

THE COMPUTATIONAL BASIS OF CONSCIOUSNESS

HOW YOUR BRAIN COMPUTES YOUR SOUL

PREFACE

THIS IS A WORK IN PROGRESS

It's an exploration of a great mystery: how God -- however you define him, her, it -- breathed the light of consciousness into the meat and bones of our bodies. It explores in the footsteps of great thinkers in brain science, cognitive psychology, artificial intelligence, physics, and philosophy.

I welcome your input, both positive and negative. If we are to understand this mystery, and how to explain it to the world, we need open minds, cooperation, and brilliant guides and helpers.

My goal is to explain how thought and consciousness are computed. This is too important to be known only by academics and geeks. I want it explained to the world. I want videos (and, if I can, a movie), interviews with experts, a story line that relates it to viewers' lives, and programmable animations to visualize so a bright eight-year old can understand it.

Why? Because the technologies of mind and consciousness (collectively "mindtech") are on the verge of creating conscious, electronic, superintelligent minds. Minds of this unbelievable power can either enslave (and perhaps ultimately kill) us, or enlighten and help us solve the extremely serious problems already threatening humanity. If democracies are to succeed in using mindtech to make our future democratic, humane, and enlightened, voters need to truly understand their own minds, the collective minds of human institutions, and the minds of superintelligent machines. They need to do so they -- the people -- and not extreme concentrations of power -- can hold the reins, at least on earth, of the universe-changing power of superintelligent conscious machines.

I welcome your help in this exploration, and in explaining it to the world.

Ed Porter

MY HYPOTHESIS: CONSCIOUSNESS IS SPECIAL COMPUTATIONAL AWARENESS

-PEOPLE EXPERIENCE CONSCIOUSNESS AS AWARENESS OF INFORMATION AND ITS COMPUTATION

-Awareness of what they see, hear, taste, touch, smell, feel, emote, intuit, understand, think, and imagine. These are nothing but awareness of information and its computation.

-SCIENCE DESCRIBES REALITY AS NOTHING BUT INFORMATION, ITS COMPUTATION, AND THE AWARENESS INHERENT IN ALL COMPUTATION

-When a computer adds X to Y to get Z, it has to be aware of the values of X and Y. When reality computes the acceleration of objects, it has to be aware of their mass and position, and of the many forces acting upon them. This is "computational awareness," "COMP-WARENESS" to save five syllables) the awareness of input values required for a computation's output to vary as a function of those inputs. It's causal information flow creating mutual information between inputs and outputs.

-SO BOTH CONSCIOUSNESS AND PHYSICAL REALITY ARE THE SAME THING -- BOTH WEBS OF INFORMATION, COMPUTATION, AND THEIR COMP-WARENESS

-No dualism, and no mysticism, is required to explain consciousness, because -- despite vastly different characteristics -- consciousness and physical reality are made of the same basic "stuff."

-THE "HARD PROBLEM OF CONSCIOUSNESS" IS NOT ...

.....HOW CONSCIOUSNESS HAS AWARENESS

.....Because all physical reality has awareness to some degree, however limited.

.....HOW CONSCIOUSNESS CAN HAVE SOMETHING "IT IS LIKE TO BE"

.....Because all reality has something "it is like to be." It has both "being" and comp-awareness of that being.

.....HOW CONSCIOUSNESS IS SUBJECTIVE WHEN THE REST OF REALITY IS SUPPOSEDLY OBJECTIVE

.....Because the comp-awareness of all reality is "subjective" in the sense that each part of reality has awareness of information no other part can even begin to fully share.

-INSTEAD, THE "HARD PROBLEM" IS EXPLAINING HOW CONSCIOUSNESS IS COMP-WARENESS

-That is, how can our particular, seemingly miraculous, consciousness -- with its sense of self, unity, simultaneity, and many distinct phenomenal qualities -- arise from the comp-awareness of tens of billions of individual neurons and hundreds of trillions of individual synapses.

TO ANSWER THE HARD PROBLEM WE SHOULD DO THE FOLLOWING...

...THINK ABOUT WHAT COMP-WARENESS IS IN GENERAL -- AND WHAT IT IS IN THE HUMAN BRAIN IN PARTICULAR

-This involves thinking about how comp-awareness could be generated by what we know from brain science, artificial intelligence, and simulated computer models using knowledge from both fields.

...THINK MORE SERIOUSLY ABOUT WHAT OUR CONSCIOUSNESS SEEMS TO BE

-This is something that receives much less attention than it deserves -- something that is often hard to put into words.

...ATTEMPT AN EXPLANATORY MAPPING BETWEEN CONSCIOUSNESS AND COMP-WARENESS

-Taking into account the inherent limitations of any attempt to fully understand either, or the transformation between them.

IN GENERAL, COMP-WARENESS HAS PROPERTIES OF NON-LOCALITY AND UNITY

-UNITIES OF COMP-WARENESS CAN BE CREATED ACROSS MULTIPLE ORGANIZATIONAL, SPATIAL, AND TEMPORAL SCALES BY COORDINATED INTERACTION BETWEEN INDIVIDUAL COMPUTATIONAL UNITS AT ONE SCALE AND COLLECTIVES OF SUCH UNITS AT ANOTHER.

-IN ROCKS ---- When viewed at the scale of angstroms and terahertz, a rock does not move as one. But when viewed at a large temporal and spatial scale, rock atoms move as a unit because of the feedback loop between the electromagnetic forces of individual atoms and large collections of them.

-IN SOUND WAVES ---- Sound waves are pressure waves, but pressure is a statistical concept that only has meaning when measured over many air molecules. A volume of air can have computational awareness of multiple sound waves at once, creating comp-awareness that is unified in at least one of the ways our consciousness is unified.

-IN STADIUM CROWDS ---- In an exciting game, a stadium crowd can seem to have a collective consciousness of its own. This is because:

- (1) Each individual senses separately.
- (2) But many individuals sense the same thing -- or part of the same thing.
- (3) As a result, many individuals respond in a correlated, collective manner -- such as through chants, waves, or roars -- generating strong audio, visual, vibrational inputs from the collective crowd.
- (4) Each of many individuals has correlated awareness of the same strong signals generated by this collective.
- (5) This feedback loop repeatedly computes between individual and collective awareness, creating sustained collective computational awareness and correlated individual awarenesses that are much larger in number and amplitude than any of their individual awarenesses.

-QUALITIES OF COMP-WARENESS DEPEND ON ITS ARCHITECTURE

-ARCHITECTURE DETERMINES WHAT'S COMP-WARE OF WHAT, WHEN, AND HOW

-It includes complexity, topology, computational transformations, timing, and interaction between individuals and collectives.

-MORE COMPLEX ARCHITECTURES ALLOW EMERGENCE OF NEW TYPES OF COMP-WARENESS

-Chemistry emerges from complex comp-awareness of physics (the wetness of water);

-Life emerges from complex comp-awareness of water solution chemistry; and

-Consciousness emerges from the comp-awareness of the brain's neuro-nano-tech.

THE BRAIN'S COMP-WARENESS IS THAT OF THE MOST POWERFUL, HI-PHI, SEMANTIC COMPUTER IN THE UNIVERSE*

*(with the possible exception of the Googleplex, NSA, and extraterrestrials)

-THE CORTEX COMPUTES WITH AN INFORMATIONAL RESOLUTION EQUAL TO 100 MILLION SIMULTANEOUS HDTV VIDEO DISPLAYS

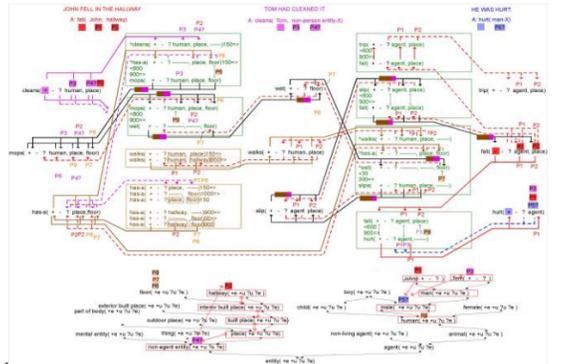
-MORE IMPORTANTLY, THE CORTEX'S INTERCONNECT GIVES IT THE FASTEST READ-MODIFY-WRITES ACROSS BRAIN SCALE MEMORY, AND THE FASTEST "HI-PHI" COMPUTING OF ANY COMPUTER ON EARTH

-THUS, OUR BRAIN'S COMP-WARENESS IS EXTREMELY DIFFERENT THAN THAT OF MOST OF REALITY

-Giving it the richness, complexity, and interconnect to compute the virtual reality of consciousness.

-There is no evidence the brain's computational power is insufficient to create consciousness.

THE BRAIN COMPUTES MEANING --- CONSCIOUSNESS IS COMP-WARENESS OF MEANING



-OUR BRAIN HAS EVOLVED AS A MEANING MACHINE, BECAUSE OF THE GREAT EVOLUTIONARY ADVANTAGE OF THE COMP-WARENESS OF MEANING, IN THE FORM OF SPREADING ACTIVATIONS OF VAST CLOUDS OF EXPERIENTIALLY-ASSOCIATED MEMORY PATTERNS

-MY K-LINE THEORY

-In 1969, MIT's Marvin Minsky gave me a short paper on K-Line theory. It captured my imagination and I have been expanding it ever since. In my expanded version, a hypothetical computer detects the patterns and pattern sequences in sensory information that it receives over time. It records these detected patterns and their sequences, and, as it does so, compares them against the information it has previously recorded. It, at least partially, activates the patterns or sequences that match the currently sensed patterns and sequences, with the degree of activation varying as a function of the degree of match. It dynamically

generalizes from the population of activated memories to generate expectations, at the appropriate degree of generalization, of the implications, benefits, harms, uses, and consequences of currently detected patterns and sequences. Since 1969, I have believed that activation of such clouds of pattern memories was the source of our sense of meaning. It wasn't until about 1997 that I came to understand that interconnected hierarchies of generalization and composition ("gencomp" hierarchies) could enable both non-literal matching and dynamic generalization. Together these two allow the brain to use K-Line-like mechanisms in an extremely powerful way.

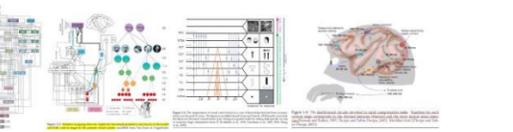
-THE CORTEX PERFORMS SEMANTIC COMPUTATION LARGELY IN TERMS OF INTERACTIVE CLOUDS OF MEMORY PATTERNS ("PATTERN CLOUDS") -- A FORM OF EDALMAN'S "REMEMBERED PRESENT"

-These pattern clouds are defined by the demographics of their populations of patterns, and the various degrees of activation of those patterns. These clouds dynamically provide the grounding necessary for meaning, and they enable the massively parallel search required to find the various patterns in successions of pattern clouds that best fit the current situation.

-PATTERN CLOUDS ARE GENERATED OUTWARDLY FROM FOCI OF ATTENTION IN WAVES OF SPREADING ACTIVATION

-As a result, most comp-awareness is "of" (or about) the patterns in the focus of activation energy. But because of spreading activation, there will also be at least some comp-awareness of many things one, two, or more activation levels out from the focus. In many cases, however, the comp-awareness of these successive levels of activation will be too small for us to be explicitly aware of them. But we may have a vague sense of them. The focus of attention can shift to such successively generated parts of the spreading activation by attention controlling mechanisms.

MEANING IS ASSOCIATIONS OF PATTERNS, AND THE BRAIN COMPUTES ASSOCIATIONS WITH NEURAL NET PATTERNS



-THE BRAIN STORES MEMORIES AS ACTIVE NEURAL NET PATTERNS

-These memories form both the actors and the audience in Baars' theater of consciousness analogy. The distinction between being on the stage and in the audience is one of degree, based on how much pattern cloud comp-awareness there is of a given memory's activation at a given time.

-NEURONS AND NEURAL NETS ARE OPTIMIZED FOR SOPHISTICATED COMP-WARENESS

-Neurons are amazing generators of comp-awareness of patterns.

-The brain is composed of a gencomp of hierarchical neural nets ("HNNs"), in which hierarchies and associational networks of nodes can detect and project complex patterns of patterns of patterns.

-THE AMAZING COMPUTATIONAL POWERS OF GENCOMP HNNS

-Non-literal, bottom-up, context-appropriate perception.

-Top-down, context-appropriate projection in behavior and imagination.

-Interactive combination of such bottom-up and top-down processing to help perception find the various parts of a pattern, and how to project a desired behavior into a current context.

-Dynamic generalization ("DYGEN") to find appropriate level of generalizations for the various implications from the pattern cloud associated with the various parts and relationships of a concept or scene of interest.

-The brain's associative, topological, and semantic networks are embedded in this gencomp hierarchy and share in its benefits.

-ASSOCIATIVE NETS

-The brain uses auto-associative nets to record experiential episodes and instantiations of activation patterns, and otherwise to learn patterns that solely hierarchical processes of the brain would be unlikely to capture.

-TOPOGRAPHICAL NETS

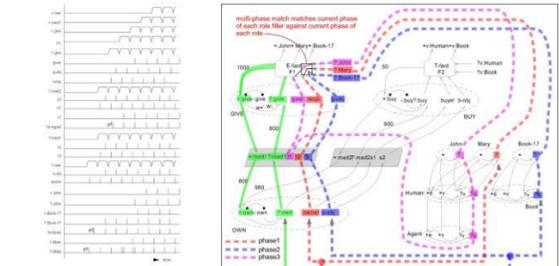
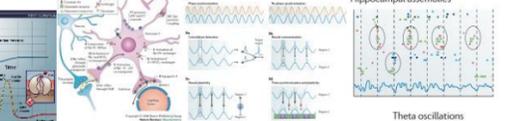
-All neural nets have a topology (a "what is connected to what"), but here I mean a net representing a relatively low dimensional, relatively regular, continuous space, such as that of 2D projections from the eyes, the 3D topology of interactive near-body space, or the 2D projection of sound pitch vs. time. The higher levels in the HNN receiving input from such maps detect relationships in their respective spaces, and project patterns into them. Thus, the pattern cloud of activated memories around concepts in such topological spaces generate experiential understanding of the nature of such spaces, and of the patterns, distances, continuities, and other relationships within them.

-SEMANTIC NETS

-These are hierarchical and associative patterns and networks in the higher, more abstract, levels of the brain. These are more removed from the more regular spaces of lower-level sensory nodes, but their meaning can be grounded into such regular spaces. Language and self-talk allow low-level, experientially concrete audio sensory patterns to be associated with such semantic nodes.

EM WAVES SELECTIVELY TUNE COORDINATION BETWEEN PARTS OF THE BRAIN'S NEURAL NET

-THE BRAIN IS A WAVE-TUNED, NEURAL-NET, MEANING MACHINE -- ENABLING IT TO FOCUS, UNIFY, AND SIGNIFY RELATIONSHIPS BETWEEN BILLIONS OF SIMULTANEOUS, PARALLEL COMPUTATIONS OF COMP-WARENESS



-SYNCHRONY ("WAVETUNING") PLAYS A KEY ROLE IN CONSCIOUSNESS

-It allows significant portions of the brain's active memories to tune into a given memory, allowing large context-sensitive, pattern-cloud activations of that given memory's meaning, as defined by its context-appropriate, experiential associations and generalizations.

-WHEN DIFFERENT SETS OF NEURONS ARE DRIVEN BY THE SAME FREQUENCY AND PHASE, THEY TUNE INTO, AND BECOME PREFERENTIALLY RESPONSIVE TO, EACH OTHER'S FIRINGS

-Neurons are more likely to fire when their local electric field voltage is high, because less extra positive voltage from inputs is required to make them fire. A neuron is more receptive to inputs that are timed to occur in phase with peaks in their local electric fields. This effectively changes the functional topology of the brain, allowing multiplexing and something akin to brain-wide broadcasts.

-WHEN SETS OF NEURONS ARE SYNCHRONIZED, THEIR FIRINGS ARE SYNCHRONIZED, MAKING OTHER NEURONS MORE LIKELY TO RESPOND TO THEM, TO RECOGNIZE THEM AS PART OF A UNIFIED PATTERN, AND BE DRIVEN TO JOIN THEIR SYNCHRONY

-This allows simple temporal binding.

-SYNCHRONY CAN CREATE GLOBAL THEATER OF CONSCIOUSNESS

-Since everything is connected to everything in the cortex, either directly or indirectly, wavetuning can allow substantial portions of the brain to tune into -- i.e., focus attention on -- a selected pattern or pattern cloud.

-THETA-GAMA WAVE TUNING ENABLES RELATIONAL BINDING

-Shastri's Shruti! shows the computational power of using a repeated set of multi-phase synchronies to tune the pattern clouds for separate concepts in multi-concept spatial, temporal, and/or semantic patterns. This allows the brain to think in relational logic.

-Granger has shown how the cortico-thalamic loop can perform dygen on such multi-phase relational pattern clouds.

-SYNCHRONY CAN TEMPORALLY POLL ACTIVATION STRENGTHS OF PATTERNS COMPETING FOR INSTANTIATION BASED ON HOW LOW A VOLTAGE THEY FIRE AT IN THE RISING PART OF A BRAIN WAVE

-Granger shows how the cortico-thalamic feedback loop can preferentially select the stronger, earlier firing, patterns, and inhibit the others.

-TYPES OF HYPOTHESIZED WAVETUNING

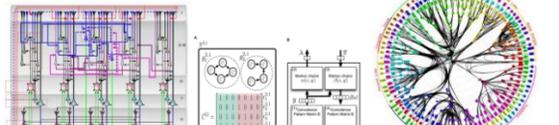
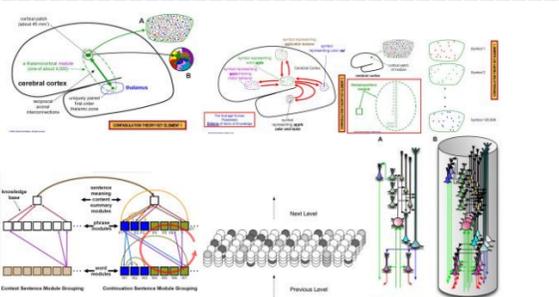
-Linna's 40hz cortical scanning from front to back to facilitate temporal coding of activations and/or top-down synchronies.

-Ringing hierarchical and associational pattern instantiations, to create brain-wide comp-awareness that the different parts and levels of such patterns are unified.

-e.g., combining "what" vision patterns with corresponding "where" patterns, and corresponding semantic pattern clouds to superimpose such various aspects of meaning in one unified conscious awareness.

-Using traveling waves to ring visual object hierarchies to time code the various parts of a multi-level object pattern onto a body-relative spatial map.

THE HOMUNCULUS IS THE COLLECTIVE AWARENESS OF THE AUDIENCE OF ACTIVE PATTERNS IN THE SKULL'S STADIUM OF STADIUMS



-THE CORTEX IS A STADIUM WHOSE SPECTATORS ARE CORTICAL MINI-COLUMNS SEATED IN 2 TO 20 K SEPARATE CORTICAL PATCHES -- EACH PATCH BEING A SUB-STADIUM WITH 100 TO 10 K MINI-COLUMNS --- AND EACH MINI-COLUMN BEING A RESPECTABLE NEURAL NET OF ROUGHLY 100 NEURONS

-CORTICAL PATCH STADIUMS DIFFER

-In size, slightly different neuronal architecture, and the population of mini-columns in other patches they are connected to.

-PATCHES CAN BE SYNCHRONIZED WITH OTHER PATCHES BY TOP-DOWN PROCESSES

-Such as, during behaviors in which it has been learned what set of patches are to be dynamically connected by synchrony. A slight controlled phase delay can be used to indicate which patch's patterns are to be the drivers and which are to be the followers.

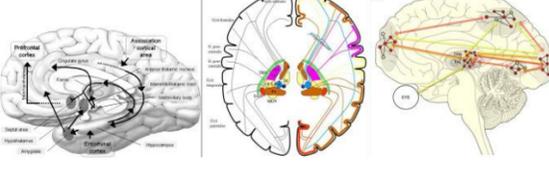
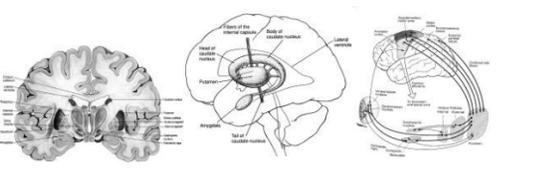
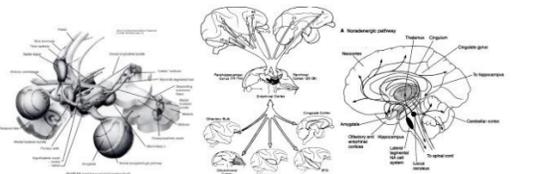
-MINI-COLUMNS OPERATE AS SPARSE CODE ASSEMBLIES

-One mini-column takes part in representing different patterns, as part of different neural assemblies. The set of neurons associated with a given pattern in a cortical patch form sparse codes. The number of codes that can be formed in a patch far exceeds its number of mini-columns, and a code can be reliably detected by detecting only a fraction of its mini-columns.

-SUPERSYNCHRONY

-Although there are noticeable phase delays in communications between cortically distant patches, it has been observed that synchronies can occur with little or no phase delay across such distances. This implies mechanisms exist to compensate for phase delays. Given the amazing ability of neural nets to compensate for things much more complicated and dynamic than such delays, it seems likely the brain actually has mechanisms for accurately correcting for such phase delays. This could make the effective timing of synchronies across the brain accurate to within a few milliseconds.

WHAT TUNES WHAT?



-DIFFERENT SCALES OF TUNING --- pattern scale -- patch scale -- brain scale

-CORTICO-THALAMIC LOOP --- What are the mappings into, out of, and within core and matrix nuclei?

-ANTERIOR THALAMUS --- What does it do? Does it control the gain or synchrony of TRN as a whole?

-THALAMIC RETICULAR NUCLEUS --- What controls it? Does it operate locally, globally, or both?

-IS THERE A THALAMIC MECHANISM FOR GLOBAL WAVETUNING?

-BASAL GANGLIA --- How does the cortico-thalamic loop map through it? What exactly does it do?

-PFC AND HIPPOCAMPUS IN WORKING MEMORY -- How they collaborate to use top-down theta-gama synchrony?

-AMYGDALA AND THE SEPTAL REGION --- Do they play a major role in selecting what gets wavetuned to what?

-HYPOTHALAMUS --- How does its control over the body and its chemistry control the brain?

-HIPPOCAMPUS AND THE PAPEZ CIRCUIT --- Does it use wavetuning to integrate emotionally-weighted patterns' control over working memory and learning?

-MAMMARY BODIES --- What do they do?

-CENTRAL MEDIAL NUCLEUS --- What does its connection to the basal ganglia do? What does it do, besides generating Linna's repeated 40hz front-to-back cortical wave?

-CEREBELLUM --- What role does it have in cognition, synchrony, and thresholding?

-ASTROCYTES --- What is their role in synchrony?

-THE BRAIN'S NEURO-CHEMICAL "VALUE SYSTEM" --- How does it effect thought and consciousness?

-POSSIBILITY OF QUANTUM SYNCHRONY THROUGH ENTANGLEMENT?

COMP-WARENESS, MEANING, THEATER OF MIND, & PHI: CAN THEY BE UNIFIED?

IT SEEMS ALL OF THESE APPROACHES ARE LARGELY COMPATIBLE

PHI

Is a measure of the type of integrated computational power needed for consciousness, expressed in abstract mathematical terms.

MEANING

Relates to the purpose of consciousness and the semantic topology of our awareness. Meaning is the grounding of awareness in experiential memories of the regularities of the reality around us. It is what gives consciousness its coherence and comprehensible, relational qualities.

COMP-WARENESS

Shows that the "awareness" of consciousness is not something totally different than what occurs in the rest of physical reality. Comp-awareness can be unified across large numbers of

computational entities, such as the neurons in our brain. There is a strong correlation between comp-awareness and conscious awareness. I am not aware of any strong argument against their being the same thing.

THEATER OF MIND

-Stresses the importance of collective awareness. It implies we are most conscious of that which is most watched by the audience in the brain. This is similar to the comp-awareness hypothesis that suggests we are most conscious of the things there is the most awareness of.

ISSUES OF MAPPING CONSCIOUSNESS INTO COMP-WARENESS

-THE HARDEST PROBLEM OF THE "HARD PROBLEM" IS DEFINING WHAT WE'RE TRYING TO EXPLAIN

-There has been too little clear thinking about what the "consciousness" we are trying to explain actually is. Nagel, for example, largely avoided the question by talking hypothetically about "what it is like to be" a bat, without explaining in any detail what it is like to be a bat.

-CONSCIOUSNESS IS CLEARLY AWARE OF WHAT COMP-WARENESS IS

-AI has shown that much of what we are aware of requires huge amounts of computation, such as segmentation in visual and speech recognition.

-The more we learn about the brain, the more we see significant correlations between brain computation and consciousness.

-We can now even begin to read minds by fMRI.

-THE CONCEPTUAL TRANSFORM FROM OBJECTIVE TO SUBJECTIVE IS DIFFICULT AND CAN ONLY, AT BEST, BE APPROXIMATE

-The conversion from modeling something to being it is a matter of bandwidth and point-of-view.

-Mary the neuroscientist' problem is the result of this subjective/objective transform and a lack of computational bandwidth.

-My hypothesis suggests following the topology of awareness for a guide.

CAN I CONVINCE YOU THESE QUALITIES OF CONSCIOUSNESS ARE COMP-WARENESS?

-HARD TO DEFINE

-AWARENESS

-UNITY OF SIMULTANEITY

-AWARENESS OF AWARENESS

-SUBJECTIVITY

-SELF-AWARENESS

-EXPERIENCING SENSATIONS, THOUGHTS, FEELINGS

-EXPERIENCING SENSATION NOT JUST AS PATTERNS OF SENSORY INFORMATION, BUT AS OBJECTS, SCENES, EVENTS, AND THEIR MEANING

-FEELING INSIDE THE EXTERNAL REALITY AROUND US

-HAVING VERY DIFFERENT QUALIA FOR DIFFERENT SENSES

-SEEING LIGHT AND COLOR AS WE DO

seeing red as red and not blue

-COMING IN MANY DIFFERENT DEGREES AND QUALITIES -- AT THE SAME AND DIFFERENT TIMES

-THE MIND BEING LIKE AN ICEBERG --- WITH MOST OF ITS COMPUTATION BEING BELOW OUR LEVEL OF EXPLICIT AWARENESS

-SOME QUALIA BEING MUCH MORE EXPLICIT THAN OTHERS

-HALLUCINATIONS

-VARIATIONS IN DEGREE OF ALERTNESS AND CONCENTRATION

-LIMITED CAPACITY

-BEING AWARE OF MORE THAN WE THINK

visual scanning consciousness can be partially aware of many more things at once than our working memory

-BEING AWARE OF LESS THAN WE THINK

THE BIG PICTURE

-PHILOSOPHICAL QUESTIONS

-The purpose of consciousness?

-The effect of understanding consciousness on the human spirit?

-Why we are in the particular consciousness we are in?

-There is life after death -- but to what extent will it be yours?

-Is the soul anything other than comp-awareness?

-The role of quantum weirdness?

-The paranormal?

-Free will?

-Meditation?

-Altered states of consciousness?

-Can computers become conscious?

-Will we be able to share consciousnesses much more than now?

-THE RAPIDLY APPROACHING AGE OF MACHINE SUPERINTELLIGENCE

-The rise of machine superintelligence within 5 to 15 years -- and the singularity.

-Machine consciousness and superconsciousness.

-Augmented and modified human consciousness.

-Globally shared human consciousness.

-COLLECTIVE INTELLIGENCE AS OUR ONLY SALVATION

-If the transition to the age of machine superintelligence is to be good for humanity, human society, institutions and governments will have to become much more collectively intelligent.

THINKERS WHO HAVE LED THE WAY...