information as a basis for automatic reasoning capabilities. The eventual realization that human-computer interaction could be raised to the level of meaningful collaboration came not as a result of creative discovery, but because the requirement of interpreting the vast amount of computer-stored data simply outstripped the availability of human resources. In other words, it was not the opportunity for using computers in this far more useful role, but the necessity of dealing with an overwhelming volume of data that virtually forced computer users to elevate data-processing to information representation in support of automatic reasoning capabilities.

A second weakness is our apparent inability to resist the temptation of applying old and tried methods to new situations, even though the characteristics of the new situation are actually quite unlike the situations in which the existing methods were found to be useful. This typically casts us into an involuntary experimental role, in which we learn from our initial failures. Examples abound, ranging from the development of new materials (e.g., the flawed introduction of plastics as a structural building material in the 1950s) to the reluctance of the military to change their intelligence gathering and war fighting strategies long after the conclusion of the Cold War era in the 1990s.

A third weakness is our tendency to view new incremental solutions as final comprehensive solutions. A well known example of such a problem situation was the insistence of astronomers from the 2nd to the 15th Century, despite mounting evidence to the contrary, that the heavenly bodies revolve in perfect circular paths around the Earth (Taylor 1949). This forced astronomers to progressively modify an increasingly complex geometric mathematical model of concentric circles revolving at different speeds and on different axes to reproduce the apparently erratic movement of the planets when viewed from Earth. Neither the current scientific paradigm nor the religious dogma of the church interwoven within the social environment allowed the increasingly flawed conceptual solution of Ptolemaic epicycles to be discarded. Despite the obviously extreme nature of this historical example, it is worthy of mention because it clearly demonstrates how vulnerable the rational side of the human cognitive system is to emotional influences (Pohl et al.1997).

Range of Human Capabilities

Human competencies can be categorized into five principal capability groups. Since these categories are closely associated with the dominating role played by experience, it can be argued that human beings are situated in the environment physically, biologically, intellectually, emotionally, and socially (Fig.1). In each of these categories the range of capabilities varies widely, not only in respect to individual differences but more profoundly in respect to two situational factors. The first of these factors is centered on the environment and involves all of the natural, artificial, community, group, and family stimuli and forces that surround each human being. The second factor is related to the personal demeanor and qualities of the individual, such as motivation, diligence, perseverance, communication skills, willingness to cooperate, strength of character, and courage to pursue the unknown.

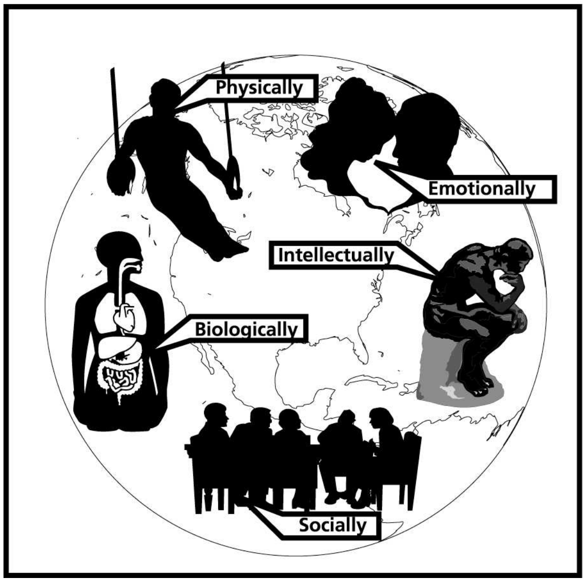

Fig.1: Categories of human capabilities

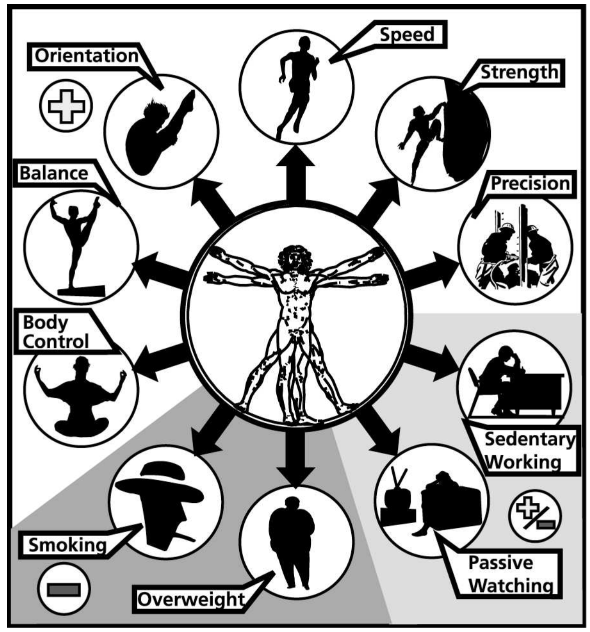

Fig.2: Range of ***physical*** capabilities

In the ***physical domain*** human beings are naturally endowed with a wide range of competencies involving both biologically based evolutionary capabilities such as body control, balance and orientation, and acquired skills such speed of movement, bodily strength and precision (Fig.2). While all of these physical capabilities can be significantly improved through training, repetition and concentration, they are also subject to fairly rapid deterioration through neglect and willful ignorance. Typically, the level of skill achieved in any of these physical areas is directly related to the effort invested by the individual, although at the highest levels of achievement intrinsic biological factors such as height, body type and innate talent may play an increasingly significant role. For example, to become a world class athlete will normally require a favorable physical disposition, as well as an enormous amount of training. However, interestingly enough, there are exceptions. Even today, we find examples of individuals who despite physical disabilities or even chronic illness, are able to achieve through sheer determination the highest level of athletic performance.

Clearly, the level of human achievement in the physical domain is largely a function of the effort that the individual is willing to invest. Although only a modest effort is required to maintain a baseline of physical capabilities and health, many human beings are unwilling to make this effort even under the most favorable environmental conditions that are prevalent in much of the Western world. Addiction to nicotine (i.e., smoking) and the excessive consumption of food leading to obesity are two primary examples. It seems apparent that even in the physical domain the intellectual and emotional disposition of the individual play a dominant role. While this role allows a few individuals to excel and achieve amazing physical feats, it prevents a much larger number of individuals from maintaining a healthy and enjoyable lifestyle.

Arguably it is in the ***biological domain*** that human beings are endowed with their most powerful and effective natural attributes. As shown in Fig.3 these range from reproduction, through growth and the protection offered by the immune system, to the natural repair of physical injuries and recovery from illness. At the same time, the effectiveness of these attributes diminishes with age. While the aging process may be delayed through good living habits, advances in medicine, and remedies provided by the rapidly developing field of bio-engineering, it cannot be stopped altogether. Unfortunately, human beings collectively and individually have found many ways to accelerate the aging process. Examples are readily found in environmental pollution, drug addiction, and overindulgence. Summarizing, in the biological domain the human being tends to be subject to inevitable degradation in the long term, relatively durable in the medium term, and self-repairing in the short term.

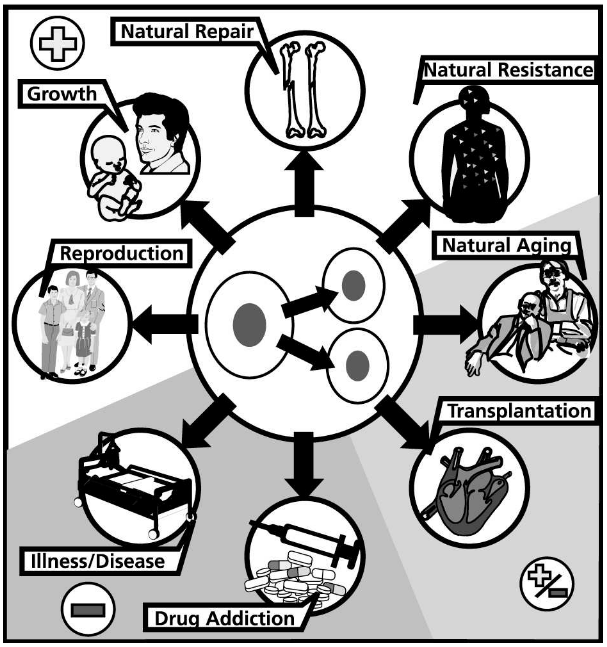

Fig.3: Range of ***biological*** capabilities

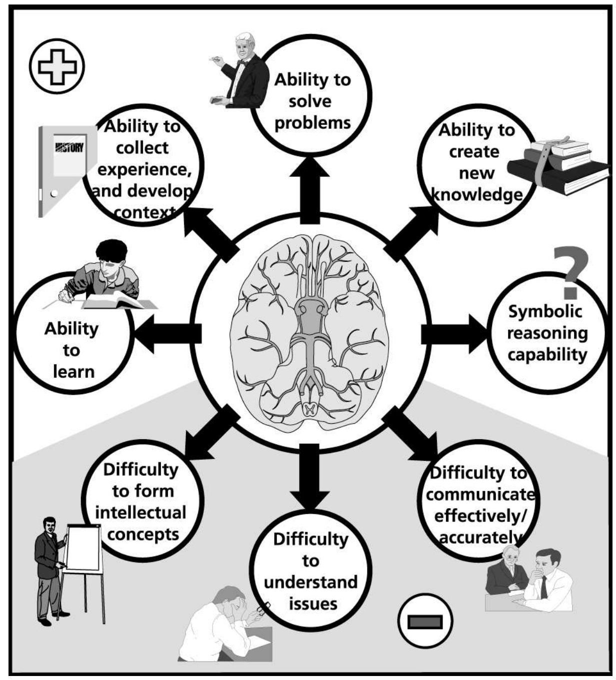

Fig.4: Range of ***intellectual*** capabilities

As discussed earlier, it is in the ***intellectual domain*** that human beings have easily outperformed all other species on Earth. Due, at least partly, to the power and versatility of their symbolic reasoning capabilities, human beings are able to learn, collect experience and thereby accumulate context, solve problems, and create new knowledge (Fig.4). However, it can also be argued that the human process of knowledge acquisition is rather slow, impeded by the fact that the attention and focus of the individual is easily diverted from the task at hand, and that the willingness to explore new horizons of knowledge is severely limited by both the experience-based nature of the human cognitive system and emotional factors.

In particular the human being struggles with the formulation of new concepts. Typically, it takes decades and sometimes generations for a very small number of gifted individuals to create new knowledge. Once this ground breaking intellectual work has been performed two interesting and apparently conflicting phenomena can be observed. First, more often than not the acceptance of the new knowledge is initially opposed by the current community of piers. Kuhn (1977) has drawn attention to the stagnating influence on progress of existing scientific paradigms, the resistance experienced by individuals who wish to correct flaws in the accepted paradigm, and the resurgence of innovative activity after the paradigm has been broken. The second phenomenon occurs later after the paradigm shift has been generally accepted and the new knowledge becomes part of the current body of knowledge in a field. Progressively this knowledge that was not long ago the sole province of the most learned members of a community of experts migrates to lower and lower levels of the educational structure, until it finally becomes part of the regular secondary school curriculum. In other words, the creation of new knowledge is a much more difficult task for the human being than understanding existing knowledge.

A good example of these two phenomena is the historical development of the digital computer. Commencing with Babbage in the early 19^{th} Century (Hyman 1982) it took more than 100 years to develop the half dozen intellectual concepts (such as binary representation, serial calculation, electricity as a medium, persistence through capacitance, etc.) that form the foundation of much of current computer hardware technology. Yet, today, these same concepts are readily understood by young children. The same example serves well to illustrate a third phenomenon that relates directly to the experience-based nature of the human cognitive system. Subsequent to the prolonged development cycle of the underlying concepts, the incremental engineering refinement of computer hardware proceeded at the astounding pace predicted by Moore's Law (Bell and Gray 1997). This difference in human performance exemplifies the difficulties encountered by an experience-based cognitive system in the creation of knowledge that deviates markedly from existing knowledge. The advances in engineering technology that were required for the implementation of computers built incrementally on existing knowledge, with each advance constituting only a small extension of what was already known. The formulation of the intellectual concepts that formed the foundations of this technology, on the other hand, required a change in prevailing scientific understandings and interests that constituted a paradigm shift.

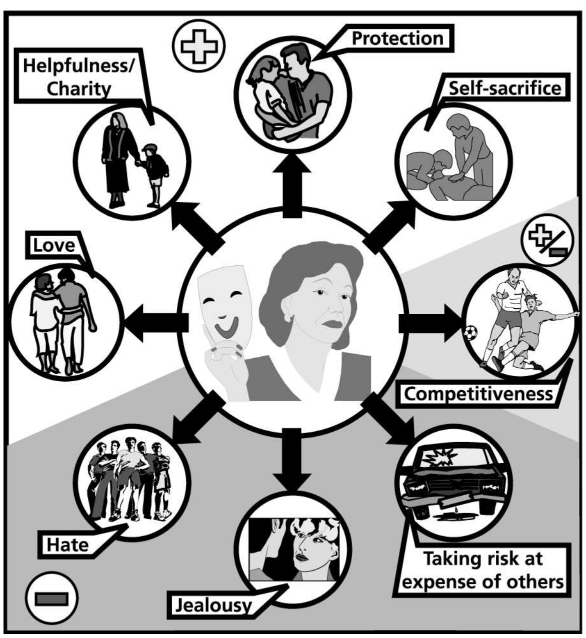

Fig.5: Range of ***emotional*** capabilities

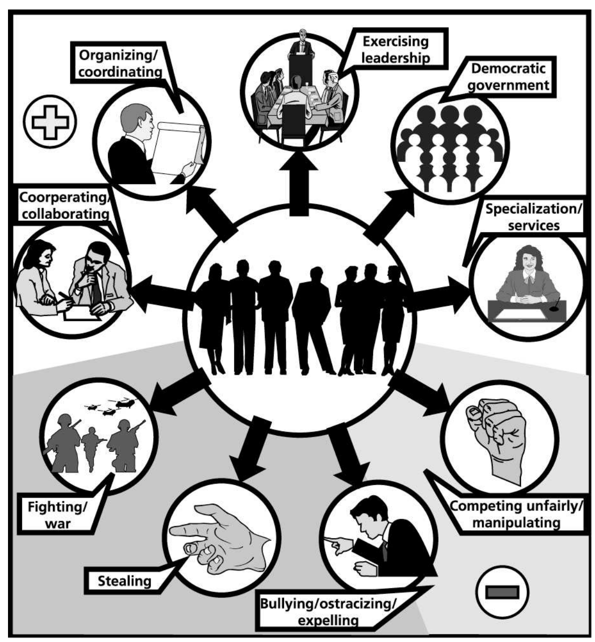

Fig.6: Range of ***social*** capabilities

The ***emotional domain*** is in many respects the primary governing domain in human beings. Driven by and at the same time generating biochemical reactions, emotional forces can easily transcend logic and intelligence, and under extreme conditions even apparent physical limitations (e.g., a mother lifting a car that far exceeds her apparent maximum lifting capabilities, to save her crushed child). The stronger the emotional forces the less likely that the individual will be able to make rational decisions based on logical reasoning.

In assessing the nature of the human being, the spontaneous ability to generate emotions could be considered the most powerful and valuable human characteristic. On the positive side emotions are the motivating force that drives individuals to achieve goals and objectives, to love and help others, and to perform a variety of protective and self-sacrificing acts that are altruistic in nature (Fig.5). Underlying many of the emotional acts is an instinctive competitiveness that varies greatly in strength from one individual to another. The positive products of this instinctive competitiveness include high levels of motivation and the ability to sustain a focused effort until an objective has been achieved.

However, the need for personal advantage which is certainly a fundamental ingredient of any competitive act can easily lead to negative results that are destructive to others. Among these are willful acts that are designed to disadvantage opponents, risks that an individual may take at the expense of others, jealousy, and hate. These negative outcomes of the emotional capabilities of human beings are typically more prominent, since they are usually the direct result of clearly discernable provocative acts that can cause a great deal of harm. Positive emotional behavior, on the other hand, tends to be less impulsive and is typically spread over longer periods of time. The results of the latter are therefore more apparent on a cumulative basis, as a series of less pronounced acts that eventually lead to either the fulfillment of a goal or at least a positive and useful trend. It is interesting to note that while the negative results of human emotions receive a great deal of attention, due to their hurtful and destructive nature, history has shown that the less prominent positive behavior easily outweighs the negative behavior over longer periods of time.

Through their abilities in the ***social domain*** human beings have been able to achieve collectively, in groups, much more than what can be achieved by individuals acting on their own. In fact, one could argue that the ability and willingness to organize, coordinate, collaborate, and provide leadership, is the principal vehicle used by human groups and organizations to advance their mission (Fig.6). Similar to the other four domains, the social domain also incorporates positive and negative behavior. On the positive side the individual members of the group, and the group as a whole, work together toward a set of goals and objectives that are acceptable to all group members and are compatible with other related social components that together form local, state and national communities. As the size of the group increases the role of leadership tends to be more clearly defined and circumscribed within a framework of increasing formality and representational power.

At least two negative factors impact the social domain. First, the competitive nature of human interactions often leads to unscrupulous manipulation (e.g., unfair trading practices, monopolies), expropriation (e.g., stealing), and in extreme cases forceful annexation and subjugation of the territories and people of other countries (e.g., war). Second, the experience-based nature of the human being fosters an intolerance to others with different views, ideals, customs, or habits. This can easily lead to the ostracizing of individuals and groups who deviate significantly from the experience base of the ostracizers. Collectively these negative tendencies continuously compete with the positive social capabilities to require a governed environment in which the conforming members are protected and the non-conforming members are restrained in their efforts to disrupt the social structure.

Symptoms and Causes of Human Tension

Survival is certainly one of the basic biological instincts of all animals. The human manifestations of this instinct are readily apparent in a strong desire for absolute certainty and ***security*** in a changing and largely unpredictable environment. We have great difficulties coming to terms with the fact that many of the forces that influence our situation are beyond our individual influence and control. We endeavor to make long range predictions, even though time and again we see evidence that these predictions fall far off the mark. Not only do we insist on such predictions, but we also apply the most precise mathematical techniques in a misguided attempt to ensure accuracy. While developments in the field of mathematics were certainly driven by the need for tools that could be applied to current endeavors, there has always been a correspondingly strong desire to apply these tools to the prediction of future outcomes and events. Elaborate mathematical models are often constructed to simulate the interaction of complex relationships over extended periods of time. When we are forced to explore why the real world behavior has diverged significantly from these simulations, we find that not only was the mathematical model simplistic and incorrect in the postulated behavior of individual variables but that many of the boundary assumptions were erroneous.

Other symptoms of the tension induced by the intrinsic human struggle with insecurity include: our insistence on applying only true and tried methods to current problem situations even though those situations may differ significantly from previous experiences (i.e., we simply find it very difficult to overcome our emotional aversion to experimentation and the risk of failure); our strong resistance to change (i.e., we typically have to be forced to change by an impending threat); our need to explain any currently unexplained phenomenon to eliminate uncertainty, even if we have to oversimplify the complex behavior of the phenomenon; and, our preference for ready-made solutions over tools (i.e., even though the tools would provide us with the flexibility of adjusting to real world conditions).

Another source of tension is the apparent desire to ***dominate***. It is a common trait in human beings to seek control and compliance, and to be intolerant to individual preferences. Typical examples range from: hierarchical organizational structures; unwillingness to share information; monopolies and unfair trade practices; orders without explanations; social classes and castes; dictatorships; regional invasions and wars; and, ethnic cleansing.

However during the past decade this source of tension has been mitigated by an increasing focus on the individual and the flattening of the traditionally favored hierarchical organizational structure into a web-like structure with a high degree of local autonomy. Driven mostly by the widespread availability of information technology, this has placed an unprecedented emphasis on knowledge and the value of human capital in a knowledge-based organization. As a result the notion of knowledge management has started to receive considerable attention in both government and corporate organizations. Simply stated knowledge management involves the effective acquisition, development and utilization of the human capital in an organization. The emphasis of this definition is on maximizing the contributions of the individual to the collective benefit of the organization. In this respect knowledge management serves primarily as a facilitating vehicle, with the objective of enabling the human and organizational capabilities for the benefit of the individual and the organization.

Through the distributed framework of leadership and communication made possible by the availability of information technology, knowledge management is able to execute its enabling role in several ways. First, knowledge management recognizes that every member of the organization is a contributor and a potential decision maker. Therefore its methods are designed to emphasize the encouragement, cultivation (e.g., professional development), and motivation of the individual. Second, by definition, knowledge management emphasizes local autonomy and concurrent activities. This recognizes that leadership should be exercised through example, clarity and communication, and not through authority. Under these conditions the principal tools of leadership are the continuous analysis of feedback, the meticulous explanation and justification of intent and direction, and the maintenance of effective self-development opportunities throughout the organization. Third, knowledge management tends to foster the formation of internal and external relationships, because the relationship capital of the organization becomes one of the most important catalysts for increasing the productivity of the organization.

Related to the desire for dominance is the inherent human behavioral characteristic of ***intolerance***. Generally speaking human beings seek conformity with currently accepted norms and tend to be intolerant of individual differences that deviate from these norms. Human society has always been pervaded with discrimination based on race, social position, and even personal appearance, as well as political and religious persuasion. In recent times democratic governments have found it necessary to pass anti-discrimination laws to, for example, safeguard the interests of ethnic minority groups, force consideration of the special needs of physically handicapped persons, and prevent the superficial profiling of criminal suspects by law enforcement authorities.

There is some doubt whether human beings are at all capable of altruistic behavior. The strong survival instinct leads to ***selfishness*** and behavior that is often detrimental to others. Certainly there is a pronounced human tendency to react aggressively to any perceived physical threat or psychological denigration.

Our deep seated self-preservation instinct manifests itself in several additional ways. For example, we find it very difficult to view a situation from any perspective other than our own. This leads to many misunderstandings and unnecessary retaliatory actions at all levels of human interaction. It also constitutes a major obstacle to meaningful cooperation among individuals and successful negotiations among groups. On a more personal level, individuals find it difficult to admit mistakes for fear of losing status in their interactions with others, and perhaps even more perilously for fear of losing confidence. In this respect human beings find it very easy to invent reasons that allow them to blame others for their own misfortunes.

The inherent human resistance to change, discussed previously, is accompanied by a general ***complacency***. Relatively few human beings are consistently able to motivate themselves to actively identify and pursue new opportunities. The vast majority judiciously avoid voluntary intellectual explorations and appear to lack the confidence to take risks. As a rule, we prefer to blindly continue rather than question old habits and preferences. In summary, we are uncomfortable with change, generally frightened of the unknown, and likely to support the status quo unless extremely threatening circumstances exist.

We human beings are inquisitive creatures who, for the reasons discussed previously, seek explanations for all that we observe and experience in our living environment. The influence of the tensions discussed above in our quest for understanding is evident in our problem solving behavior. We have a tendency to accept partial understandings and superficial explanations when the degree of complexity of the problem situation confounds our mental capabilities. In other words, often a superficial or partial explanation is considered better than no explanation at all. One could argue that as flawed as this approach may be, it has helped us to solve difficult problems in stages. By first oversimplifying a problem we are able to develop an initial solution that is later refined as a better understanding of the nature of the problem evolves. Unfortunately, due to our strong resistance to change, aversion to risk taking and inherent complacency, this approach can lead to ingrained misconceptions that may take years and sometimes decades to correct. Once we have found an apparently reasonable and workable explanation or solution we tend to lose interest in pursuing its intrinsic shortcomings and increasingly believe in its validity. Whether driven by complacency or lack of confidence, this state of affairs leads to many surprises. We are continuously discovering that what we believed to be true is only partly true or not true at all, because the problem is more complicated than we had previously assumed.

Human Limitations and Weaknesses

Deeply embedded in the evolution of the human intellect is the rationalistic approach to problem solving. At face value this approach appears to be entirely sound. It suggests that problem solving should proceed in a logical sequence of clearly defined steps. One begins by defining the problem and then decomposing the defined problem into sub-problems. Decomposition appears to make a great deal of sense because the parts of a problem are intrinsically easier to solve than the whole problem. The reason for this is that the complexity of a problem is normally due to the nature and number of relationships among the elements of the problem and not due to the elements themselves. Decomposition allows us to temporarily neglect consideration of many of these relationships. However, this over-simplification of the problem is valid only as long as the problem remains in a decomposed state. As soon as we try to integrate the separate solutions of the parts into a solution of the whole the relationships that we so conveniently disregarded reappear and invalidate many if not most of our neatly packaged sub-solutions. We find to our consternation that the characteristics of a part of a problem situation considered in isolation are not necessarily similar (let alone the same) as the behavior of that part within the context of the whole problem.

Within the rationalistic paradigm this forces the human problem solver to repeat the decomposition process multiple times in a cyclic manner, shaping the sub-solutions to incrementally accommodate the influences of the various relationships until an apparently acceptable solution of the whole has been found. This process is laborious and in many complex and dynamic problem situations does not lead to a solution that should be considered as acceptable, but is nonetheless often adopted out of desperation.

Why have we human beings come to rely so heavily on this flawed approach to problem solving? The reasons are related primarily to the biological nature of our cognitive system, and secondarily to some of the tensions discussed in the previous section. While the biological basis of human cognition is massively parallel (i.e., millions of neurons and billions of connections, referred to as synapses) our conscious reasoning capabilities are largely sequential. The fact is that our short term memory has a severely limited capacity of only a few chunks of data at any one time. Therefore, we can differentiate among only a small number of objects at any one point in time, even though we continuously move new data chunks from long term memory into short term memory. As a consequence we have great difficulty dealing with more than three or four relationships concurrently.

In summary, we decompose complex problems to temporarily reduce the number of relationships, thereby oversimplifying the problem to make it solvable utilizing a sequential logical process. We are forced to do this because our conscious reasoning facilities are easily overloaded with information.

Secondary limitations and tensions that contribute to our human problem solving difficulties include our tendency to seek a degree of accuracy that is often unrealistic and usually unnecessary. Our aversion to risk and instinctive need to survive drives us to try to predict the future with great accuracy. In this respect, as mentioned previously, we place a great deal of reliance on mathematics even though mathematical models often fail due to oversimplification of the problem situation and incorrect boundary assumptions (Pohl 1999).

We often seek to produce an optimum solution even though the problem conditions are continuously changing and, therefore, we have no benchmark that would allow us to judge whether a particular (apparent) solution is in fact optimal. In other words, under dynamic conditions there is no static benchmark available. This creates related difficulties, because our ability to interpret and judge any situation is necessarily based on comparative analysis. Subject to the experiential basis of the human cognitive system we normally have no alternative but to measure new situations with existing metrics based on past experience. However, the further the new situation deviates from past experience the more misleading the available metrics are likely to be. As a result, since we have no effective metrics for assessing new situations, we typically require a considerable period of time to correctly evaluate such situations. Accordingly, it is not unreasonable to conclude that human judgements are more influenced by the past than the present.

More comprehensively stated, the essentially experience-based nature of human cognition forces us almost always (i.e., at least initially) to apply existing methods, notions, and concepts to new situations. Therefore, our most effective problem solving capabilities utilize prototype solutions based on past experience. While we have become quite skilled in adapting, modifying and combining such prototype solutions, we find it very difficult to create new prototypes. As a consequence we invariably apply existing solution methods to new problem situations and develop new methods only through painful trial and error. This also leads us to generally underestimate the complexity and impact of new situations.

Human Strengths

So far in this paper the discussion has centered on the apparently numerous limitations and weaknesses of human beings, particularly in respect to intellectual and emotional capabilities. Surely we human beings also have intellectual strengths. The answer is yes, of course, but with some qualifications. Certainly human learning capabilities, supported by a very large associative long-term memory, are vast. However, our rate of learning is rather slow and appears to lack efficiency. While some of this inefficiency is undoubtedly due to human communication inadequacies, the very process of progressively collecting experience by building onto existing associative knowledge structures would appear to be cumbersome and rather time consuming. It is not simply a matter of adding new knowledge elements or associating existing elements by inserting linkages, but instead patterns of neural activations (i.e., firings) have to be repeated many times before they are literally grooved into long-term memory. It is therefore not surprising that formal education takes up one quarter to one third of a human life span and involves a great deal of concentration, as well as assistance from other human beings who have acquired special teaching skills.

An important part of the human learning capability is the ability to conceptualize experiences into knowledge that we consider to be true in most cases. In this way we place emphasis on being able to deal with general conditions and consider the exceptions to the general rules to be much less important. This again exemplifies the human tendency to oversimplify a situation for the sake of being able to reach a quick solution to a problem or an explanation of an observed phenomenon. In fact, as we discover to our consternation time and again, the exceptions are often more important than the generalizations (Minsky, 1990).

It must also be noted that much of human learning is involuntary and therefore virtually effortless. This applies in particular to the acquisition of low-level, largely involuntary skills such as sensory pattern matching that allows us to automatically convert data to information. For example, when we enter a restaurant we immediately recognize the furniture in the room. In fact, our eyes see only image patterns. However, these are automatically interpreted as tables and chairs by our cognitive system which has by experience related these image patterns to the appropriate symbolic entities.

At a higher level, symbolic reasoning allows us to infer knowledge from information. When our reasoning capabilities are unable to cope in complex situations that include many relationships, conceptual pattern matching (i.e., intuition) allows us to assess situations without resorting to logical reasoning. However, again there is evidence that this process is greatly facilitated by experience. Klein (1998) found that highly experienced fire captains will resort to the situation analysis methods employed by novices when they are confronted with situations outside their sphere of experience.

While the creation of new knowledge is normally the province of individuals, once such an intellectual leap has been accomplished we collectively excel in the technological exploitation of this contribution. Typically, this exploitation proceeds incrementally and involves a large number of persons, coordinated in a self-organizing fashion but willing to collaborate to leverage the capabilities of individual contributors.

Although our ability to create new knowledge is severely limited, each generation of human beings appears to be capable of producing at least a small number of individuals with far superior intellectual capabilities and insights. How these individuals create new knowledge is not at all understood, however, the ability to associate the characteristics of one situation with another apparently unrelated situation is suspected of playing an important role (Lakoff and Johnson 1980). Such analogous associations appear to provide a mental bridge that extends existing experience into unknown territory to provide a necessary basis for the creation of new knowledge through deductive reasoning.

There are other human strengths that should be briefly mentioned even though they fall outside the principal focus of this paper. Firstly, human beings appear to have some extra-sensory perception capabilities, although these have been demonstrated by very few individuals. Secondly, although human beings have generally similar needs and capabilities, they display a relatively wide range of individual differences (particularly in the intellectual and emotional realms). Thirdly, human beings tend to degrade gracefully and recover relatively quickly. For example, we recover from sleep deprivation by sleeping far fewer hours than we have previously been deprived of. Another example is the ability of our cognitive system to at least partially compensate for many forms of physical brain damage. Fourthly, human beings can be tenaciously persistent in their efforts, and unwilling to give up even under the most adverse conditions. Added to this is our ability to provide leadership and motivate others. At times we can be highly persuasive and even inspirational. And, despite all of our intellectual and emotional limitations we tend to be generally constructive and are able to maintain an innate sense of moral integrity.

However, finally, perhaps one of our greatest human strengths is the discovery of the usefulness of tools early on in our evolution. Since then we have been successful in the development and application of more and more powerful tools. Today, as discussed at the beginning of this paper we are on the verge of merging computer-based tools with the biological fabric of our very existence.

Overall Assessment and Conclusions

Clearly, the fundamental role that experience plays in all human endeavors cannot be overstated. Virtually all of our intellectual abilities are centered on the collection, analysis, and application of experience. While we can readily refine and extend our existing knowledge base, we have great difficulty creating new knowledge that is not founded on existing understandings. This is of course entirely consistent with the symbolic reasoning processes that are at the core of human cognitive capabilities. Reasoning cannot take place without information. The most readily available information is the experience that is held in long-term memory. New data that are collected through the senses are processed within the context of the existing experience, and may either confirm that experience or extend it in multiple ways. Sensory data that are totally inconsistent with the body of existing experience are likely to be rejected at first. Only if these inconsistencies become in themselves consistent or pose a serious emotional threat (e.g., confidence) or physical threat (e.g., bodily harm) are they consciously integrated into the experience base. There are at least two consequences of these inherently human cognitive characteristics. Firstly, we are governed by a deeply rooted emotional resistance to change that allows us to abandon experience and existing understandings only under extreme and threatening conditions. Secondly, we have great difficulties creating new knowledge and adjusting to paradigm shifts in experience and understanding.

The discussion of human characteristics presented in this paper is of course by no means comprehensive, nor does it pretend to represent a scientific treatise based on physiological and psychological experimental findings. Rather, it represents the author's experiences, reflections and views collected as a willing participant in the complex adaptive system of human interactions. The impetus for this paper stems from the author's involvement in the development and exploitation of information systems technology over the past several decades. There is no question in the author's mind that the human species stands at the threshold of a paradigm shift that will progressively over the next millennium merge computing technology with biology, to the benefit of human kind.

Hypothetically, it might be argued that computing devices are a natural ingredient and necessary requirement for accelerating the intellectual evolution of human beings. For this hypothesis to hold true, computers would need to be able to compensate for at least three current limitations of the human cognitive system; namely: poor performance in the absence of experience; emotional interference with logical processes; and, a distinct lack of motivation for proactive endeavors.

Existing computer capabilities that show promise in this regard include: information storage in context building ontological structures; symbolic reasoning; pattern matching; computation speed; virtually unlimited parallelism; low level learning; analogy detection; and, tireless unemotional task performance. However, several additional capabilities would appear to be required. These include at least the following: accelerated automatic context generation to form the basis of higher level learning capabilities; a seamless interface with the human nervous system; and, knowledge creation through analogous reasoning or other (as yet unknown) processes.

Returning to present reality, a succinct overall assessment of current human capabilities, as might be suitably recorded in a 'report card', could state:

> *"An instinctive need for survival, a desire for short-term gratification, and experience-centered mental processes coupled with largely uncontrolled emotional responses, provide a reasonable basis for incremental intellectual contributions but neither foster nor support intellectual paradigm shifts."*

Behavioral Categories	***Grade***	***Evaluation Comments***
'Physical' performance:	***B+***	*Substantial inherent capabilities, mostly underutilized due to lack of motivation, confidence, and appreciation.*
'Biological' performance:	***A-***	*Regenerative and forgiving, but susceptible to short-term attack and long-term deterioration due to aging.*
'Intellectual' performance:	***C-***	*Strongly experience-based, leading to incremental rather than leap-frog contributions.*
'Emotional' performance:	***B-***	*Wide range of mostly reactive emotional swings, slightly favoring positive behavior.*
'Social' performance:	***C+***	*Generally positive community spirit, but severely dampened by competitiveness, selfishness, and intolerance.*

Fig. 7: A Report Card: Homo sapiens

The author is certainly open to the dual criticism of being presumptuous and biased in having the audacity to attempt to issue a report card assessing the performance of the human species (Fig.7). The reader might well ask what benchmarks has the author used in his evaluation? The answer is that no independent scientifically valid benchmark is available. That is of course one of the points made in this paper. Assessments of human capabilities and performance have always been based on what is statistically determined to be a normative standard for a representative sample of human subjects. In other words, we human beings always measure ourselves against other human beings. The intent of this paper, on the other hand, is to critically evaluate human beings not in respect to other human beings but in respect to their behavioral characteristics and to what extent the interaction of these characteristics will by themselves be able to support the continuing advancement of human problem solving skills and adaptation capabilities.

Why is this of any consequence? Surely, we live in a world that is dominated by human beings and the only threats to human beings are the actions or results of actions perpetrated by other human beings. While that assumption has certainly been true in the past, it may not hold true for the future.

The first serious challenge to survival that mankind will face is likely to come from the environment we live in (Wilson 2002a). For example, with the present rate of consumption and population growth we are projected to soon experience significant usable water shortages in many regions of the world. From a more general point of view we are still largely oblivious to the world's needs for supporting seven billion inhabitants, and the appropriate proportion of natural resources that each of us might be reasonably entitled to, if we wish to sustain our planet. The lifetime consumption rates projected for the average American by the Mineral Information Institute of Golden Colorado are foreboding, to say the least (Fig.8). With a current population of 280 million the USA alone is projected to consume more than 1 billion pounds of minerals and fuels over the next 70 to 80 years.

Wilson (2002b, 84) measures the sustainability capabilities of Earth in terms of ***ecological footprint*** (i.e., the area of productive land and shallow sea required to support a single person in terms of food, water, housing, energy, transportation, commerce, and waste disposal). The average ecological footprints in the USA and for the world population as a whole are 24 acres (9.6 hectares) and 5.2 acres (2.1 hectares), respectively. If the more than five billion people in developing countries were to achieve even half of the US levels of resource consumption then based on current technological capabilities we would require at least two Earth planets to support the world population.

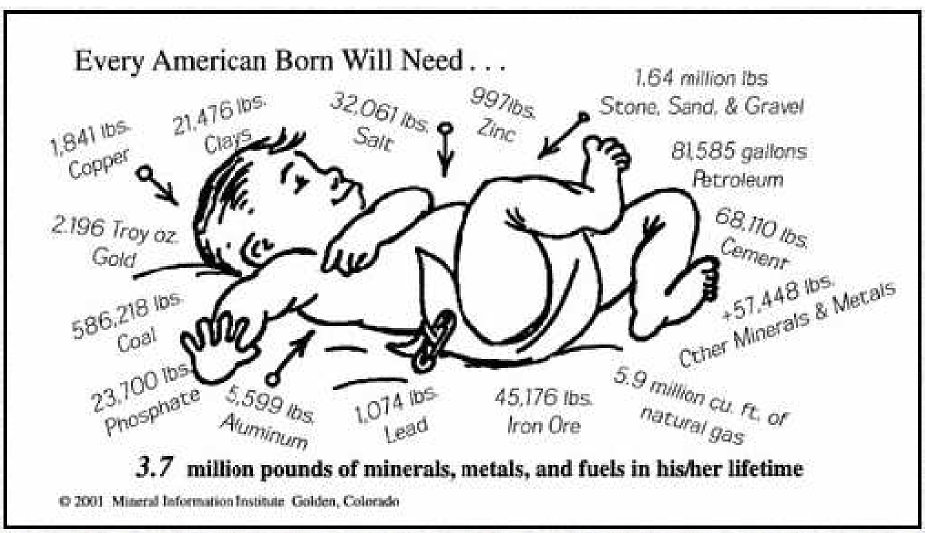

Fig. 8: Lifetime consumption of resources by the average American
(Source: Mineral Information Institute of Golden Colorado (http://www.mii.org/))

It may be argued that Homo sapiens is the first species in the history of our planet that has become a geophysical force. In Wilson's (2002b, 84) words "… we have entered the Century of the Environment, in which the immediate future is usefully conceived as a bottleneck". Mankind will require every possible intellectual and physical enabler that technology can provide to pass through this bottleneck and emerge with a fighting chance on the other side.

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