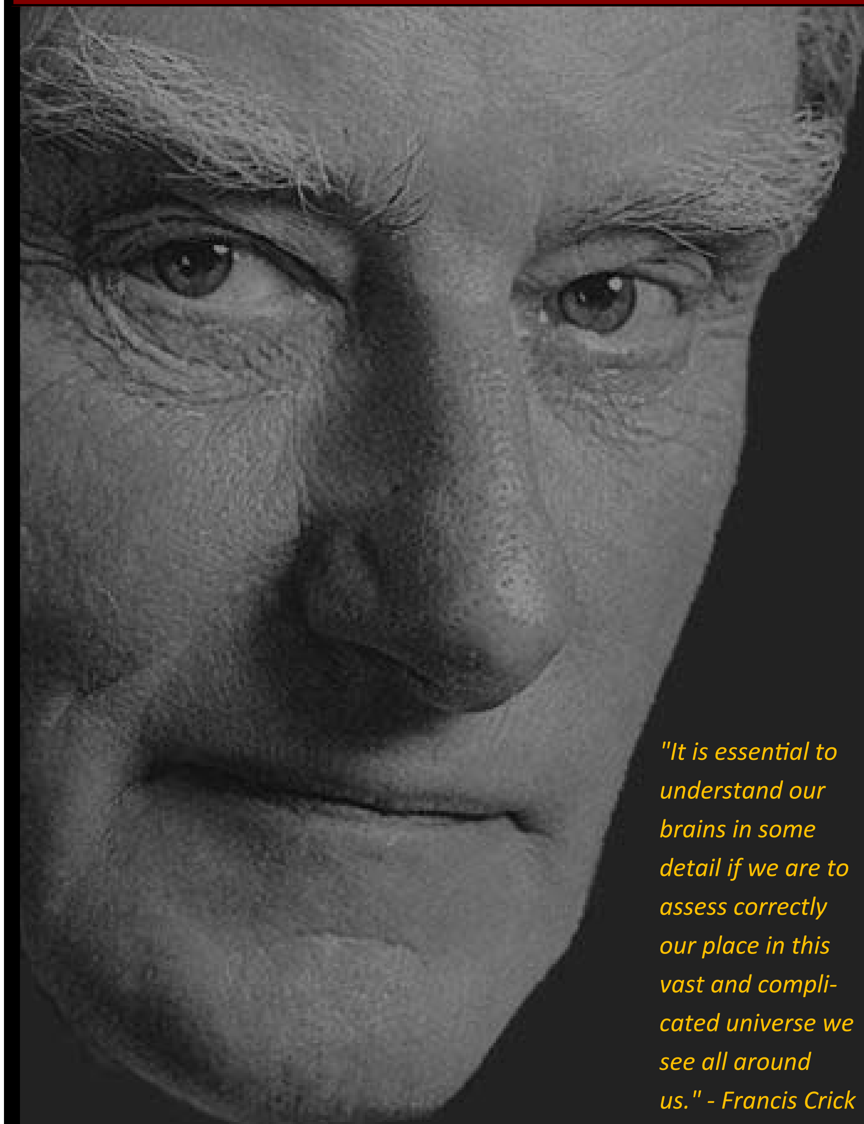
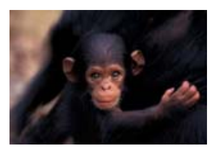
The Francis Crick Memorial Conference

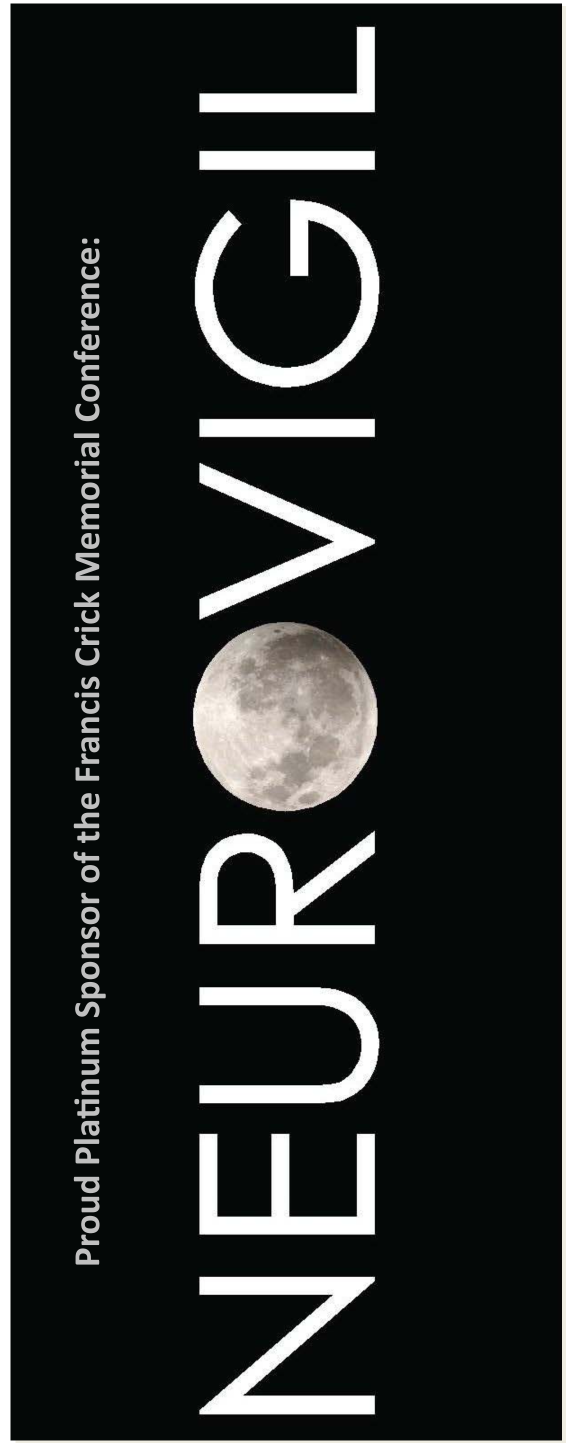
Consciousness in Human and Non-Human Animals

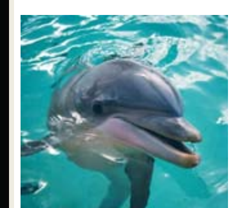
Wolfson Hall, Churchill College

Cambridge, United Kingdom









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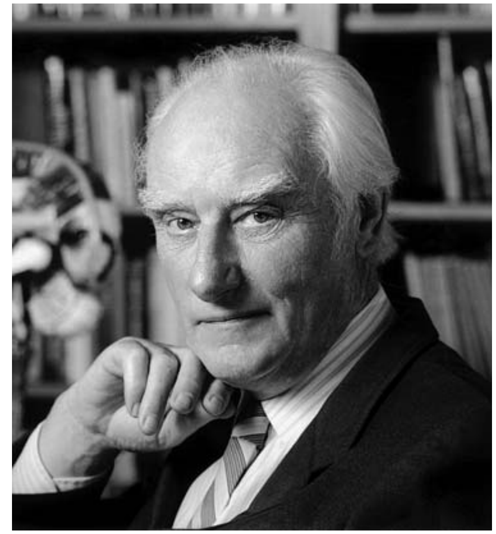

Francis Crick
(1916-2004)

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Schedule of Events

7:45	**Check-in / Complimentary Breakfast**	
8:30	**Christof Koch, Ph.D.** Allen Institute for Brain Science, Caltech	*Studying the Murine Mind*
9:00	**Invited Lecture:** **Baltazar Gomez-Mancilla, MD Ph.D.** Novartis Institute of Biomedical Research	*Consciousness: A Pharmacological Perspective*
9:30	**Ryan Remedios, Ph.D.*** CalTech **Nikos K. Logothetis, Ph.D.** **Christoph Kayser, Ph.D.** MaxPlanck Institute for Biological Cybernetics	*The Claustrum and the Orchestra of Cognitive Control*
10:00	**Coffee Break** **Special Unveiling Ceremony in Memory of Francis Crick**	*Located in the Foyer* *Artist: John Houser*
10:30	**Bruno van Swinderen, Ph.D.** The University of Queensland	*Neural Correlates of Unconsciousness in Drosophila*
11:00	**David B. Edelman, Ph.D.** The Neurosciences Institute, The Scripps Research Institute	*Through the Eyes of an Octopus: An Invertebrate Model for Consciousness Studies*
11:30	**Irene Pepperberg, Ph.D.** Brandeis University, Harvard University, The Alex Foundation	*Human-like Consciousness in Non-Humans: Evidence from Grey Parrots*
12:00	**Invited Lecture:** **Harvey Karten, MD** The University of California, San Diego	*Are Commonalities in Brain Microarchitecture and Behavior in Humans and Birds a Coincidence?*
12:30	**Keynote Speaker:** **Jaak Panksepp, Ph.D.** Washington State University	*Emotional Feelings of Other Animals: Are Their Affects Homologous to Our Own?*

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Schedule of Events

13:00	**Complimentary Lunch**	
14:00	**Diana Reiss, Ph.D.** Hunter College and City University of New York	*Mirror Self-recognition: A Case of Cognitive Convergence in Humans and other Animals*
14:30	**Franz X. Vollenweider, MD** University of Zürich School of Medicine, Heffter Research Centre	*Neuronal Correlates of Psychedelic Drug-Induced Imagery in Humans*
15:00	**Naotsugu Tsuchiya, Ph.D.** RIKEN, ATR, Japan, Caltech, Monash University	*Visual Consciousness Tracked with Direct Intracranial Recording from Early Visual Cortices in Humans*
15:30	**Coffee Break** **Special Unveiling Ceremony in Memory of Francis Crick**	*Located in the Foyer* *Artist: Odile Crick*
16:00	**Steven Laureys, MD, Ph.D.** Cyclotron Research Center, University of Liège, FNRS	*Identifying the Brain's Awareness System: Lessons from Coma and Related States*
16:30	**Melanie Boly, MD, Ph.D.** University of Liège, University of Wisconsin	*Cerebral Connectivity in Disorders of Consciousness*
17:00	**Philip Low, Ph.D.*** NeuroVigil, Stanford, MIT **&** **Stephen W. Hawking, D.Phil.** University of Cambridge	*Towards Establishing Neural Correlates of Intended Movements and Speech*
17:30	**Panel**	*The Cambridge Declaration on Consciousness in Human and Non-Human Animals*
18:00	**Philip Low, Ph.D.** NeuroVigil, Stanford, MIT	*Closing Remarks*

* Presenting Author

<u>Christof Koch, *Ph.D.*</u>
Chief Scientific Officer at the Allen Institute for Brain Science, Seattle. Lois and Victor Troendle Professor of Cognitive and Behavioral Biology at California Institute of Technology, Pasadena, CA

Dr. Christof Koch joined the Allen Institute as Chief Scientific Officer in 2011. For the past 25 years, Koch has served on the faculty at the California Institute of Technology (Caltech), from his initial appointment as Assistant Professor, Division of Biology and Division of Engineering and Applied Sciences in 1986, to his most recent position as Lois and Victor Troendle Professor of Cognitive & Behavioral Biology. Previously, he spent four years as a postdoctoral fellow in the Artificial Intelligence Laboratory and the Brain and Cognitive Sciences Department at the Massachusetts Institute of Technology. He received his baccalaureate from the Lycée Descartes in Rabat, Morocco, his M.S. in physics from the University of Tübingen in Germany and his Ph.D. from the Max-Planck-Institut für Biologische Kybernetik, Tübingen.
Koch has published extensively, and his writings and interests integrate theoretical, computational and experimental neuroscience. Stemming in part from a long-standing collaboration with the late Nobel Laureate Francis Crick, Koch authored the book "The Quest for Consciousness: A Neurobiological Approach." He has also authored the technical books "Biophysics of Computation: Information Processing in Single Neurons" and "Methods in Neuronal Modeling: From Ions to Networks," and served as editor for several books on neural modeling and information processing. Koch's research addresses scientific questions using a widely multidisciplinary approach.
His research interests include elucidating the biophysical mechanisms underlying neural computation, understanding the mechanisms and purpose of visual attention, and uncovering the neural basis of consciousness and the subjective mind. Koch maintains a part-time appointment and laboratory at Caltech.
Text: Courtesy of Allen Institute for Brain Science

Studying the Murine Mind

Christof Koch, Ph.D.

Mice are a very promising model system for studying the neuronal correlates of consciousness. Their brain structure is similar to that of the human, they display complex behavior, and their underlying neuronal responses can be measured using optics and silicon probes at cellular level of resolution. In contrast to the blunt and edentate tools available to probe the human brain, the recent emergence of optogenetics allows scientists to delicately, transiently, and reversibly control defined events in defined cell types at defined times in mice. This allows us to move from correlation to causation, from observing that this circuit is activated whenever the subject is perceiving something to inferring that this circuit is necessary for conscious perception. I shall report on the large-scale and high throughput efforts to build brain observatories to understand the mouse visual system that are ongoing at the Allen Institute.

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<u>Baltazar Gomez-Mancilla MD PhD</u>
Executive Director of Neuroscience Translational Medicine Novartis Institute of BioMedical Research

Dr. Gomez-Mancilla obtained a Medicine Degree at the National Autonomous University of State of Mexico in Toluca, Mexico. Then he moved to Canada, where he obtained a Doctoral Degree in Experimental Neurology, developing a Primate Model of l-dopa induced dyskinesias, at the Faculty of Medicine Laval University. He obtained "The Gorge Copty Award on Neurological Sciences" for his contributions in the understanding of Basal Ganglia circuit in Parkinson's disease. He continued his Clinical Neurological training at l'Hôpital de l'Enfant-Jésus in Quebec under Prof. Paul Bedard's supervision. He was awarded a Fellowship from Medical Research Council of Canada to perform Post-Doctoral studies in Clinical Pharmacology and Drug Metabolism leading him to obtain the 'Psychopharmacology Award' by the University of Toronto for his contributions to the understanding of psychotropic drug metabolism in the CNS. Dr. Gomez-Mancilla took on the role of Director of Clinical Research at The Upjohn Company in Kalamazoo, Michigan, leading the clinical strategy for the development of two successful new drug applications to the FDA, including Pramipexole for the treatment of Parkinson's disease, and Almotriptan for the treatment of Migraine.
Dr. Gomez-Mancilla currently holds the position of Executive Director of Translational Medicine in Neuroscience at the Novartis Institute of Biomedical Research in Basel, Switzerland. In 2008 he received the Novartis NSO Navigator Award, the Novartis Translational Science Award in 2009, and the 'VIVA Award" as a Leading Scientist in 2010 for his contributions to the development of new therapeutic strategies in Parkinson's disease and developmental pervasive disorders, respectively.
Dr Gomez-Mancilla holds a professorship at the Max Planck Institute of Neurobiology, University of Tübingen. Throughout his career, he has identified several new drugs and alternative indications in neurological and psychiatric disorders. He has filed 15 patent applications and has authored more than 50 peer-reviewed scientific articles and book chapters.

Consciousness: A Pharmacological Perspective

Baltazar Gomez-Mancilla, MD Ph.D.

Consciousness has been traditionally defined by the ability of an individual to effectively communicate with his/her surrounding world. The classical medical classification of state of consciousness in a patient (i.e. Glasgow scale) is derived from an observational study of the individual's physical reactions to external stimuli, but is not able to capture any residual cognitive brain activity.
The developments of new technologies that permit to capture neuronal activity have made a revolution in terms of our understanding of the definition of consciousness. Functional Magnetic Resonance imaging has allowed the identification of brain circuits involved in complex mental interactions like awareness and cognition. Cognition is a key brain process that mediates our interaction with the external environment. It defines how do we perceive the world and react in consequence. Cognition as a process is indeed intimately bound to the perception of consciousness that the external world will have from us, as individuals.
The understanding of the molecular mechanism involved in cognition such as synaptic plasticity, neural connectivity and brain circuits are continually evolving as it is the use of pharmacological interventions as tools to understand and /or restore synaptic plasticity

Ryan Remedios, *Ph.D.*
Postdoctoral Researcher, California Institute of Technology, Pasadena, CA

Dr. Ryan Remedios is a neuroscientist at the California Institute of Technology (Caltech). He earned his MSc at the Tata Institute of Fundamental Research in 2005 and his Ph.D. at the Max Planck Institute for Biological Cybernetics in 2011.
Ryan has worked in several key areas in neuroscience and has published about brain development, the physiology of cognitive processes, and communication in primates. His recent work focused on the functional significance of the claustrum and he is currently exploring the neuronal basis of innate, social behaviors using the mouse as a model system.

The Claustrum and the Orchestra of Cognitive Control

Ryan Remedios, Ph.D. , Nikos K. Logothetis, Ph.D.,
Christoph Kayser, Ph.D.
Max Planck Institute for Biological Cybernetics

Francis Crick and Christoph Koch were interested in the claustrum as a site of multisensory integration due to its extensive topographic connections with the sensory cortices (1). We showed that the claustrum did not integrate sensory information as neurons here were highly modality specific and did not exhibit the response characteristics typically associated with multisensory processing (2). Our recent observations do however support Crick and Koch's conjecture of the claustrum as a *conductor in the orchestra of cortical regions* (1). To identify claustrum function, we targetedly ablated claustral neurons and observed free-exploratory behaviors, as well as behaviors within paradigms designed to distinguish between cognitive and motor abilities. We uncovered a severe impairment in cost-benefit decision making by lesioned animals contingent to emotional modulation, paralleling the emotive role of the prefrontal cortex. We correspondingly identified a direct, interhemispheric, bidirectional network between the claustrum and prefrontal areas, and determined changes in global and regional brain network activity on claustral ablation using functional magnetic resonance imaging. Overall we suggest that the claustrum regulates cognitive control.

(1) Crick & Koch, 2005. (2) Remedios, Logothetis, Kayser, 2010.

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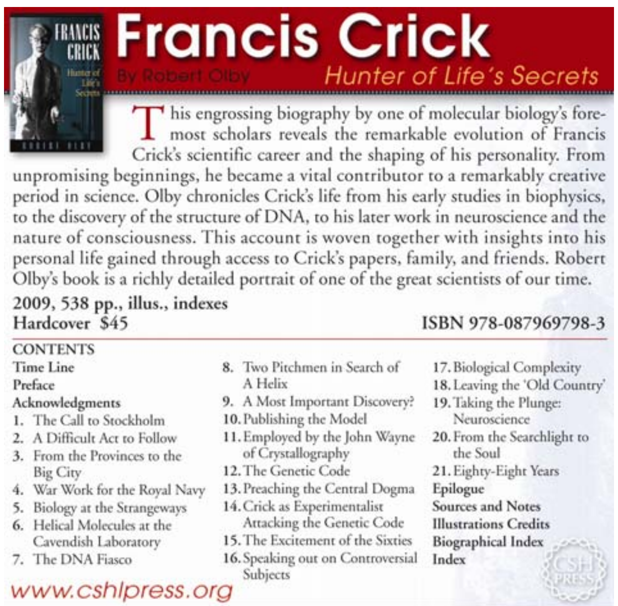
Nikos K. Logotheits, Ph.D.
Director of “Physiology of Cognitive Processes” department, the Max Planck Institute for Biological Cybernetics

Nikos K. Logothetis is director of the department “Physiology of Cognitive Processes” at the Max Planck Institute for Biological Cybernetics (MPIK), in Tübingen, Germany. He received a B.S. in mathematics from the University of Athens, a B.S. in biology from the University of Thessaloniki, and his Ph.D. in human neurobiology from the Ludwig-Maximilians University in Munich. In 1985 he moved to the Brain and Cognitive Sciences Department of M.I.T., where he initially worked as a postdoctoral fellow and later as Research Scientist. In 1990 he joined the faculty of the Division of Neuroscience at the Baylor College of Medicine. Seven years later he moved to the Max Planck Institute for Biological Cybernetics to continue his work on the physiological mechanisms underlying visual perception and object recognition. In addition to visual cognition, his work at MPIC includes auditory perception and multisensory integration, as well as studies of plasticity and neuromodulation.
Since 1992 Nikos K. Logothetis has been Adjunct Professor of Neurobiology at the Salk Institute in San Diego, since 1995 Adjunct Professor of Ophthalmology at the Baylor College of Medicine, Houston, Associate of the Neurosciences Institute, San Diego, Senior Visiting Fellow in University College, London, Adjunct Professor in the Department of Cognitive and Neural Systems and of Cognitive and Neural Systems in the College of Arts and Sciences, both at the Boston University, Massachusetts, a faculty member at the Victoria University of Manchester (VUM) in England, and Honorary Professor in the Department of Biology at the University of Tübingen.
Text: Courtesy the Max Planck Institute for Biological Cybernetics

Christoph Kayser *Ph.D.*
Otto Hahn Research Group Leader, the Max Planck Institute for Biological Cybernetics

Dr. Christoph Kayser is a research group leader at the Max Planck Institute for Biological Cybernetics in Tubingen, Germany. He studied mathematics and theoretical physics at the ETH Zurich, Switzerland, and obtained a PhD in Neuroscience. Work in his lab focuses on the processing of auditory information in temporal cortex and how this benefits from multisensory information. Specifically, he employs a combination of functional imaging, electrophysiological and theoretical methods to study the neural information representation in auditory cortices and how this is modified by non-acoustic inputs. The goal is to enhance our understanding of the neural basis underlying perception, and to provide useful insights for potential medical applications, such as prosthetic devices or rehabilitation approaches.
Text: Courtesy Frontiers in Neuroscience



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Bruno van Swinderen, *Ph.D.*
Associate Professor, Queensland Brain Institute, The University of Queensland, Brisbane, AU

Dr. Bruno van Swinderen received his PhD in Evolutionary and Population Biology in 1998 from Washington University in St. Louis, Missouri. His graduate work was on general anesthesia in a Caenorhabditis elegans model, applying both quantitative genetics and molecular genetic approaches. For his postdoc at The Neurosciences Institute (NSI) in San Diego, California (1999-2003), he switched to Drosophila melanogaster to develop methods of studying perception in the fruitfly model. He ran a lab at NSI from 2003 to 2007, with a primary interest on consciousness and the measurable phenomena associated with it, such as selective attention, memory, sleep, and general anesthesia. His approaches included both brain recording paradigms and behavioral assays that focused on measures of visual perception. In February 2008, van Swinderen established a new laboratory at the Queensland Brain Institute. The group combines expertise in electrophysiology, behavior, and molecular genetics to understand fundamental brain mechanisms. The main research focus of the laboratory is to understand stimulus suppression mechanisms. These mechanisms pertain to the ability to pay attention, but also the ability to suppress stimuli during sleep, and how this can be induced with drugs such as general anesthesia.
Text: Courtesy The University of Queensland and The Neurosciences Institute

Neural Correlates of Unconsciousness in Drosophila
Bruno van Swinderen, Ph.D.

Our understanding of consciousness often follows from studies of selective attention, sleep, and general anaesthesia in humans. However, these behavioural states can also be studied in the simpler animals, such as the fruit fly *Drosophila melanogaster*, where responsiveness to stimuli can be indicative of the level arousal in the animal. Multichannel brain recordings from flies can then be used to identify processes, such as local field potential coherence, associated with different arousal states in the tiny insect brain. In my talk, I will argue that distinct arousal states, such as sleep and selective attention, may involve similar stimulus suppression mechanisms, and that perceptual suppression may have been the evolutionary innovation leading to conscious and unconscious states in higher animals. I will then proceed to show how one can use the genetic model *Drosophila* to manipulate and dissect perceptual suppression mechanisms in a small brain.

David B. Edelman, *Ph.D.*
Associate Fellow, Experimental Neurobiology, The Neurosciences Institute
Assistant Professor of Neurobiology, The Scripps Research Institute

Dr. David Edelman graduated from Swarthmore College with a B.A. in Sociology and Anthropology, received his Ph.D. in Physical Anthropology, with a specialization in paleoanthropology, from the University of Pennsylvania. From 1997 to 2005, he was a postdoctoral fellow at both the Scripps Research Institute and the Neurosciences Institute. As a Fellow at the Neuroscientists Institute and Professor at the Scripps Research Institute, Edelman is presently investigating the major features of octopus vision, from the various properties that are most salient to the behaving animal to the electrophysiological signatures of those properties and their associated functional anatomies. In order to characterize the octopus visual system, he uses a variety of techniques, including high-definition video presentation of stimuli, electrophysiological recording in live animals, and molecular labelling to define the anatomy of visual pathways in the central octopus brain.
Text: Courtesy of The Neurosciences Institute

Through the Eyes of an Octopus: An Invertebrate Model for Consciousness Studies
David B. Edelman, Ph.D.

Endowed with a nervous system containing as many as 500 million neurons, as well as eyes that are structurally convergent with those of vertebrates, the octopus may be an excellent model for investigating consciousness in an invertebrate. Here, I will make such a case on neuroanatomical, neurophysiological, and behavioral grounds. I will: 1) lay out a working definition for consciousness that may be extended beyond the vertebrate case; 2) describe structural and functional properties which may be the *sine qua non* of consciousness; 3) suggest evolutionary trends (e.g., the emergence of complex vision) that may have set the stage for the advent of conscious states in a variety of species; and 4) discuss the latest results from ongoing studies of cephalopod vision and offer a 'roadmap' for additional experiments that may lead to a robust methodology for the explicit investigation of sensory consciousness in these, and perhaps certain other, invertebrates (e.g., jumping spiders).

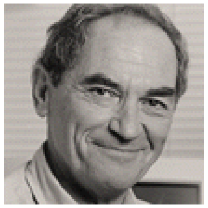
Irene Pepperberg, *Ph.D.*
Adjunct Associate Professor in Psychology, Brandeis University
Lecturer and Research Associate, Harvard University
President, The Alex Foundation

Dr. Irene Pepperberg received a B.S. in Chemistry from MIT, and was awarded a M.A. in Chemistry followed by a Ph.D. in Chemical Physics from Harvard University. She has held posts at Purdue, Northwestern, University of Arizona, the MIT Media Lab, and currently a research associate at Harvard University, and an adjunct associate professor at Brandeis University . The main focus of Pepperberg's work is the cognitive and communicative abilities of Grey Parrots, and she has shown that these birds have capacities comparable to non-human primates and young children. The training process she has employed is based on the rival-model technique in which two humans demonstrate to the bird what is to be learned. Through numerous pioneering studies, her subjects have proven able to use English labels to identify, request, refuse, and categorize more than fifty objects, seven colors, five shapes, and quantities to six, as well as understand concepts such as big vs. small, same vs. different, and absence.
Text: Courtesy The Alex Foundation, Radcliffe Institute

Human-like Consciousness in Non-Humans: Evidence from Grey Parrots
Irene Pepperberg, Ph.D.

To obtain data on nonhuman consciousness, researchers often examine "perceptual consciousness"[(1)] —how sensory information is acknowledged, processed, and integrated [(2).] An organism may be aware it *is* processing information, possibly of *how* it is processing information, but not necessarily be aware it *is* aware of how information is processed. This awareness is required for complex tasks which require integrating perception, centralized monitoring, and behavioral control[(3)] and is a form of higher-order cognition[(4)]; it may involve the capacity to choose, from various possible sets of acquired rules, the set that appropriately governs the processing of certain data [(5)]. Sometimes, however, even this information-processing account cannot explain observed data. Three studies on Grey parrots—predominantly on Alex, who used English speech intentionally to label objects, colors, shapes, and categories, who understood concepts of same-different, relative size, absence, conjunction, exact numbers, conjunctivity, equivalence, and segmentation[(6)] provide evidence for some level of consciousness approaching that of humans.

(1) Griffin, 1998, 2000; Griffin & Speck, 2004. (2) Natsoulas, 1978. (3) Pepperberg & Lynn, 2000. (4) Delacour, 1997. (5) Pepperberg, 1999. (6) Pepperberg, 1999, 2006a,b, 2007



Harvey Karten, *MD.*
Professor of Neurosciences, University of California San Diego Professor of Psychiatry, The University of California San Diego School of Medicine

Dr. Harvey Karten received a B.A. in Chemistry from Yeshiva College, and a M.D. from Albert Einstein College of Medicine. After an Internship Internal Medicine at University of Utah, he completed his Residency in Psychiatry at University of Colorado. Before accepting a position at UCSD, Dr. Karten held research posts at the Walter Reed Army Institute of Research, and at MIT, as well as a Professorship of Psychiatry and Neurobiology at SUNY at Stony Brook. Karten's current research focuses on studies of the neural circuitry, biophysics, and evolution of motion detection in birds and mammals. His laboratory utilizes a broad spectrum of anatomical and neurochemical methods; including pathway tracing, immunohistochemical and biochemical methods for the identification of transmitters, peptides, trophic factors and their respective receptors, a single cell filling of identified neurons and quantitative morphometry, and electron microscopic immunohistochemistry. Research activities led by Dr. Karten have led to a greater appreciation of the importance of evolutionary analyses of non-mammalian brains, both vertebrates and invertebrates, at a cellular, circuit, and molecular level. Important findings continue to produce shifts in perspective regarding the organization of the brain in non-mammalian vertebrates, sensory organization of ascending paths, their evolution, and their consequences for understanding the human brain.
Text: Courtesy of University of California, San Diego

Are Commonalities in Brain Microarchitecture and Behavior in Humans and Birds a Coincidence?
Harvey Karten, MD

A "Turing Test" for cognitive and sensory-motor capabilities presuming to distinguish Monkeys and Parrots would likely prove difficult for an external observor/predictor. Which animal is hiding behind each "Turing Curtain"? Rigid conformity to semantics and outdated definitions of homology remains an obstacle to understanding brain evolution. Are there common features in brain organization of birds and mammals that mediate such striking similarities? Comparative studies of brain evolution over the past 50 years have resulted in a drastically modified view of brain organization amongst these closely related vertebrates. With very few exceptions, virtually identical neuronal connections and microcircuits have been found to mediate similar behaviors.

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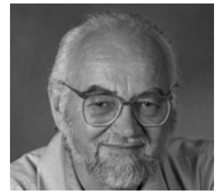

Jaak Panskepp, Ph.D.
Baily Endowed Chair of Animal Well-Being Science & Professor, Veterinary & Comparative Anatomy, Pharmacy, Physiology (VCAPP), Washington State University, Distinguished Research Professor Emeritus of Psychology, Bowling Green State University, Head, Affective Neuroscience Research, Falk Center for Molecular Therapeutics, Northwestern University

Dr. Jaak Panksepp holds the Baily Endowed Chair of Animal Well-Being Science in Washington State University's College of Veterinary Medicine and is Emeritus Distinguished Research Professor of the Department of Psychology at Bowling Green State University. His research pioneered the neuroscientific study of primary-process emotions in mammals, with the goal of understanding the evolutionary infrastructure of human emotional feelings. He coined the term "affective neuroscience" as the name for the field that studies the neural mechanisms of emotion, not only from neuro-ethological but also experiential perspectives (i.e., monitoring the rewarding and punishing properties of artificial arousal of basic mammalian emotional action systems). His group generated the first neural (opioid-addictive) model of mother-infant social bonding, and the understanding of various other basic affective processes, especially the nature of playful joy, that have important psychiatric implications, especially for the development of new therapies. Along with Ken Davis, the Affective Neuroscience Personality Scale was developed as a potential bridge between basic preclinical and human research endeavors. He is known in the popular press for his research on laughter in non-human animals, a topic that has led his extended research group to identify several novel treatments of depression. His forthcoming book is the *Archaeology of Mind* (Norton, 2012).

Emotional Feelings of Other Animals: Are Their Affects Homologous to Our Own?
Jaak Panskepp, Ph.D.

Because of its bipolar positive and negative affective structure, raw emotional feelings are an optimal way to make scientific progress on the neural constitution of consciousness. Such research has revealed the existence of profound neuroanatomical and neurochemical homologies in the systems that control emotionality in mammalian and avian species. Wherever in their brains one applies localized Deep Brain Stimulation (DBS), whether electrical or chemical, and obtains coherent instinctual emotional behavior patterns, animals treat these within-brain state shifts as 'rewards' and 'punishments' in various learning tasks. Humans consistently report desirable and undesirable affective changes to such DBS. These effects serve as gold standards for the detailed scientific study of affective qualia in animal and human brains. Such work helps clarify the neural nature of phenomenal-affective consciousness, namely why various emotional arousals feel *good* and *bad* in distinct ways. Abundant convergent evidence indicates how such primary-process subcortical neural networks generate homologous emotional feelings in all mammals that have been studied, and how they control learning and memory. This knowledge illuminates our own deeper nature, and allows us to understanding cross-species core-self processes that generate organismic and affective coherence that serves as a coherent BrainMind infrastructure for understanding higher mental processes. This type of research helps reveal the causal/constitutive infrastructure of human and other minds (i.e., the "hard problem" of consciousness). It provides a new foundation for understanding psychiatric disorders as well and the development of new mind medicines. The progressive understanding of the evolutionary infrastructure of a cross-species mental apparatus helps us come to terms with the affective depths of our own minds, as well as of our fellow animals.

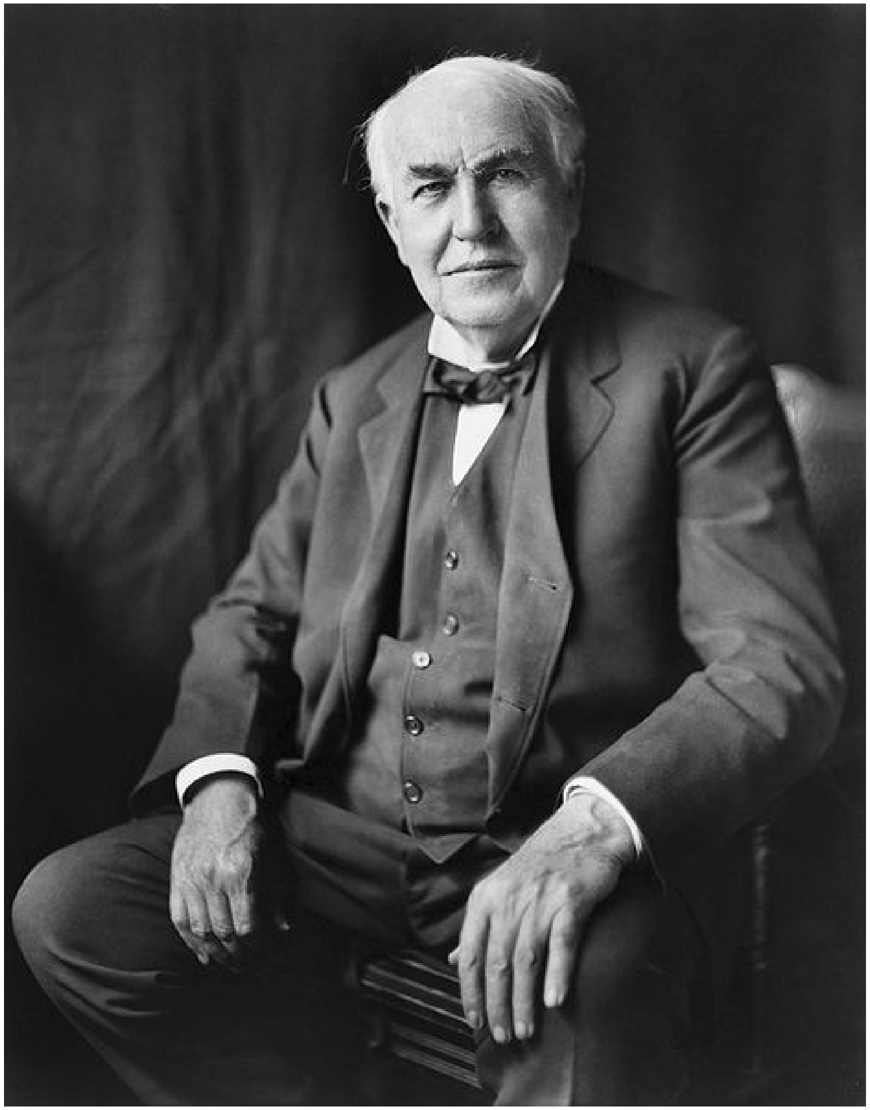

Photo Courtesy Wikipedia.com

“Non-violence leads to the highest ethics, which is the goal of all evolution. Until we stop harming all other living beings, we are still savages.” - Thomas A. Edison

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Diana Reiss, *Ph.D.*
Professor of Psychology, Hunter College and City University of New York Biopsychology Graduate Program

Dr. Diana Reiss attended Moore College of Art in Philadelphia and pursued a career in theatrical set design, before entering a program in bioacoustics at Temple University Department of Speech and Communications. After receiving her Ph.D. in Developmental Psychology, Reiss opened a laboratory called Marine World Africa U.S.A., where she pioneered protocols that utilized underwater keyboards to study dolphin communication and learning. At her laboratory at the National Aquarium in Baltimore, Reiss continues to research dolphins through mirror self-recognition paradigms that are designed to correlate with higher forms of empathy and altruistic behavior. By using mirrors as research tools, Dr. Reiss has been able to conduct comparative investigations in animal cognition, and collect results that provide insight into the evolution of intelligence.
Text: Courtesy of National Aquarium Baltimore, New York Times, Lifeboat Foundation

Mirror Self-recognition: A Case of Cognitive Convergence in Humans and other Animals
Diana Reiss, Ph.D.

The ability to recognize oneself in a mirror, once considered a uniquely human attribute, is shared by great apes, dolphins, elephants and magpies. In comparative studies of mirror self-recognition (MSR) dolphins and elephants, show striking similarities to humans and the great apes in the stages of behavior and the specific types of behaviors they show when exposed to a mirror. MSR emerges in children between 18-24 months and in chimpanzees between 2.5-4.5 years of age. In a developmental study conducted to determine the age of onset of self-directed behaviors and MSR in dolphins, we found dolphins at 14-18 months of age exhibiting self-directed behavior - evidence of MSR. Dolphins are precocious at birth and exceed human and non-human primates in motor skills and coordination. Our findings suggest that young dolphins may show advanced cognition at an earlier age with respect to mirror self-directed behavior as compared to humans and chimpanzees.

Franz X. Vollenweider, *MD.*
Professor of Psychiatry, University of Zürich School of Medicine, Vice-Director of Research and Teaching and Director of the Neuropsychopharmacology and Brain Imaging Research Unit of the University Hospital of Psychiatry Zürich , Director of Heffter Research Centre Zürich for Consciousness Studies

Dr. Franz Vollenweider received his M.D. degree at the University of Zürich. He completed his doctoral thesis in experimental medicine at the Institute of Toxicology of the University and ETH of Zürich, was trained in neurochemistry at the Brain Research Institute of the University of Zürich, and in neuroimaging at the PET Centre of the PSI-ETH. In 1994 he became certified in the specialities of psychiatry and psychotherapy. His research interests encompass the area of psychopathology, cognitive neuroscience, and behavioural psychopharmacology of psychotic and affective disorders. Vollenweider's current research focuses on the investigation of the functional networks and transmitter dynamics underlying the experience of self, visual perception, cognitive and emotional processes and the dysfunctions of these processes in human models of psychoses and psychiatric patients. Multiple approaches including measures of information processing, event-related potentials, and brain imaging techniques are used for studying these functions, and addressing the mechanisms of action of psychostimulants, hallucinogens, and entactogens in humans.
Text: Courtesy of Heffter Research Institute

Neuronal Correlates of Psychedelic Drug-Induced Imagery in Humans
Franz X. Vollenweider, MD.

Classic psychedelics such as psilocybin produce an altered state of consciousness (ASC) characterized by vivid imagery and profound changes in mood, thought, intuition, and self that is otherwise rarely experienced except in dreams. Recent findings suggest that the serotonin system and particularly agonistic activity at 5-HT2A/1A receptors is implicated in the formation of psilocybin-induced and also naturally occurring visual hallucinations. To elucidate the relationship between regional brain activity and imagery and the mechanism of action of psychedelics, the effect of psilocybin in combination w/o serotonin 2A and 1A receptor antagonists on visual processing and subjective experience was investigated using high-density electrical mapping with source analysis and H2O-PET imaging. The results show reduced activation in the right extrastriate and posterior parietal areas, and disrupted modal object completion. Furthermore, they suggest that psilocybin-induced imagery is primarily mediated by 5-HT2A receptor activation based on a disruption in cortical feedforward and feedback processing.

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Dr. Naotsugu Tsuchiya was awarded a B.S. in Biology from the Kyoto University. From 2000 to 2005 Tsuchiya pursued a doctorate at California Institute of Technology as a member of Chistoph Koch's research group. After receiving his Ph.D. in Computation and Neural Systems, he joined Ralph Adolphs' lab as post-doctoral fellow until 2010, where he investigated visual attention, unconscious visual processing, and the amygdala's categorical selectivity to visual stimuli. Dr. Tsuchiya's most recent research has focused on the enigmatic triumvirate of relations between consciousness, attention, and emotion. Through the analysis of multichannel neurophysiological data, recorded intracranially or by fMRI, Tsuchiya aims to identify the distinction between consciousness and attention, and locate the neural correlates of each.

Visual Consciousness Tracked with Direct Intracranial Recording from Early Visual Cortices in Humans
Naotsugu Tsuchiya, Ph.D.

A fundamental question in cognitive neuroscience is how neuronal representations are related to conscious experience. Two key questions are: where in the brain such representations are located, and at what point in time they correlate with conscious experience. In line with this issue, a hotly debated question is whether primary visual cortex (V1) contributes to visual consciousness, or whether this depends only on higher-order cortices. Here we investigated this issue by recording directly from early visual cortex in two neurosurgical patients undergoing epilepsy monitoring with intracranial electrocorticogram (ECoG) electrodes that covered early visual cortices, including the dorsal and ventral banks of the calcarine sulcus. We used Continuous Flash Suppression (CFS) to investigate the time course of when 'invisible' stimuli broke interocular suppression. Participants were asked to watch faces presented under CFS, to push a button when they started to see any part of the face, and then to indicate its spatial location. This occured over several seconds. During the task performance we recorded intracranial ECoG at high spatiotemporal resolution from all contacts in parallel. We used multivariate decoding techniques and found that the location of the invisible face stimulus became decodable from neuronal activity 1.8 sec before the subject's button press. We will discuss the neuronal dynamics associated with the break of inter-ocular suppression.

<u>Steven Laureys, *MD, Ph.D.*</u>
Research Associate at the Belgian National Fund for Scientific Research (FNRS)
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Dr. Steven Laureys received his MD from Vrije Universiteit Brussel, in Belgium, and was awarded an M.Sc. in Pharmaceutical Medicine for his research on pain and stroke using in vivo microdialysis and diffusion MRI in rats. Drawn by functional neuroimaging, Laureys moved to the Cyclotron Research Center at the University of Liège, Belgium, where he received a Ph.D. for his investigations into residual brain function in coma, vegetative, minimally conscious and locked-in states. Laureys has used fMRI to demonstrate awareness the awareness of patients in vegetative states and has published widely on related topics such as brain-death, locked-in syndrome, anesthesia, pain, and sleep. Text: Courtesy of Coma Science Group

Identifying the Brain's Awareness System: Lessons from Coma and Related States

Steven Laureys, MD, Ph.D.

Following severe brain damage some patients loose all brain and brainstem functions and evolve to brain death while others can open their eyes, but only show reflex behavior. Some patients will remain unresponsive for decades; others may evolve to a minimally responsive/conscious state with more than simple reflex behaviors but lacking communication. Finally, coma patients may awaken, being fully aware but paralyzed and mute. We here review neuroimaging and electrophysiology studies that illuminate the relationships between awareness and brain function in these challenging conditions. Such studies show that awareness is an emergent property of the collective behavior of frontoparietal top-down connectivity where external (sensory) awareness depends on lateral prefrontal/parietal cortices, while internal (self) awareness correlates with precuneal/ mesiofrontal midline activity. This knowledge improves diagnosis of patients with disorders of consciousness. Technology can also now show command-specific changes in EEG or fMRI signals providing motor-independent evidence of conscious thoughts and in some cases communication.

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<u>Melanie Boly, MD, Ph.D.</u>
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Dr. Melanie Boly is a Postdoctoral Research Fellow at the Belgian National Fund for Scientific Research. She works since more than ten years with Steven Laureys at the Coma Science Group (Cyclotron Research Centre, University of Liege). Her research aims at investigating the neural correlates of decreased consciousness during vegetative state, anesthesia or sleep using a variety of functional neuroimaging techniques (including PET, functional MRI, high density EEG and TMS-EEG). She also worked with the team of Adrian Owen in Cambridge, in order to design some active paradigms (such as the fMRI 'imagine playing tennis') able to detect consciousness in unresponsive non-communicative brain damaged patients. In 2010 she also performed a post-doctoral stay in Karl Friston's group at University College London, in order to apply dynamic causal modeling to the study of effective connectivity in anesthesia vegetative state. She is now performing a second postdoctoral stay at the Center for Sleep and Consciousness, University of Wisconsin (with Giulio Tononi). Her present work aims at combining functional neuroimaging studies on the neural correlates of the level of consciousness in various states such as sleep, anesthesia, or brain damaged patients to a more theoretical approach. Text: Courtesy Frontiers in Neuroscience

Cerebral Connectivity in Disorders of Consciousness

Melanie Boly, MD, Ph.D.

During the last decade, functional neuroimaging of disorders of consciousness (i.e., coma, vegetative state and minimally conscious state) has evolved from measuring resting cerebral blood flow or electrical activity to studying functional response to sensory stimuli and to active paradigm asking patients to concentrate on doing a task like playing tennis. While these methods have improved the care of the patients, they also show how difficult it is to distinguish different states of consciousness. Brain connectivity studies aim at evaluating global cerebral function in patients with disorders of consciousness. In this talk, I will cover results obtained using a range of functional and effective connectivity approaches based on PET, fMRI, high density EEG, and TMS-EEG recordings. Experimental work performed in other unconscious states (i.e., anesthesia and deep sleep) will also be compared and reviewed. Practical and conceptual implications of these studies will be discussed in light of recent theories of consciousness.

<u>Philip Low, *Ph.D.*</u>
Founder, Chairman, and CEO of NeuroVigil, Inc.
Adjunct Professor, Stanford School of Medicine
Research Affiliate, MIT Media Lab

Philip Low is the Founder, Chairman, CSO and CEO of NeuroVigil and the inventor of the SPEARS algorithm. He holds dual appointments at the Stanford School of Medicine and the MIT Media Lab and two extraordinary ability clearances in the field of brain signal detection from the US Government. At the recommendation of Francis Crick, he joined the Salk Institute for Biological Studies where he authored in 2007 a single page Ph.D. dissertation, *"A New Way To Look At Sleep: Separation and Convergence"*, unanimously approved by six members of the US National Academy of Sciences, including two former presidents of the Society for Neuroscience, which opened a new framework for humans and comparative brainwave research. Low demonstrated that sleep patterns could be computationally identified using a single channel of EEG, that REM sleep was not paradoxical, that the Neocortex was not necessary for the production of mammalian-like sleep patterns and that EEGs contained high-frequency signals which could themselves be extracted non-invasively.

In 2009, NeuroVigil created iBrain, a portable neural activity monitor, which in combination with Low's algorithmic methods, made the first outpatient pharmaceutical clinical trial for the Brain possible. His technology has since been requested by academic, industrial and government institutions throughout the world, for a myriad of neurological applications, from Autism to TBI and was listed by the *New York Times* among "32 Innovations That Will Change Your Tomorrow." Low's honors include the MIT TR-35 Top Young Innovator Award and the Inaugural Jacobs-Rady Pioneer Award, given every five years. In 2011, NeuroVigil was recognized by *Fast Company* and *The Washington Post* as one of the "Top 10 Most Innovative Companies in Health Care" and the following year, he was asked by the White House to advise on Neuroscience projects.

<u>Stephen W. Hawking, *D.Phil.*</u>
Director of Research, Centre for Theoretical Cosmology, University of Cambridge

Stephen Hawking is the former Lucasian Professor of Mathematics at the University of Cambridge and author of *A Brief History of Time* which was an international bestseller. Now Director of Research at the Institute for Theoretical Cosmology at Cambridge, his other books for the general reader include *A Briefer History of Time*, the essay collection *Black Holes and Baby Universe* and *The Universe in a Nutshell.*
In 1963, Hawking contracted motor neurone disease and was given two years to live. Yet he went on to Cambridge to become a brilliant researcher and Professorial Fellow at Gonville and Caius College. Since 1979 he has held the post of Lucasian Professor at Cambridge, the chair held by Isaac Newton in 1663. Professor Hawking has over a dozen honorary degrees and was awarded the CBE in 1982. He is a fellow of the Royal Society and a Member of the US National Academy of Science. Stephen Hawking is regarded as one of the most brilliant theoretical physicists since Einstein.
Text: Courtesy Hawking.org.uk

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Towards Establishing Neural Correlates of Intended Movements and Speech
Philip Low, Ph.D. & Stephen W. Hawking, D.Phil.

Single-Channel iBrain EEG recordings were conducted in a high-functioning 70 year old ALS patient attempting to move one of four limbs after a verbal cue: the left and right hand and foot. Raw EEG signals were analyzed with the SPEARS algorithm in order to make high-frequency/low spectral power signals detectable. Concurrent video recordings were obtained. During the attempted movements, the subject's brain activity demonstrated distinct broad-spectrum pulses extending to the Gamma and ultra-high Gamma ranges. Such pulses were present in the absence of actual movement and absent when the subject was not attempting motion. Activity in the Alpha range was detected when the subject closed his eyes, as expected. The emergence of such high bandwidth biomarkers opens the possibility to link intended movements to a library of words and convert them into speech, thus providing ALS sufferers with communication tools more dependent on the brain than on the body.

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