Brain and Mind: The Ultimate Grand Challenge

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Abstract: Questions about the nature of brain and mind are raised. It is argued that the fundumental understanding of the functions and operation of the brain and its relationship to mind must be regarded as the Ultimate Grand Challenge problem of science. National research initiatives such as the Decade of the Brain are discussed. **Keywords:** brain, mind, awareness, consciousness, computers, artificial intelligence, meme, evolution, mental health, virtual reality, cyberspace, supercomputers.

I. Introduction.

The notion of Grand Challenge problems is beginning to emerge as massively parallel computer systems are nearing the ability to perform 10^{12} floating operations per second [teraflops]. Grand Challenge problems are theoretical / computational problems whose solution will contribute knowledge and understanding comparable to or exceeding that obtained past national research and development projects represented by the manned mission to the moon and the most energetic particle accelerators. Grand Challenge problems are intrinsically computationally complex problems that stand at the forefront of science. Examples of recognized Grand Challenge problems are modeling and simulations of global climate, calculation of chemical properties and reaction rates from first principles [Schroedinger's equation], pattern recognition in extremely long sequences such as those found in DNA, and the field of artificial life where computer simulations model the evolution of artificial life forms [not necessarily biological].

Some of the computer platforms presently being considered for Grand Challenge applications include the Touchstone Delta System, a 528 Intel-80860 processor architecture, the Touchstone Sigma [a 2048 I80860 processor system], evolutions of Thinking Machine's Connection Machine series computers [CM2] and of CRAY Y-MP series computers. The Touchstone Delta, to be operated by the California Institute of Technology, is designed for a peak speed of 32 Gflops while the Touchstone Sigma is being designed for a peak speed of 150 Gflops.

The Grand Challenge applications being discussed widely are principally those of the physical/engineering sciences. In this paper, the notion of the Ultimate Grand Challenge problem is presented. *It is argued here that the most interesting and significant problem of science is that of Brain and Mind.* In his later years Schrodinger (1944, 1959) focused attention on the study of life and the question of who we are. According to Eccles (1953), Schrodinger regarded the answer to the question "not only one of the tasks, but *the* task of science." Eccles extended the articulation of the problem to the "nature of man, and the way in which the brain achieves liaison with mind". Others, such as Edelman (1990) pose the question "when and how did mind appear in nature?"

As with Eccles, the term 'mind' will be used in the context of conscious or 'aware' mind. The principal activities of mind are thinking, remembering, perceiving, willing, feeling, recognizing, liking and wanting.

Brain and Mind

The human brain is regarded by some as the single most complex entity in the universe. Currently it is viewed as the organ with which mind is associated. It is presently straightforward to characterize the components and the totality of the brain. One can characterize size-hierarchical levels of organization [e.g. synapse, dendrite, neuron, layer, column, map, and brain]. Another way to characterize the brain is by specific regional/functional groupings such as the peripheral ganglia, the olfactory bulb, the retina, the cerebellum, the hippocampus, the neocortex, Wernicke's speech area, Broca's speech area, Corpus Callosum, etc. One may describe various molecular components such as neurotransmitter compounds, receptors, and membranes.

The mind is infintely more complex to describe! Essentialy, the brain can be and is described objectively. One can obtain optical, x-ray, PET, CAT and NMR images of the brain; one can examine parts of the brain under a microscope. One can measure activity of the brain using EEG (electroencephalography), and magnetic sensors. Essentially, description of the brain is procedural, and is independent of the observer (although different observers may interpret their observations differently). By contrast, the mind is intrinsically a subjectively described entity. All one can describe is one's own perception of one's own mind and results of actions of another's mind. Associated with minds are entitites known as selves. Minsky (1986) states that human minds contain entities known as selves [the identity or personality of a given person as distinct from all others], and mentions the single self and multiple self views.

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Minsky has done much to collect and present a variety of approaches to modeling brain/mind events in basic terms. He presents views of philosphers, such as D. Hume, who regard mind as a collection of diverse perceptions with certain relationships that are falsely endowed with simplicity and identity.

Other investigators view the brain as control organs. Turchin [1977] ascribes to the brain the functions of receiving impressions, sorting them, grouping them but also the basic function of controlling the organism and affecting its environment. In Turchin's theory, successive hierarchical developments emerge from control [in the sense of control theory and cybernetics].

There are many components to the Ultimate Grand Challenge. There is the long standing question of how minds form. Lockian issues of in-built nature vs. growth of mind. The questions of Spinozza's thoughts and emotions. The contrasts of pleasure and pain and other contrasting mental states. A major issue is that of self-knowledge or self awareness. There is the question of language, and the theory of language as continuation of brain [Turchin]. Language being the 'mental' result of efforts of most members of a society. There are the aspects of language as building things [models, concepts and ideas] in our minds. Yet the fact that words themselves can't be the substance of our thought.[Minsky]. It is clear that words are words involved with mental processes, but what are the physiological connections? Dawkins, Bonner, Lumsden, Wilson, Moritz and others have presented a foundation for discussion of language and culture in terms of memes. One can restate Minsky's question " How does language allow people to communicate? What is consciousness? Edelman presents vexing possibilities in terms of re-entrant dynamics. Minsky's straightforward definition is that consciousness is knowing what happens in our mind right at the present moment. There are the application question of mind and brain extended to culture and society. There are the questions of will and of creativity. There are the questions of goal setting; nature does not give man goals, man gives man goals. There are the possibility of metaphors which allow us to replace one thought by another. Perhaps the best modern statement of the Ultimate Grand Challenge is the derivative of Schrodinger's question as posed by Minsky, "How can genes build concepts into mind when genes themselves are merely linked-together chemicals? "

A derivative but important question is whether mind and brain are constrained to exist solely in biochemically based architectures [human beings], or can they exist in sufficiently complex electronic implimentations that have billions of elements and still larger number of connections? If so, where does one start in representing the building blocks of mind? In all likelihood, these are the questions that will pace the next century?

The Decade of the Brain and the McDonnel-Pew Program.

Several major initiatives that lay a solid foundation for tackling the Ultimate Grand Challenge are already in place. The ***Decade of the Brain*** is a special initiative submitted by the National Institute for Mental Health as a result of a comprehensive study conducted by the National Advisory Mental Health Council. This initiative was approved by Congress and officially launched by the President of the United States. While the underlying justification for this initative was the need to embark on a concentrated effort for neuroscience research on mental illness, the initiative requires a thorough understanding of normal brain functions. Included as part of the specific challenges in the NIMH report are the [report] numbered challenges listed below:

2. How do environmental factors, such as stress or experience, alter brain structure and function?
6. How are memories encoded, stored, and retrieved?
7. How does neurnal activity influence genomic expression of nerve cells?
16. How is the correct wiring of the brain achieved?
22. What are the significant structural and functional changes in the frontal cortex and subcortical structures in schizophrenia?
25. Can we develop useful data-based computer models of the brain?
28. What essential properties of the brain give rise to conscious awareness?
30. What is the function of sleep, and how is it regulated by the brain?
32. Why is thinking so easy for normal people and so abberant in schizophrenics?
40. What new insights into brain function and human behavior can be gained through the application of nonlinear dynamic theory?
46. What advances in mathematics, physics, and computer science can be used to enhance noninvasive brain imaging techniques?
50. Given the degree of homology between the human brain and those of other species, what makes us unique?

These are some of the major challenge questions posed by the Advisory Council which appear to be relevant to the Grand Challenge problem. NIMH has emplaced and embarked on execution of a plan that calls for an annual investment of approximately $100 Million in Decade of the Brain neuroscience research activities. Results of research of the past decade indicate that much progress will be made and relevant pieces of the Mind/Brain puzzle will emerge.

Another, privately funded, research initiative program is the McDonnell-Pew Program in Cognitive Neuroscience. This program, administered by Princeton University, is in the process of allocating $12 Million over a three year period to study brain processes that make mental events possible. A principal part of this program falls in the Brain and Mind category. It is intended that images of the living brain will be correlated with neural and mental processes. This program has sponsored centers for cognitive neuroscience research at Oxford University, MIT, UCSD, University of Arizona, Dartmouth University, The Johns Hopkins University, Montreal Neurological Institute and the University of Oregon.

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In the support of the Ultimate Grand Challenge, one of the stated goals of the program is to "to develop new theories of the human mind/brain system".

Conclusions

The Ultimate Grand Challenge of describing the emergence of mind from brain is stated. Computational resources and research funding resources which will allow progress towards solving the Ultimate Grand Challenge are beginning to emerge. A significant element of the Ultimate Grand Challenge is the understanding of the role of language in the emergence of mind. Given that language is a societal phenomena [requiring several members], there is a strong argument for understanding the way language is used and the way words and ideas [combinations of words] spread in society. It is suggested that the computational study of dynamics of language formation and idea spread be considered a fundumental aspect of the Ultimate Grand Challenge. The computational study of language and idea formation and spread then offers the very real possibility of simulation of the emergence of mind in electronic [or other non organic] architectures.

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