PART II

INSIGHTS FROM MODERN SCIENCE THAT CAN CONTRIBUTE NEW INSIGHTS ON THE SOUL

CHAPTER 1

NEUROSCIENCE

Neuroscientist Joaquín M.Fuster speculates that if Aristotle commissioned a team of neuroscientists from the twentieth century to write an all-inclusive and systematic version of *De Anima* following Thomas Aquinas and Juan Luis Vives, the treatise would be an encyclopaedic tome on cognitive neuroscience.[1] The field originated in the late 1970s when scientists were studying "how the brain enables the mind, a subject in need of a new name."[2] It includes the sciences studying the mind, for instance, cognitive science, neuroscience, computer science and philosophy of mind. Cognitive means knowing and perceiving; cognitive scientists seek to understand mental phenomena e.g. perceiving, remembering, thinking, language, learning, and other mental phenomena.[3]

This chapter examines some areas of the brain sciences, its methods and some philosophical issues, which potentially have relevance for our understanding of the soul, while omitting others, such as split brain,[4] gender,[5] etc. so as not to

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[1] Joaquín M.Fuster, "The Module: Crisis of a paradigm," *Neuron* Vol.26 No.1 (April 2000), p.51-53. Fuster reviews *The New Cognitive Neurosciences,* Second Edition, Editor-in-chief: Michael S.Gazzaniga.

[2] Neuroscientist Michael Gazzaniga was travelling with cognitive psychologist George A.Miller in the back seat of a New York City taxi to attend a dinner meeting for Cornell University and Rockefeller University scientists. "Out of that taxi ride came the term 'cognitive neuroscience', which took hold in the scientific community." Michael S.Gazzaniga, Richard B.Ivry & George R.Mangun, *Cognitive Neuroscience: The Biology of the Mind*, Second Edition (New York & London: W.W. Norton & Company, 2002), p.1

[3] Neil A.Stillings et.al., *Cognitive Science: An Introduction,* Second Edition (Cambridge, Massachusetts and London: The MIT Press, 1995), p.1. See also Peter Baumgartner and Sabine Payr (eds.), *Speaking Minds: Interviews with Twenty Eminent Cognitive Scientists* (Princeton: Princeton University Press, 1995).

[4] Lisette J. van der Knaap and Ineke J.M. van der Ham, "How does the corpus callosum mediate interhemispheric transfer? A review," *Behavioural Brain Research* Vol.223 No.1 (30 September 2011), pp.211-221; Michael S.Gazzaniga, "Forty-five years of split-brain research and still going strong," *Nature Reviews Neuroscience* Vol.6 No.8 (August 2005), pp.653-659.

[5] Irit Weissman-Fogel et.al., "Cognitive and default-mode resting state networks: Do male and female brains 'rest' differently?," *Human Brain Mapping* Vol.31 No.11 (November 2010), pp.1713–1726;

unnecessarily lengthen the thesis. But the areas examined these are only representative of a rapidly-progressing scientific discipline which illuminates subjects once restricted to philosophers and theologians.

Neuroscience is a multilevel, multidisciplinary subject which studies the nervous system, whose two major parts are the central nervous system (CNS) composed of the brain and spinal cord; and the peripheral nervous system (PNS) composed of all else outside the CNS.[6] The autonomic nervous system, a part of the PNS, controls the heart, smooth muscles and various glands.[7] Many body parts are regulated by the brain which, while not cognitive, are essential for life, like the respiratory system and cardiovascular system. For example, lung function relies on synchronised movements of respiratory muscles that are enacted by rhythmic nerve signalling from the lower brainstem to the spinal motorneurons.[8]

Neurons, Neurogenesis, Plasticity, Complexity

Many agree that modern neuroscience and neurobiology were born with Santiago Ramón y Cajal (1852-1934), who pioneered the 'neuron doctrine.'[9] The nerve cell or neuron is the principal, internally-intricate cellular unit of the nervous system. Neurons transmit information across networks needed for experience-dependent mechanisms like learning, memory, and consciousness.[10] It is argued that since all understanding of the mind is founded on the brain, the neuron is an important component of that account of mind.[11]

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and a contrasting view in Gaolang Gong, Yong He and Alan C.Evans, "Brain Connectivity: Gender Makes a Difference," *The Neuroscientist* Vol.17 No.5 (October 2011), pp.575-591

[6] Gazzaniga, Ivry & Mangun, *Cognitive Neuroscience*, pp.70-95

[7] See also Wilfrid Jänig & Heinz-Joachim Häbler, "Specificity in the organization of the autonomic nervous system: a basis for precise neural regulation of homeostatic and protective body functions," *Progress in Brain Research* Vol.122 (1999), pp.349-365 (p.352)

[8] Diethelm W.Richter et.al., "Respiratory Rhythm Generation: Plasticity of a Neuronal Network," *The Neuroscientist* Vol.6 No.3 (Jun 2000), pp.181-198

[9] Pedro J Andres-Barquin, "Santiago Ramón y Cajal and the Spanish school of neurology," *The Lancet Neurology* Vol.1 No.7 (November 2002), pp.445-452. A 1906 Nobel laureate, Ramón y Cajal is "probably the most prominent neuroscientist of all time," who published "the most influential body of work by a single scientist in the history of neuroscience." (p.452 & p.447)

[10] Oliver von Bohlen und Halbach, Rolf Dermietzel, *Neurotransmitters and neuromodulators: handbook of receptors and biological effects, 2nd edition* (Weinheim: Wiley-VCH, 2006), p.1

[11] Efrain C.Azmitia, "Cajal and brain plasticity: Insights relevant to emerging concepts of mind," *Brain Research Reviews* Vol.55 No.2 (October 2007), pp.395-405. Cf also Theodore Holmes Bullock, "Neuron Doctrine and Electrophysiology," *Science* Vol.129 No.3355 (17 April 1959), pp.997-1002

The neuron doctrine was a potent reductionist tool for examining the nervous system, with the functional idea of single nerve cells linked by single axons to possibly multiple outputs, all essentially transmitting the same message.[12] Ramón y Cajal viewed the neuron as an individual functional unit, polarised so that signals are received through the dendrites and transmitted through the long axonal process. He proposed that while an axon terminates adjacent to a dendrite of the next neuron, the cleft in-between would function a synaptic switch regulating information flow through neural circuits.[13] A century later, the modern accounts views the neuron as a discrete cell that processes information in more ways such as intercellular communication by gap junctions, slow electrical potentials, action potentials initiated in dendrites, and neuromodulatory effects.[14]

Neurogenesis is a process of forming functionally integrated nerve cells.[15] It was customarily thought to happen in the embryonic phases of the CNS of mammals. Nerve cells and nervous systems are malleable, adapting to environmental challenges:[16] the concept of *plasticity.*[17] Once, neuroscientists dared not publish papers using the word 'neuroplasticity'; it would attract criticism, but the dogma of an unchanging brain itself has changed.[18] This confronted the idea of the brain being 'hard-wired'. As one neuroscientist reflects, "I do not know to how many generations of medical students I have preached 'You are born with all the nerve cells you will

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[12] R.W.Guillery, "Relating the neuron doctrine to the cell theory. Should contemporary knowledge change our view of the neuron doctrine?" *Brain Research Reviews* Vol.55 No.2 (October 2007), pp.411-421 (p.416)
[13] Theodore H. Bullock et.al., "The Neuron Doctrine, Redux," *Science* Vol. 310 No.5749 (4 November 2005) pp.791-793. Bullock writes as co-author, 46 years after his 1959 *Science* article above.
[14] Nowadays neurons are still considered discrete units but are understood to function less individually J.Jermakowicz & Vivien A. Casagrande, "Neural networks a century after Cajal," *Brain Research Reviews* Vol.55 No.2 (October 2007), pp.264-284
[15] Guo-li Ming and Hongjun Song, "Adult Neurogenesis in the Mammalian Central Nervous System," *Annual Review of Neuroscience* Vol.28 (2005), pp.223-250; Bryan Kolb & Robbin Gibb, "Frontal Lobe Plasticity and Behavior," in Donald T.Stuss and Robert T.Knight (eds.), *Principles of Frontal Lobe Function* (Oxford: Oxford University Press, 2002), pp.541-557
[16] Friedhelm Hummel, Christian Gerloff and Leonardo G.Cohen, "Modulation of Cortical Function and Plasticity in the Human Brain," in Ford F.Ebner (ed.), *Neural Plasticity in Adult Somatic Sensory-Motor Systems*, Frontiers in Neuroscience series (Boca Raton: CRC Press, 2005), pp.207-226.
[17] Mark R. Rosenzweig, "Modification of Brain Circuits through Experience," in Federico Bermúdez-Rattoni (ed.), *Neural Plasticity and Memory: From Genes to Brain Imaging* (Boca Baton, Florida: CRC Press, 2007), pp.67-94
[18] Norman Doidge, *The Brain that Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science* (Carlton North, Vic.: Scribe Publications, 2008), p.xv

ever have, after that they can only die.'…my statement about nerve cells was and is wrong." [19]

There are approximately100 billion neurons in the human brain.[20] It is a multi-scaled and complex organ. Smaller brain structures form together into larger entities such as networks (Table 1).

Units of Measurement	Levels of Brain Anatomy
1 m	CNS (central nervous system)
10 cm	Systems
1 cm	Maps
1 mm	Networks
100 μm (micron) 100×10^{-6} m	Neurons
1 μm (micron) 1×10^{-6} m	Synapses
1 Å (ångström) 1×10^{-10} m	Molecules

Table 1: *Levels of investigation of the brain arranged by spatial scale*[21]

Each neuron extends one nerve fibre that branches to form a concentrated network of fibres enabling this one cell to link to hundreds of other cells. If in one cubic millimetre of white matter. White matter constitutes 40% to 50% of the cerebral volume and 40% of the cross-sectional area in the adult human brain. White matter contains millions of axons with myelin forming many tracts that connect the hemispheres, brainstem and cerebella regions.[22] All the axon 'wires' were joined up the final single wire would be nine metres long. For one cubic millimetre of grey matter, the final single wire is four kilometres long. This is due to the wiring in grey matter being thinner than white matter.[23] The corpus callosum, the greatest bundle of fibres connecting the two cerebral hemispheres of the human brain, has over than

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[19] Guy M.McKhann, "The new world of neuroscience: the perspective of a clinical neuroscientist," *Technology in Society* Vol.26 Nos.2-3 (April-August 2004), pp.391-404 (p.392)

[20] Terrence Sejnowski, "The Computational Self," *Annals of the New York Academy of Sciences* Vol.1001 (October 2003), pp.262–271 (p.266)

[21] Adapted from Figure 1 in Sejnowski, *The Computational Self,* p.263

[22] Cf. Christopher M.Filley, *The Behavioral Neruology of White Matter* (New York: Oxford University Press, 2001), pp.19-31. It also has clinical significance, e.g. Paul Y.Geha et.al., "The Brain in Chronic CRPS Pain: Abnormal Gray-White Matter Interactions in Emotional and Autonomic Regions." *Neuron* Vol.60 No.4 (26 November 2008), pp.571-581

[23]Rodney J. Douglas & Kevan A.C. Martin, "The butterfly and the loom," *Brain Research Reviews* Vol.55 No.2 (October 2007), p.314-328 (p.320). Interestingly, the eye is connected to the thalamus with slightly more than one million fibres; the ear has merely 10,000 sensory fibres, yet these are crucial to a musician or listener's quality of life. The motor cortex has only one million fibres which connect to the spinal cord and the hand has 10,000 of these. Douglas & Martin, *Butterfly and the loom,* p.321

300 million fibres.[24] The brain is thus vastly interconnected, and has been fascinating to humanity historically.

Brain and Body

The 'soul' has featured in the localisation of brain function, which is the idea that particular mental functions were undertaken by specific parts of the brain.[25] From antiquity to about the second century AD, questions pertained to the location of the soul and the spring of mental life. The Greek anatomist Galen (130-200 AD) thought that the brain was the locus of sensations from the five external senses and the place of all mental activity including the internal senses e.g. memory, imagination and thoughts; and where voluntary movements originated from. The contrasting proposal held for instance by Aristotle and foundational in Western culture, was that the heart was the locus of mental functions or some of these.[26]

From the second to the eighteenth centuries, the debate centred on whether cognitive functions were localised in the ventricular system[27] of the brain or in the brain itself. There have been studies from the nineteenth century until today concerned with how the mental or cognitive activities are organised in the brain. An alternative 'equipotential' view holds that major parts of the brain are equally involved in all mental activity

The idea that the brain can be sectioned into discrete regions, each with a distinct function, was called 'phrenology,'[28] associated with Johann Spurzheim (1776-1832) and Franz Joseph Gall (1758-1828). Phrenology explored possible links between contours of the human head and personality.[29] For example, Wilhelm Gwinner's biography in 1862 of philosopher Arthur Schopenhauer featured a comparison of

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[24] Sabine Hofer and Jens Frahm, "Topography of the human corpus callosum revisited - Comprehensive fiber tractography using diffusion tensor magnetic resonance imaging," *NeuroImage* Vol.32 No.3 (September 2006), pp.989-994.

[25] S.Zola-Morgan, "Localization of Brain Function: The Legacy of Franz Joseph Gall (1758-1828)," *Annual Review of Neuroscience* Vol.18 (1995), pp.359-383. Zola-Morgan identifies three eras.

[26] Larry W.Swanson, "Quest for the basic plan of nervous system circuitry," *Brain Research Reviews* Vol.55 No.2 (October 2007), pp.357-358

[27] We now know these as cavities or spaces within the brain enclosed by the skull. They are filled with cerebrospinal fluid which also flows into the spinal cord.

[28] John Van Wyhe, "The authority of human nature: the *Schädellehre* of Franz Joseph Gall*," The British Journal for the History of Science* Vol.35 No.1 (March 2002), p.22

[29] See Anne Harrington, "How to house a mind inside a brain, Lessons from history," *EMBO reports* Vol.8 Special Issue (2007), pp.S12- S15

Schopenhauer’s skull with those of other skulls. The smallest skull belonged to a cretin; the others were of famous persons like Immanuel Kant, Friedrich Schiller, and Napoleon.[30]

Thus different areas of the cerebral hemispheres were structurally and functionally defined unsystematically as subdivisions arose, with confusion of concepts and levels. There are, e.g. no universally accepted definitions for terms and relationships between basal ganglia, amygdala, limbic system, neocortex, the major lobes of cerebral cortex and so forth. Under these circumstances, “a formal ontology of cerebral hemisphere organization is a distant hope.”[31]

Nonetheless today the brain is known to be centrally interlinked with the body, e.g. cognition correlates with immunological states: psychoneuroimmunology. Stress can affect the immune system in numerous ways like self-blame.[32] Brain and body support higher cognitive functions as wilful action and consciousness. These are the realms of the mind, self, and human nature and were studied in philosophy and theology. They are co-relatable with brain processes, which are measurable. We consider one such area of mind and soul: memory, now open to neuroscientific investigation.

Brain and Mind: Memory

The notion of residues in the soul or mind left by mental experience is ancient. Yet the notion that the residue is physically found in the brain is a relatively modern idea.[33] Memory, the “capacity that permits organisms to benefit from their past experiences,”[34] is generally regarded as several memory systems such as procedural, semantic and episodic. Procedural memory is the ability to retain learned connections

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[30] Michael Hagner, “Skulls, Brains, and Memorial Culture: On Cerebral Biographies of Scientists in the Nineteenth Century,” *Science in Context* Vol.16 No.1-2 (March 2003) pp.195-218

[31] Larry W.Swanson, “Anatomy of the soul as reflected in the cerebral hemispheres: Neural circuits underlying voluntary control of basic motivated behaviors,” *The Journal of Comparative Neurology* Vol.493 No.1 (5 December 2005), pp.122-131 (p.123)

[32] Janice K.Kiecolt-Glaser, “Psychoneuroimmunology: Psychology's Gateway to the Biomedical Future,” *Perspectives on Psychological Science* July Vol.4 No.4 (July 2009), pp.367-369

[33] Tulving notes that it was first proposed by Robert Hooke (1627-1703)’ cf. Endel Tulving, “Coding and representation: Searching for a home in the brain,” in Henry L.Roediger III, Yadin Dudai and Susan M.Fitzpatrick (eds.), *Science of Memory: Concepts* (New York: Oxford University Press, 2007), pp.65-68

[34] Endel Tulving, “How Many Memory Systems Are There?” *American Psychologist* Vol.40 No.4 (April 1985), pp.385-398 (p.385)

between simple and complex stimuli and their responses, to adapt to the environment. Semantic memory has the added inner capacity to represent the world which is not perceptually present, e.g. mental models. Episodic memory furnishes an extra ability to acquire and retain knowledge that is experienced personally with its time context, plus a mental ability to travel back in time. But episodic memory relies on both semantic and procedural memory.[35] A memory system comprises organised structures of more basic operating components, themselves consisting of neural substrates and their cognitive and behavioural correlates.[36]

Memory traces (also known as representation, coding, engram, memory image), involve "the neural change that accompanies a mental experience at one time (time 1) whose retention, modified or otherwise, allows the individual later (at time 2) to have mental experiences of the kind that would not have been possible in the absence of the trace."[37]

Each cortical cell is connected to around 4000 to 10,000 other cells in the cortex.[38] If memory was represented in present connections, there would be insufficient to store all memory traces. Questions arise about: brain substrates of memory, the character of memory traces, how memories originate in the brain, their storage and retrieval.[39]

The essential memory trace, along with its allied brain circuits, is necessary and sufficient for primary dimensions of a particular form of learning like acquisition and retention.[40] Memory traces, described freely as learning-induced changes in neural activity, may also derive from other brain regions but need not be essential for

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[35] See Tulving, *How Many Memory System*, p.387

[36] Tulving, *How Many Memory System*, p.386. Tulving notes that to think of multiple memory systems is to break with a long tradition which understood memory as a single system.

[37] Tulving, *Coding and representation*, p.66. Previously Tulving placed them in the 'memory system', now he finds a home for them in the brain.

[38] Niels Birbaumer & Herta Flor, "Psychobiology," in Alan S.Bellack and Michael Hersen (Eds.), *Comprehensive Clinical Psychology, Volume 1: Foundations (C.Eugene Walker, editor)* (Amsterdam: Pergamon Elsevier,1998), pp.115-172 (p.143)

[39] Richard F.Thompson, "In Search of Memory Traces," Annual *Review of Psychology* Vol.56 (2005), pp.1-23. Generally, explicit or declarative memory involves awareness of the memory via verbal reports. Implicit or non-declarative memory does not inevitably involve awareness of memory. When an organism learns or remembers, several brain systems can be active. Yet in most instances, one decisive brain system is involved. Brain damage of that system results in lasting deficits its associated learning and memory.

[40] Thompson, *In Search of Memory Traces*, p.3

learning. Lesions identify the essential memory trace and the essential circuits by inhibiting or eliminating the learned response.

Simplified models have been used to find memory traces. The gill withdrawal reflex of the sea snail *Aplysia* has been studied to examine habituation, e.g. the memory trace is contained in the reflex pathway such that lesions will eliminate the reflex and the trace.[41]

Learning and memory entails representation and storing of particular sensory experiences. Such memory traces can be stored in the primary sensory cortices, e.g. the primary auditory cortex (A1) attains and preserves particular memory traces about the behavioural implications of certain sounds. Human and animal studies show that the primary auditory cortex develops very specialised associative plasticity during various kinds of motivation, reinforcement and learning e.g. long-term retention, which resembles memory.[42] The investigations continue using diverse methods.[43]

One hypothesis is memory preservation-consolidation. In the twentieth century, despite theoretical speculations, little is as yet known about consolidation that continues for some hours or more after learning to produce lifelong memories.[44] There is a growing stabilisation of long-term memory and its associated memory phases after initial acquisition, because new memories require time to stabilise, with traces inclined to interference by toxins, injury or distracting stimuli.[45] Another model is multiple traces.[46] Again there are various methods e.g. neuroimaging and

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[41] Thompson, *In Search of Memory Traces*, p.4. The sea snail continues to be studied to as a model to understand the neural foundations of classical conditioning, sensitisation etc. See e.g. Robert D.Hawkins, Gregory A. Clark, and Eric R.Kandel, “Operant Conditioning of Gill Withdrawal in Aplysia,” *The Journal of Neuroscience* Vol.26 No.9 (1 March 2006), pp. 2443-2448.
[42] Weinberger, *Specific long-term memory traces,* p.288
[43] Guilherme Neves, Sam F.Cooke and Tim V.P.Bliss, “Synaptic plasticity, memory and the hippocampus: a neural network approach to causality,” *Nature Reviews Neuroscience* Vol.9 No.1 (January 2008), pp.65-75
[44] James L.McGaugh, “Memory – a Century of Consolidation,” *Science* Vol.287 No.5451 (14 January 2000), pp.248-251 (p.250)
[45] Yadin Dudai, “The Neurobiology of Consolidations, Or, How Stable is the Engram?,” *Annual Review of Psychology* Vol.55 (2004), pp.51-86 (p.52)
[46] Lynn Nadel and Morris Moscovitch, “Memory consolidation, retrograde amnesia and the hippocampal complex,” *Current Opinion in Neurobiology* Vol.7 No.2 (April 1997), pp.217-227. The authors reviewed human and non-human animal studies.

lesions studies on the function of the hippocampus.[47] The debates and research continue.[48]

Memory is important for identity and the self, and in this thesis, the soul. Overall the self is being increasingly explained scientifically rather than religiously, e.g. human genome, evolution; and now neuroscience has much to contribute.

Critical Comment

From the cellular level of neurons, to how cells are formed in neurogenesis, then ascending to brain structures and networks, neuroscience reveals the intricate physical structures and functions of the human brain. The scientific disciplines include neuroanatomy, neurophysiology, and overall neurobiology. Cognitive neuroscience has been called 'the biology of the mind,'[49] although it would be more accurate if it were the biology of the brain and CNS. Once the mind is invoked, we are in the domains of neuropsychology, cognitive science, and behavioural neurology.

If the area of interest is on the body side, then it would be subjects like psychophysiology, biological psychology, and psychobiology. These invite philosophical debates about brain and mind. Psychophysiology studies how mental events are embodied in humans who are biological.[50] Specifically, "the study of relations between psychological manipulations and resulting physiological responses, measured in a living organism, to promote understanding of the relation between mental and bodily processes."[51] The bodily substrates of behaviour addresses the philosophical 'mind-body problem' wherein questions arise about the locus of those mental or spiritual events, even thoughts and feelings, that could not plainly be called

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[47] Morris Moscovitch et al., "Functional neuroanatomy of remote episodic, semantic and spatial memory: a unified account based on multiple trace theory," *Journal of Anatomy* Vol.207 No.1 (July 2005), pp.35-66

[48] There is ongoing debate about whether consolidation occurs once, or perhaps memories become labile and need further consolidation, and questions about how the memory trace may mature, persist, be retrieved and modified. Lynn Nadel et al., "Systems consolidation and hippocampus: two views," *Debates in Neuroscience* Vol.1 No.2-4 (December 2007), pp.55-66

[49].Gazzaniga, Ivry &.Mangun, *Cognitive Neuroscience: The Biology of the Mind*.

[50] Richard J.Davidson, "Affective neuroscience and psychophysiology: Toward a synthesis," *Psychophysiology* Vol.40 No.5 (September 2003), pp.655-665 (p.663)

[51] John L Andreassi, *Psychophysiology: Human Behavior and Physiological Response,* Fifth Edition (Mahwah, New Jersey: Lawrence Erlbaum Associates Inc., 2007), p.2

physical activities.[52] The brain is the central organ for thinking, movement, sensation, perception, action, etc. but these other physiological measurements offer insights into behaviour not measurable via the brain. Physiological measures used include heart, muscles, skin, the blood and eyes.[53]

The neurosciences are substantial and should be acknowledged by philosophers and theologians. Memory is now explainable, neuroscientifically; it is rich, philosophically; and associated with the soul, traditionally. When a scientifically intelligible account is provided by 'soulless' neuroscience, it may lead to the conclusion that the soul is redundant, the notion of that neuroscience explains everything the soul used to. However, a coherent understanding of brain and mind is not automatic grounds for dismissing the soul, although it raises crucial questions for the Catholic understanding of the soul. Neuroscience itself does not aim to deny the soul, something non-physical; it studies the brain, using physicalist methods. It is worth probing some of these methods.

Neuroscience Methods

It is argued that the integral hallmarks of the cerebrum [2 main brain hemispheres] can only be grasped by studying the complex exchanges between numerous networked structures in the living brain. The opposite is the study of simplified networks of reduced preparations used in most laboratories.[54] Localisation has been examined using stimulation, lesion, recording and imaging methods, leading to advances in dissecting and reducing the brain to its neural networks. Neuroscientists delight in finding "the smallest piece of nervous tissue that may accomplish the rudiments of a certain function." [55]

When the systems contained in the basic unit of the kidney, the nephron, was accurately understood, a deeper knowledge of the kidney and kidney disease

[52] Andreassi, *Psychophysiology*, p.2
[53] Eileen Kowler, "What Movements of the Eye Tell us about the Mind," in Ernest Lepore and Zenon Pylyshyn (eds.) *What is Cognitive Science?* (Malden, Massachusetts and London: Blackwell Publishers, 1999), pp.248-262; M.F.Marmor et.al., "ISCEV Standard for full-field clinical electroretinography (2008 update)," *Documenta Ophthalmologica* Vol.118 No.1 (February 2009), pp.69-77
[54] Mircea Steriade, *The Intact and Sliced Brain* (Cambridge, Massachusetts/London: The MIT Press, 2001), p.291.
[55] Steriade, *The Intact and Sliced Brain*, p.2

resulted. But grasping the basic unit of the brain does not lead to a comprehensive knowledge of the brain.[56] Researchers continue genetics,[57] brain slice and culture research.[58]

There are numerous methods in neuroscience. This part of the chapter concentrates on just two areas at the macro level of the whole brain and its functions: some neuroimaging methods and brain mapping.

Whole Brain Neuroimaging

Before the medical use of x-ray radiation, neurosurgery was entirely dependent on clinical signs and symptoms.[59] Then, neuroimaging turned the traditional nature of psychology towards cognitive neuroscience.[60] Knowing the structure and function of the human brain depends on complex technology.[61] In time and space, neuroimaging covers a temporal range from milliseconds to decades and a spatial range from neurons to systems.[62]

Several standard methods are relatively recent:
computed tomography (1972),
positron emission tomography (PET, 1975),
single positron emission tomography (SPECT)

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[56] György Buzsáki, "Interconnected Stories of Brain Rhythms," review *of The Intact and sliced Brain* by Mircea Steriade, *Science* Vol.294 No.5550 (14 December 2001), pp.2295-2297

[57] The human genome has about 30,000 genes. The neocortex has about ten thousand million nerve cells and the number of neurons in the brain nears 100 billion, each one has distinctive characteristics. In quantitative terms, "the genetic information available for constructing not only the body but also the brain appears to be severely limited." Jean-Pierre Changeux, *The Physiology of Truth, Neuroscience and Human Knowledge,* translated by M.B.DeBevoise (Cambridge, Mass. and London, England: The Belknap Press of Harvard University Press, 2004), p.156

[58] H.Luksch, "More than the Sum of its Parts - A Critical Assessment of Isolated Tissue Techniques in the Neurosciences," review of *The Intact and the Sliced Brain* by Mircea Steriade, *Journal of Chemical Neuroanatomy* Vol.26 No.1 (August 2003), p.75

[59] This point is illustrated in an interesting historical paper by D.A.Simpson and J.L.Crompton, "The Visual Fields: An Interdisciplinary History II. Neurosurgeons and Quantitative Perimetry," *Journal of Clinical Neuroscience* Vol.15 No.3 (March 2008), pp.229-236

[60] A.Gjedde, "Functional brain imaging celebrates 30th anniversary," *Acta Neurologica Scandinavica* Vol.117 No.4 (April 2008), pp.219-223

[61] Steve Webb, "The contribution, history, impact and future of physics in medicine," *Acta Oncologica* Vol.48 No.2 (February 2009), pp.169-177; Peter A.Bandettini, "What's New in Neuroimaging Methods?," *Annals of the New York Academy of Sciences* Vol.1156 No.1 (March 2009), pp.260–293

[62] John C.Mazziotta, "Time and Space," in Arthur W.Toga and John C.Mazziotta, (eds.), *Brain Mapping: The Methods,* (Amsterdam and Boston: Academic Press, 2002), pp.33-46. Indeed, "as thousands of papers per year are published in neuroimaging, it is impossible to keep up with the developments in any area other than one's own subspecialty." Bandettini, *What's New,* p.260

or photon emission tomography (1976),
and magnetic resonance imaging (MRI, 1980).[63]

The ideal brain mapping technique would have low invasiveness and costs, with exceptionally high spatial and temporal resolution[64] able to continuously sample a bulky amount of brain.[65]

In magnetic resonance imaging (MRI) a "technological tidal wave broke over neurology" [66] and transformed medicine. In functional MRI (fMRI) as the flow of blood rises in normal brain activity, the quantity of oxygen used by the brain does not.[67] The fMRI records blood flow in this situation. There is more oxygen locally in the tissue due to the greater flow of blood yet the demand for oxygen has not increased. Then because the presence of oxygen in the tissues changes its magnetic properties, fMRI can monitor any alterations. This is commonly called the blood oxygen level-dependent (BOLD) effect. fMRI BOLD has remained central in functional research.[68] It has had far-reaching effects.[69]

Originally known as positron emission transaxial tomography (PETT), positron emission tomography (PET) for human use emerged in the late 1970s.[70] PET uses radioactively labelled water: a radioactive isotope of oxygen called oxygen-15,

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[63] Each technology had contributions from other researchers, preceded by lead-up inventions and breakthroughs, animal experiments etc. Joel E.Gray and Colin G.Orton, "Medical Physics: Some Recollections in Diagnostic X-ray Imaging and Therapeutic Radiology," *Radiology* Vol.217 No.3 (December 2000), pp.619-625.
[64] Resolution is the capability of differentiating two entities as individual and distinct. Mazziotta, *Time and Space,* p.36 & p.39.
[65] Mazziotta, *Time and Space,* p.45
[66]Simon D.Shorvon, "A history of neuroimaging in epilepsy 1909–2009," *Epilepsia* Vol.50 No.S3 (March 2009), pp.39-49 (p.44). Originating in chemistry as nuclear magnetic resonance (NMR) pertaining to magnetic resonance of nuclei, NMR was applied to scan the human body. Manufacturers of scanners for the United States swiftly altered the name from NMR to *MRI* (magnetic resonance imaging) since the word 'nuclear' had a negative market impact.
[67] Marcus E.Raichle, "Functional Imaging in Cognitive Neuroscience," in Martha J.Farah and Todd E.Feinberg (eds.), *Patient-Based Approaches to Cognitive Neuroscience* (Cambridge, Massachusetts and London, England: The MIT Press, 2000), pp.37-52, especially pp.37-38
[68] See Marcus E.Raichle, "A brief history of human brain mapping," *Trends in Neurosciences* Vol.32 No.2 (February 2009), pp.118-126
[69] Bruce R.Rosen and Robert L.Savoy, "fMRI at 20: Has it changed the world?," *NeuroImage* Vol.62 No.2 (15 August 2012), pp.1316-1324
[70] "Transaxial" was omitted since it was possible to reconstruct images in other planes besides the transaxial plane. Katherine H.Taber, Kevin J.Black and Robin A.Hurley, "Blood Flow Imaging of the Brain: 50 Years Experience," *The Journal of Neuropsychiatry and Clinical Neurosciences* Vol.17 No.4 (November, Fall, 2005), pp.441-446

together with hydrogen, to record blood flow.[71] When it is injected into vein of an individual's arm, the radioactivity reaches the brain and enables an image of blood flow to be formed. It has many applications e.g. neurosurgery.[72]

Commercial x-ray computed tomography (CT) has been revolutionary in radiology.[73] It was also known as 'computerised axial tomography' (CAT),[74] and 'computerised transverse axial scanning (tomography)',[75] where x-ray transmission recordings are made at various angles and the data processed through a computer and presented as a series of images. CT was a method for anatomy; function was the domain of MRI and PET.[76]

Cerebral Cartography and Maps of the Brain

A broader goal is cartography or maps of the brain.[77] Maps of the neocortex, 85% of human brains, are the most sophisticated maps covering various regions which themselves have multiple maps: 'cognitive maps' or a part of the sensory periphery.[78]

The neocortex has its own 'floating signifiers' with terms such as 'module', 'neural representation', 'cortical code', even 'consciousness', for use to describe the cortical circuits which has much unknown about mode of organization and operation.[79] The challenge of translating structure into function to explain neocortical circuits at synaptic resolution needs more information than the connectivity matrix or even knowing the entire schematic drawing of wires. This provides the syntax of cortex,

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[71] Marcus E.Raichle, "Positron Emission Tomography," *Annual Review of Neuroscience* Vol.6 (1983), pp. 249-267.

[72] Where brain areas for language are of interest e.g. Mohamed L.Seghier et.al., "Regional and hemispheric determinants of language laterality: Implications for preoperative fMRI," *Human Brain Mapping* Vol.32 No.10 (October 2011), pp.1602-1614

[73] Webb, *The contribution,* pp.171

[74] E.C.Beckmann, "CT scanning the early days." *The British Journal of Radiology* Vol.79 No.937 (January 2006), pp.5-8

[75] G.N.Hounsfield, "Computerized transverse axial scanning (tomography): Part 1. Description of system," *The British Journal of Radiology* Vo.46 No.552 (December 1973), pp.1016-1022 and James Ambrose, "Computerized transverse axial scanning (tomography): Part 2. Clinical application," *The British Journal of Radiology* Vo.46 No.552 (December 1973), pp.1023-1047

[76] Cognitive neuroscience, using cognitive psychology methods to relate mental activity to the functions in the brain. Hence, the focus on *functional* neuroimaging. Raichle, *A brief history,* pp.118-126

[77] Arthur W.Toga and John C.Mazziotta, **"**An Introduction to Cartography of the Brain," in Arthur W.Toga & John C.Mazziotta (eds.), *Brain Mapping: The Methods,* Second Edition (San Diego & London: Academic Press, 2002), pp.3-31

[78] Rodney J.Douglas and Kevan A.C.Martin, "Mapping the Matrix: The Ways of Neocortex," *Neuron* Vol.56 No. 2 (25 October 2007), pp.226-238

[79] Douglas & Martin, *Mapping the Matrix,* p.226

but one needs to comprehend the semantics of the many areas of neocortex and the conversations in-between.[80]

There are many kinds of brain maps.[81] Data from various laboratories, subjects and modalities, plus the dimensions and scales used in brain maps, suggests the possibilities of atlases, brain databases and computerised brain maps. But for real value it needs a database with adequate structures, e.g. a uniform coordinate system or ability to compare, contrast, sum, or categorise the contents. Similarly, in modern neuroscience, "a brain map that cannot assimilate disparate observations about structure and function or accommodate new data will be quickly outdated. Thus, in brain mapping, the atlas is the database." [82]

For some, 'cerebral cartography' is a pejorative term just below the uncomplimentary 'new phrenology'.[83] Proponents say the very use of the term 'new phrenology', even today, highlights the power and endurance of one of the main themes of cortical studies: to assign particular functions to brain areas of characteristic architecture.[84]

The assumption of the early cartographers such as Korbian Brodmann ('Brodmann's Areas'), that areas which differ in function will also differ in architecture, has proven to be substantially accurate. This is potentially surprising since many subdivisions have not been revealed in light of advanced imaging technology. They succeed because the sole hypothesis is that anatomical subdivisions will express functional subdivisions. But activations from neuroimaging rely on the nature of the stimuli used, and their interpretation is deeply hypothesis-driven.[85]

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[80] Douglas & Martin, *Mapping the Matrix,* p.236
[81] Each clearly has its place "within a collective to map the brain, but unless certain precautions are taken (enabling common registration), they will have to remain as individual and independent efforts." Toga & Mazziotta, *An Introduction to Cartography,* p.6. There are also other crucial issues such as databases and ownership of data, human subject protection, authorship, security and data sharing. See p.14ff
[82] Toga & Mazziotta, *An Introduction to Cartography,* p.25
[83] Semir Zeki, "Introduction: cerebral cartography 1905–2005," *Philosophical Transactions of the Royal Society B* Vol.360 No.1456 (29 April 2005), pp.651-652
[84] Zeki, *Introduction: cerebral cartography,* p.651
[85] Andreas Bartels and Semir Zeki, "The chronoarchitecture of the cerebral cortex," *Philosophical Transactions of the Royal Society* B Vol.360 No.1456 (29 April 2005), pp. 733-750 (p.733)

Some Cautions in Interpretation

Powerful imaging and lesion methods have inferential hazards:[86] differences in biology or individual experiences could result in unique structure–function relationships which affect interpretation; there are concerns about assigning a distinctive cognitive process to a neural region since a region may be involved in several computational processes. It depends on *ceteris paribus* assumptions where a single variable is being manipulated while all other things are equal. This may not be the case.

Spatial, temporal and resolution factors mean that there are only a number of accessible recording methods. None has the ability to simultaneously 'see' large and small areas at the temporal resolution of neuronal activity.[87] Even a combined application of methods falls short of the target to explain how neuronal groups produce representations of the environments and fitting responses in a changing environment.[88] Particular behaviours arise from the interaction of brain areas, neurons and neuronal groups.

Pioneer Marcus Raichle contemplates the wealth of research and its challenges. Neuroscientists studying at the cellular and molecular level need a grasp of ideas in cognitive psychology and social neuroscience, while behavioural science requires knowledge of biological correlates of functional neuroimaging signals, cell biology and even genetics. Under these circumstances, it is tempting to keep within into the narrow boundaries of expertise, which ultimately limits the potential of researchers' work.[89] The huge volumes of neuroscientific data results await full integration,[90] and using MRI methods and interpreting its data demands technical expertise.[91]

Neuroimaging itself is unable to settle questions about *mechanism.* An important goal of cognitive neuroscience is to recognise the mechanisms or causal chain of

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[86] Lesley K.Fellows et.al., "Method Matters: An Empirical Study of Impact in Cognitive Neuroscience," *Journal of Cognitive Neuroscience* Vol.17 No.7 (June 2005), pp.850–858
[87] György Buzsáki, *Rhythms of the Brain* (New York: Oxford University Press, 2006), pp.109-110
[88] Buzsáki, *Rhythms of the Brain,* p.110
[89] Raichle, *A brief history,* p.124
[90] Steriade, *The Intact and Sliced Brain,* p.65., for instance, research on the visual cortical areas of primates, due to the difficult methods needed to record cellular data from trained monkey, are not reconciled with the input-output structure characteristic of types of neurons characteristic.
[91] Bradley P.Sutton et.al, "Current trends and challenges in MRI acquisitions to investigate brain function," *International Journal of Psychophysiology* Vol.73 No.1 (July 2009), pp.33-42

neural events beneath cognition. Yet the data from functional neuroimaging are correlational: a specific area is activated during a particular cognitive process. Neuroimaging cannot separate correlation from causation.[92] That is, it cannot point to which brain regions are causally facilitating a cognitive process since regions activated could be otherwise activated, even epiphenomenally or they could have a true causal role.[93]

Critical Comment

Functional methods depend on computers and complex physical sciences,[94] and brain properties like electromagnetism. These physicalist methods can investigate the mind, attesting to psychophysical unity, as does psychophysiology. Cognitive activities like decision making and emotional responses like fear, are psychological processes open to physiological study.

One scientist considers it is a miracle that recording brain electrical activity can garner meaning. "Imagine what you might learn from placing electrodes on top of a computer to determine which program is in operation (or even whether the program is in hexadecimal, ASCII, or C++). Or, take a single wire and stick it into the guts of the computer (and hope you won't short anything out) to find out in machine language what is going on."[95] With effort, synthesis with data from other methods, using what is essential, meaning is possible.

Other scholars draw philosophical conclusions. Many religions believe in an immaterial soul, "yet as neuroscience advances, all aspects of a person are increasingly understood to be the functioning of a material system."[96] Some secular scientists infer the absence of the soul using neuroscientific evidence and scientific theory assumptions. "We've all heard that the soul is dead. Now we want to see the

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92 Todd E.Feinberg and Martha J.Farah, "A Historical Perspective on Cognitive Neuroscience," in Feinberg & Farah (eds.), *Patient-Based Approaches to Cognitive Neuroscience,* pp.3-20.(p.17)

93 Feinberg &Farah, *A Historical Perspective,* pp.3-20

94 The discoveries are worthy of Nobel Prizes, e.g. Felix W.Wehrli, "On the 2003 Nobel Prize in medicine or physiology awarded to Paul C.Lauterbur and Sir Peter Mansfield," *Magnetic Resonance in Medicine* Vol.51 No.1 (January 2004), pp.1–3

95 Karl H.Pribram, "Thoughts on the Meaning of Brain Electrical Activity," *International Journal of Psychology* Vol.33 No.3 (1998), pp.213- 225 (pp.223-224)

96 Martha J.Farah, "Neuroethics: The Ethical, Legal, and Societal Impact of Neuroscience," *Annual Review of Psychology* Vol.63 (2012), pp.571-591 (p.587). Brain processes are the physical bases of central dimensions of human personhood: spirituality, morality, love; "if these aspects of the person are all features of the machine, why have a ghost at all?" (p.587)

body,"[97] says Joshua D.Greene. One branch of neuroscience, social neuroscience, aims to understand all human subjective experience in physical terms. "The rise of social neuroscience is the demise of the soul."[98]

The soul has 'outsourced' operations like memory, perception, and language to the brain. Greene wonders how many of the soul's functions can be performed by the brain before the soul is jobless.[99] He compares dualist soul beliefs to cancer. The assumption of the mind being brain operations diverges from the "rest of humanity, the vast majority of whom explicitly believe that we are souls housed in bodies. Such dualist tendencies are, in my opinion, a major social problem, and may become increasingly destructive. If that is correct, then dispelling dualism is serious business, at least as serious as curing cancer, and probably more so."[100]

However, drawing conclusions about the absence of the soul goes beyond the experimenter's aim, method and recorded data. This requires expertise from philosophy and theology. If humans exist as ensouled bodies and embodied minds with brains,[101] then the brain is naturally accessible via neuroscience methods, within its physical and interpretive limits. Some of these are explored below.

Philosophical Questions

Some neuroscientists but mostly philosophers have probed philosophical ideas in neuroscience,[102] e.g. M.R.Bennett and P.M.S.Hacker,[103] and subsequent exchanges

[97] Joshua D.Greene, "Social Neuroscience and the Soul's Last Stand," in Alexander Todorov, Susan Fiske, and Deborah Prentice (eds.), *Social Neuroscience: Toward Understanding the Underpinnings of the Social Mind* (New York: Oxford University Press, 2011), pp.263-273 (p.264)
[98] Greene, *Social Neuroscience and the Soul's Last Stand,* p.264
[99] Greene, *Social Neuroscience and the Soul's Last Stand,* p.265
[100] Greene, *Social Neuroscience and the Soul's Last Stand,* p.271
[101] Marc Cortez, *Embodied Souls, Ensouled Bodies: An Exercise in Christological Anthropology and Its Significance for the Mind/Body Debate,* T&T Clark Studies in Systematic Theology (London and New York: T&T Clark, 2008).
[102] Pete Mandik, "Supervenience and neuroscience," *Synthese* Vol.180 No.3 (June 2011), pp.443-463; Philip Gerrans and Jeanette Kennett, "Neurosentimentalism and Moral Agency," *Mind* Vol.119 No.475 (July 2010), pp.585-614; Andrew S.Beedle, "A Philosopher Looks at Neuroscience," *Journal of Neuroscience Research* Vol.55 No.2 (15 January 1999), pp.141–146; Judy Illes and Barbara J.Sahakian (eds.), *Oxford Handbook of Neuroethics* (Oxford and New York: Oxford University Press, 2011); Walter Glannon, *Bioethics and the Brain* (New York: Oxford University Press, 2007)
[103] Neuroscientist M.R.Bennett and Wittgenstein philosopher P.M.S.Hacker co-authored *Philosophical Foundations of Neuroscience,* a provocative critique of the philosophy implicit in neuroscience. They named major neuroscientists and philosophers and their apparent errors in concepts and language: Francis Crick, Gerald Edelman, Colin Blakemore, Richard Gregory, Antonio

with their critics.[104] This section considers some major philosophical issues associated with brain and mind, which pertain to body and soul.

Brain and Mind Questions

Given the centrality of the brain, its relationship to the mind is perplexing.[105] One view of the mind is as "a complex phenomenon built on the physical scaffolding of the brain which neuroscientific investigation continues to examine in great detail."[106] Mind and brain are linked as shown through brain injury; brain damage entails damage to consciousness.[107] A severe traumatic brain injury assumes damage to the brain. Therefore, the focus of assessment is to document the nature and extent of cognitive and psychosocial difficulties and intact abilities, and not to assess for 'presence or absence of brain damage'.[108] Likewise, the brain of a chronic pain patient is not merely a healthy brain processing pain information; instead it is altered by continuing pain in a way suggestive of other neurological conditions related to cognitive impairments.[109]

Psychiatry pre-eminently pertains to mind/brain relationships,[110] concentrating on objective brain states and subjective constructs. Psychiatric disorders are usually

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Damasio. See M.R.Bennett and P.M.S.Hacker, *Philosophical Foundations of Neuroscience* (Oxford: Blackwell Publishing; 2003), pp.68-70. Bennett and Hacker's remarks have largely been unanswered by neuroscientists, though their book has been reviewed in philosophy and science journals.

[104] Maxwell Bennett et.al., *Neuroscience and Philosophy: Brain, Mind, and Language* (New York: Columbia University Press, 2007). M.Bennett and P.Hacker participated in the 'Authors and Critics' session at the 2005 American Philosophical Association meeting in New York. Bennett and Hacker's 2003 book *Philosophical Foundations of Neuroscience* closed with two appendices, one each critiquing the work of leading philosophers Daniel Dennett and John Searle. At the session in New York, Dennett and Searle provided rebuttals to the criticisms by Bennett and Hacker; the latter two then replied to the rebuttals of Dennett and Searle. This book captures the essence of the meeting.

[105] Danielle S.Bassett and Michael S.Gazzaniga, "Understanding complexity in the human brain," *Trends in Cognitive Sciences* Vol.15 No.5 (May 2011), pp.200-209. Bassett and Gazzaniga's paper argues for complex systems theory, that "complexity science has been posited as a potentially powerful explanation for a broad range of emergent phenomena in human neuroscience." (p.208)

[106] Bassett and Gazzaniga, *Understanding complexity*, p.200

[107] Rhawn Joseph, *Neuropsychology, Neuropsychiatry, and Behavioral Neurology* (New York and London: Plenum Press, 1990), p.vii.

[108] William W.McKinlay and John M.Gray, "Assessment of the Severely Head-Injured," in John R.Crawford, Denis M.Parker and William W.McKinlay (eds.) *A Handbook of Neuropsychological Assessment* (Hove, UK: Lawrence Erlbaum Associates Ltd, Publishers, 1992), pp363-364

[109] Marwan N.Baliki et.al., "Beyond Feeling: Chronic Pain Hurts the Brain, Disrupting the Default-Mode Network Dynamics," *The Journal of Neuroscience* Vol.28 No.6 (6 February 2008), pp.1398-1403 (p.1402)

[110] David H.Brendel, *Healing Psychiatry: Bridging the Science/Humanism Divide* (Cambridge, Massachusetts and London: The MIT Press, 2006), pp.77-90; Kenneth S. Kendler, "A Psychiatric Dialogue on the Mind-Body Problem," *The American Journal of Psychiatry* Vol.158 No.7 (July 2001), pp. 989-1000

organic, biological, brain-based, or functional, psychological, mind-based.[111] Similarly, psychotherapy to reduce symptoms of specific phobias demonstrates potential to alter the dysfunctional neural circuitry associated with anxiety disorders like spider phobia.[112] Psychotherapeutic changes made at the mind level are able to functionally 'rewire' the brain.[113]

However, there are tensions in understanding mind and brain, conceptual hindrances in accounting for mind and behaviour in terms of brain activity. [114] Decision-making is a feature of the mind but the brain does not appear to have capabilities to make 'decisions' given the rapid responses to alterations in its internal states and the complexity of recurrent networks.

Metaphysical questions are also raised. Splits between brain and mind sometimes are regarded as Cartesian dualism and this has been significant in the recent history of electrical brain stimulation.[115] Or how Cartesian dualism was seen in a split between purely organic and purely social abnormalities in the writings of neurosurgeon Vernon H.Mark. Here, paralysis, blindness and dementia were regarded as neurological problems while aggression and depression were viewed as abnormalities for psychiatrists, sociologists and criminologists, not associated with brain dysfunction.[116]

Contested claims include:
i. cognitive neuroscience can never provide a complete account of a person's psychology because it is reductionistic;

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[111] Therapies impact on the mind ('psycho' therapies) and on the brain ('somatic' therapies). The division of the United States government that funds most research in psychiatry is termed the National Institute of "Mental" Health. The manual of the American Psychiatric Association that is widely used for the diagnosis of psychiatric disorders is called the Diagnostic and Statistical Manual of "Mental" Disorders. Kendler, *A Psychiatric Dialogue on the Mind-Body Problem,* p.989
[112] Patricia Ribeiro Porto et.al., "Does Cognitive Behavioral Therapy Change the Brain? A Systematic Review of Neuroimaging in Anxiety Disorders," *The Journal of Neuropsychiatry and Clinical Neurosciences* Vol.21 No.2 (Spring 2009), pp.114-125; also Vincent Paquette et.al., "'Change the mind and you change the brain': effects of cognitive-behavioral therapy on the neural correlates of spider phobia," *NeuroImage* Vol.18 No.2 (February 2003), pp.401-409
[113] Paquette et.al., *Change the mind and you change the brain,* p.408
[114] Richard M.Vickery, "Mind the neuron! The role of the single neuron in a theory of mind," *Acta Neuropsychiatrica* Vol.19 No.3 (June 2007), pp.177–182
[115] See e.g., Joseph J. Fins, "Neuromodulation, free will and determinism: lessons from the psychosurgery debate," *Clinical Neuroscience Research* Vol.4 Nos.1-2 (July 2004), pp.113-118
[116] Fins, *Neuromodulation, free will and determinism,* p.117

ii. neuroscience can only show correlations between cognitive or behavioural events and neural events; and
iii. neuroscience is not actually relevant in psychology since it has little to comment about human history, culture, etc.[117]

Some philosophers think that psychological concepts will eventually be replaced with neuroscience descriptions.[118] Others argue this is premature, "to date, no fully developed demonstration of a mechanism by which psychology or biology affects the other has been offered. In fact, we know little about how or whether neural events drive psychological events, or the converse."[119]

From the mind side,[120] the mind–brain and brain-behaviour correspondence remains "the largest challenge in 21st-century psychology."[121] Some have explained how psychology generally accepts the Kantian idea that knowledge in the brain contributes to memories, thoughts, feelings and perceptions in a top-down manner yet it is accepted by some that *emotions, thoughts, memories, the self,* reflect the building blocks of the mind. Brain states arise from collections of neurons firing, are observer independent, and do not need the mind they create to recognise them. In realising the mind, they change moment to moment in a person and among people.[122]

Reductionism as a special program in science answers the question of what entities exist: spatio-temporally extended, micro-physical things, properties and events,

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[117] Peter Machamer and Justin Sytsma, "Neuroscience and Theoretical Psychology: What's to Worry About?," *Theory & Psychology* Vol.17 No. 2 (April 2007), pp. 199-216. One can deny that "cognitive neuroscience need be ontologically reductionistic while accepting that the knowledge it produces must be understood in terms of its methodological commitments. As such, if by 'reductive' one means a methodology that employs a 'divide and conquer' approach to complex problems, then the answer is 'yes'; cognitive neuroscience often is methodologically reductionist." (p.204)
[118] For example, Peter J.Marshall, "Relating Psychology and Neuroscience: Taking Up the Challenges," *Perspectives on Psychological Science* Vol.4 No.2 (March 2009), pp.113-125
[119] Gregory A.Miller, "Mistreating Psychology in the Decades of the Brain," *Perspectives on Psychological Science* Vol.5 No.6 (November 2010), pp.716-743 (p.716)
[120] Lisa Feldman Barrett, "The Future of Psychology: Connecting Mind to Brain," *Perspectives on Psychological Science* Vol.4 No.4 (July 2009), pp.326-339; "Erratum," *Perspectives on Psychological Science* Vol.4 No.5 (September 2009), p.531. There is a similar typological mistake on p.329 of the July 2009 paper, as confirmed in email correspondence with Professor Barrett on 30 September 2010.
[121] Barrett, *The Future of Psychology*, p.326. Barrett also says the link between psychology as a social and a natural science has "felt less like a solid footbridge and more like a tightrope requiring lightness of foot and a really strong safety net." (p.326)
[122] Barrett, *The Future of Psychology*, p.327

which are material.[123] However, even if the aetiology of a psychological disorder includes causal brain mechanisms, or gene expression impacting on brain mechanisms, it is possible that the brain mechanism or gene expression is itself caused by psychological events.[124] Within a multilevel perspective, neuroscience works toward an understanding of how the brain implements psychological functions.[125] The neuron does not think single-handedly; the brain does not reason alone. Cortical neurons are interconnected via abundant synapses; there is no single region in the brain that has access to all the brain knows.[126]

Explanatory pluralism implies that many theories are needed to understand the universe due to levels of organisation and diverse goals of human individuals.[127] Others think we do not yet know how to move between the levels of analysis and knowledge derived from different brain discourses and their techniques.[128] What is missing is a theoretical framework to incorporate volumes of data. Within a mechanistic setting of science, there has to be a coherent method to envisage multiple levels and dimensions.[129] The danger is thinking that there will be a complete understanding of neuroscience.[130]

Neuroimaging Questions

Ground-breaking researchers point to areas largely undefined in functional brain imaging.[131] In functional magnetic resonance imaging (fMRI), researchers still lack a

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[123] Sacha Bem, "The Explanatory Autonomy of Psychology: Why a Mind is Not a Brain," *Theory & Psychology* Vol.11 No.6 (1 December, 2001), pp.785-795 (pp.785-786)
[124] Miller, *Mistreating Psychology,* pp.736-737
[125] Kenneth S.Kendler, "Explanatory Models for Psychiatric Illness," *The American Journal of Psychiatry* Vol.165 No.6 (June 2008), pp. 695-702. See also K.S.Kendler and J.Campbell, "Interventionist causal models in psychiatry: repositioning the mind–body problem," *Psychological Medicine* Vol.39 No.6 (June 2009), pp.881-887.
[126] William P.Cheshire, "From Biochemical Synapse to Bioethical Syntax," *Ethics & Medicine* Vol.24 No.2 (Summer 2008), pp.77-81 (p.80).
[127] Rick Dale, Eric Dietrich and Anthony Chemero, "Explanatory Pluralism in Cognitive Science," *Cognitive Science* Vol.33 No.5 (July 2009), pp.739-742; Lauren J.Breen and Dawn Darlaston-Jones, "Moving beyond the enduring dominance of positivism in psychological research: Implications for psychology in Australia," *Australian Psychologist* Vol.45 No.1 (March 2010), pp. 67-76
[128] Steven Rose, *The Future of the Brain: The Promise and Perils of Tomorrow's Neuroscience* (New York: Oxford University Press, 2005), p.213
[129] Rose, *The Future of the Brain,* p.215. See also Chris Lucas, "Evolving an Integral Ecology of Mind," *Cortex* Vol.41 No.5 (2005), pp.709-725
[130] Yadin Dudai, "The neurosciences: the danger that we will think we have understood it all," in Dai Rees and Steven Rose (eds.), *The New Brain Sciences: Perils and Prospects* (Cambridge: Cambridge University Press, 2004), pp.167-180
[131] Louis Sokoloff, "The physiological and biochemical bases of functional brain imaging," *Cognitive Neurodynamics* Vol.2 No.1 (March 2008), pp.1-5; Marcus E.Raichle, "Behind the scenes of functional

clear grasp of sound interpretations of fMRI signals, which reflect an intricate interplay of changes in cerebral blood flow, cerebral blood volume and blood oxygenation.[132] A picture is worth a thousand words, thus images from functional imaging apparently reveal the neural mechanisms behind human thoughts and actions.[133] Yet fMRI is not and "will never be a mind reader, as some of the proponents of decoding-based methods suggest, nor is it a worthless and non-informative 'neophrenology' that is condemned to fail, as has been occasionally argued."[134]

But others remain cautious.[135] There are queries about inferences that can be drawn.[136] For some supposed mental process, the conditions that differ in the engagement of that process are examined and brain areas that demonstrate changes in activation between the conditions are inferred to be involved in that mental process. Potential problems exist since it uses correlation; it cannot be inferred that the activated areas are necessary or sufficient for the involvement of the mental process.[137] While some raise doubts about the ultimate meaning of results,[138] there has been progress in analyses of the association between brain function and behaviour.[139]

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brain imaging: A historical and physiological perspective," *Proceedings of the National Academy of Sciences of the United States Of America* Vol.95 No.3 (3 February 1998), pp.765-772

132 Nikos K.Logothetis, "The ins and outs of fMRI signals," *Nature Neuroscience* Vol.10 No.10 (October 2007), pp.12300-1232; see too Nikos K.Logothetis, "What we can do and what we cannot do with fMRI," *Nature* Vol.453 No. 7197 (12 June 2008), pp.869-878

133 Logothetis, *The ins and outs,* p.1230

134 Logothetis, *What we can do,* p.869. See also criticism of neuroimaging as the 'new phrenology', "the obsession with brain patterns that is only a minor change from the older 'science' of measuring external measurements of head circumference and shape." Peter Tyrer, "From the Editor's desk: The new phrenology," *The British Journal of Psychiatry* Vol.193 No.3 (September 2008), p.266

135 Patrizio E.Tressoldi et.al., "Using functional neuroimaging to test theories of cognition: A selective survey of studies from 2007 to 2011 as a contribution to the Decade of the Mind Initiative," *Cortex* Vol.48 No.9 (October 2012), pp.1247-1250

136 Russell A.Poldrack**, "**The role of fMRI in Cognitive Neuroscience: where do we stand*?," Current Opinion in Neurobiology* Vol.18 No.2 (April 2008), pp.223-227

137 Indeed, there are well-known examples of cases in which regions that are activated during a task are not necessary for the task. For example, the hippocampus is activated during delay classical conditioning, but lesions to the hippocampus do not impair this function." Poldrack**,** *The role of fMRI,* p.223

138 For example, Marcus E.Raichle and Mark A.Mintun, "Brain Work and Brain Imaging*," Annual Review of Neuroscience* Vol.29 (2006), pp.449-476 (p.468)

139 The guiding questions include "how to relate neuroimaging measurements to the biology and neurophysiology of brain cells and their microvasculature" and "the neurobiology of the signals generated by PET and MRI." Raichle & Mintun*, Brain Work,* p.450

The increasing use of positron emission tomography (PET) and fMRI in experimental and cognitive psychology is also questioned.[140] Some think psychology can be scientific only by becoming neuroscience or cognitive science.[141] But cognitive psychologists wish to know "*how the mind* works, not *where* the *brain* works."[142] The neural and computational mechanisms beneath particular psychological processes need correct specifications of psychological processes.[143] Cognitive psychology needs 'mindscanners' rather than brainscanners.

Mindreading is associated with social cognition[144] or psychic abilities.[145] Yet what neuroimaging can reveal about the mind is debated. Many experts think that one cannot learn anything about cognition from studying the brain. Nonetheless, to demonstrate the opposite of this, actual examples can be supplied where neuroimaging data has successfully distinguished between competing psychological theories.[146] It appear to be a brain-reading device that can objectively assess and build up an image of a person's visual experience, which answers, 'what's in your mind?'[147] This reads out the mental picture from fMRI.[148] Some look to intentions which are decipherable by neuroimaging, e.g. ability to hold an overarching goal in mind while engaged in subordinate tasks. [149]

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[140] Mike P.A.Page, "What Can't Functional Neuroimaging Tell the Cognitive Psychologist?," *Cortex* Vol.42 No.3 (2006), pp.428-443

[141] Gary Hatfield, "Psychology, Philosophy, and Cognitive Science: Reflections on the History and Philosophy of Experimental Psychology," *Mind & Language* Vol.17 No. 3 (June 2002), pp.207–232.

[142] Page, *What Can't Functional Neuroimaging Tell?,* p.429

[143] As in genetics, the first need is to identify a phenotype. John T. Cacioppo and Jean Decety, "What Are the Brain Mechanisms on Which Psychological Processes Are Based?," *Perspectives on Psychological Science* Vol.4 No.1 (January 2009), pp.10-18.

[144] Mindreading is associated with patients with autism spectrum conditions who experience impairments in emotion recognition, social attribution, mindreading and other cognitive and affective abilities. Tests of social cognition include the 'Reading the Mind in the Eyes Test' developed by Simon Baron-Cohen, first published in 1997. See Maria Unenge Hallerbäck et.al., "The Reading the Mind in the Eyes Test: Test–retest reliability of a Swedish version," *Cognitive Neuropsychiatry* Vol.14 No.2 (2009), pp.127-143; cf. also Alvin I.Goldman, *Simulating Minds: The Philosophy, Psychology, and Neuroscience of Mindreading* (New York: Oxford University Press, 2008).

[145] Isabel Dziobek et.al., "In search of 'master mindreaders': Are psychics superior in reading the language of the eyes?," *Brain and Cognition* Vol.58 No.2 (July 2005), pp.240-244.

[146] Max Coltheart, "What has Functional Neuroimaging told us about the Mind (so far)? (Position Paper Presented to the European Cognitive Neuropsychology Workshop, Bressanone, 2005)," *Cortex* Vol.42 No.3 (2006), pp.323-331. (p.330)

[147] Brian A.Wandell, "What's in your mind?," *Nature Neuroscience* Vol.11 No.4 (April 2008), pp.384-385

[148] Kendrick N.Kay et.al., "Identifying natural images from human brain activity," *Nature* 452 Vol. 7185 (20 March 2008), pp.352-355

[149] Sam J.Gilbert, "Decoding the Content of Delayed Intentions," *The Journal of Neuroscience* Vol.31 No.8 (23 February 2011), pp.2888 –2894. Also known as 'prospective memory'.

Others find an absence of self.[150] Brain imaging "does not reveal a soul. Brain images show specific, discrete areas of the brain 'lighting up' when we listen, when we speak, when we move, when we feel, but no control director, no conductor, no 'me' who decides to listen, to listen to what, what to say, what to do. The 'me' isn't present in brain imaging at all. The 'me' is nowhere to be seen."[151]

Such philosophical questions also reach down to the foundations of neuroscience. One systematic critical appraisal has found conceptual confusions in understanding how brain relates to the mind.

A Philosophical Critique

M.R.Bennett and P.M.S.Hacker describe a human being as a "psychological unity, an animal that can perceive, act intentionally, reason and feel emotions, a language-using animal that is not merely conscious, but also self-conscious."[152] They find neuroscientists are confused in saying the brain perceives, believes, or guesses. For example Susan Greenfield telling television audiences that positron emission tomography is wonderful since "for the first time it is possible *to see thoughts.*"[153] This is observing the brain of a *person* who sees.

Bennett and Hacker argue that psychological explanations using goals, values, etc. cannot be replaced by neurological concepts. It makes no sense to ascribe psychological attributes to anything less than the whole animal. It is human beings who reason, not their brains. "The brain and its activities *make* it *possible* for *us* – not

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[150] Betty Evans Streett, "Where's the 'Me'?: Reflections on Consciousness in Light of Brain Imaging Technology," *The Journal of Pastoral Care & Counseling* Vol.59 Nos.1-2 (Spring-Summer 2005), pp.131-132

[151] Streett, *Where's the 'Me'?,* p.131

[152] Bennett & Hacker, *Philosophical Foundations,* p.3. Sherrington, Eccles, and Penfield conceived of human beings as "animals in whom the mind, which they thought of as the bearer of psychological qualities, is in liaison with the brain." (p.3) They call Sherrington, "the greatest of neuroscientists," (p.11) yet Bennett and Hacker find many of his colleagues and successors have conceptual errors and problems in their writings and thinking.

[153] Bennett & Hacker, *Philosophical Foundations,* p.70, footnote 11. John Perry describes a similar idea in the 1966 Academy Award winning movie *Fantastic Voyage,* where a significant person with significant knowledge has a brain clot. The government shrinks a team of neurosurgeons, loads them onto a very small submarine which is injected the bloodstream of that person. They navigate to the bloodclot, destroy it and exit the body via a tear duct. Perry notes one remark of the rescue team while in the brain. A noticeable blue vapour rises and "Arthur Kennedy says to Raquel Welch, 'Look, we are the first to actually see human thoughts,' or words to that effect. No one in the boat finds this the least bit odd." John Perry, *Knowledge, Possibility, and Consciousness,* The 1999 Jean Nicod Lectures (Cambridge, Massachusetts and London: The MIT Press, 2001), p.2

for *it* – to perceive and think, to feel emotions, and to form and pursue projects."[154] This is the 'mereological fallacy'. Mereology is the logic of whole-part relations. Neuroscientists ascribe to the constituent *parts* of animal attributes which logically applies only to the *whole* animal.[155] The brain cannot be conscious; only living creatures with brains can be conscious or unconscious.[156]

To ask, 'what is the mind?' may be misleading say Bennett and Hacker because the mind is not a kind of thing.[157] A split brain by commissurotomy does not produce two minds; "the *brain* does not *have* a mind, and neither do the two hemispheres of the brain...it is human beings, not their brains, that are said to have minds, and to say that is simply to say that human beings have an array of distinctive capacities."[158]

Bennett and Hacker pointedly note that neuroscience ascribes properties which Cartesians gave to the mind. The immaterial mind is replaced by the material brain which is claimed to have human psychological attributes: brain-body dualism. It makes no sense to ascribe properties to the brain, nor to an inanimate object like a stone, or to a number, which is not a spatio-temporal object. Brains, stones and numbers are not living creatures that behave in ways that logically warrant ascribing psychological attributes to them.[159] Like Cartesians, today's neuroscientists envisage mental states and processes as occurring *in* the brain or *in* human beings, instead of understanding mental states as that of the *person,* and acts by that person. Indeed,

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[154] Bennett & Hacker, *Philosophical Foundations,* p.3
[155] Bennett & Hacker, *Philosophical Foundations,* p.73. The brain is "not a logically appropriate subject for psychological predicates. Only a human being and what *behaves* like one can intelligibly and literally be said to see or be blind, hear or be deaf, ask questions or refrain from asking." The authors acknowledge their own source of authority: Ludwig Wittgenstein and his thesis that only a human being sees, has sensations, is deaf, is blind, can hear, is conscious and so forth. (p.71)
[156] Bennett & Hacker, *Philosophical Foundations,* p.72. Similarly, pain is usually ascribed to an animal or person, not to a brain; the brain does not show pain-behaviour such as groaning and grimacing which is done by a person suffering pain. (p.83)
[157] Thus to ask if the mind is identical with the brain is either misconceived as a question or "it is understood as a question concerning the identity of some or all of these character traits, powers and the instances of their exemplification and exercise with states, events and processes in the brain." Bennett & Hacker, *Philosophical Foundations,* p.105. Mind is not a *something* though it is also not a *nothing,* following Wittgenstein.
[158] Bennett & Hacker, *Philosophical Foundations,* pp.106, 389-393. That is, "neither brains nor their left halves observe anything, and they do not interpret what they see, since they neither see nor interpret anything. These are functions that human beings perform." (p.106, footnotes 67). Cf. Michael Tye, *Consciousness and Persons, Unity and Identity* (Cambridge, Massachusetts & London: The MIT Press, paperback 2005), pp.109-132. Tye concludes that split-brain patients are "single persons whose consciousness is unified except in certain very special experimental situations. On those occasions, their stream of consciousness splits into two, which rejoin again once the experimental controls are removed." (p.128)
[159] Bennett & Hacker, *Philosophical Foundations,* p.112

neuroscience contains ‘crypto-Cartesianism’ which is conceptually incoherent as the Cartesianism it unintentionally originates from.[160]

Bennett and Hacker argue against Francis Crick’s ideas that human behaviours are theoretically and finally explained by neurology. A person may fear, hope and believe etc. due to a working brain. But it is another thing to hold that there are general bridge principles for identifying what a person believes with particular type of neural states.[161] Materialism does not demonstrate that human beings are reducible to their nervous systems, or that minds are brains.[162]

Moreover, it is contended that no neuroscientific breakthroughs can resolve *any* philosophical conceptual problems just as no breakthroughs in physics can prove theories in mathematics. Cognitive neuroscience descriptions “*presupposes* the relevant psychological concepts. Factual discoveries cannot determine what makes sense. They determine what is true – which *presupposes* what makes sense.”[163]

Neuroscience aims to understand the nervous system thus creating strategies to lift the burden of brain disorders like dementia and schizophrenia.[164] This differs from neuroscience which has one overall aspiration, to fully grasp consciousness.

Bennett and Hacker have drawn applause but criticism too: “this is an extraordinary view. Not only does it ignore the empirical basis of concepts, but the authors favour views because they are established…we deny that, in itself, conceptual analysis can provide a foundation for science.”[165] They hardly acknowledge lesion studies, ignore the methodology of scanning, and diminish the worth of empirical findings.

As *strict* foundationalists, “they boldly ignore many concerns of working scientists. For example, not only is consciousness separated from sensation and perception but,

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[160] Bennett & Hacker, *Philosophical Foundations,* p.114
[161] Bennett & Hacker, *Philosophical Foundations,* p.360
[162] Bennett & Hacker, *Philosophical Foundations,* p.359
[163] Bennett & Hacker, *Philosophical Foundations,* p.407. Neuroscience cannot solve conceptual difficulties about consciousness through empirical brain imaging methods, it cannot ground the study of epistemology or study the conceptual nature of knowledge.
[164] Maxwell Bennett, “Epilogue,” in Bennett et.al., *Neuroscience and Philosophy,* pp.163-170
[165] Machiel Keestra and Stephen J.Cowley, “Foundationalism and neuroscience; silence and language,” *Language Sciences* Vol.31 No.4 (July 2009), pp.531-552 (p.532)

without argument, they dismiss any human faculty of language."[166] Further, they do not fear controversy. "In part, this is because, rather than seeking connections between mental phenomena, they aim to refute the 'mereological fallacy in neuroscience'. Given this goal, they present their work as the product of a *method*. In contrast to neuroscientists, they eschew theoretical issues such as how human powers arise in neural activations."[167]

Others find Bennett and Hacker's claims as provocative and their arguments unproved.[168] Bennett and Hacker's view has been called 'neural materialism' where mental events, states and processes are roughly identical with neural states or material properties of neural states events, processes, etc.[169] It is noted how specialists make important discoveries in cognitive neuroscience without philosophical backup, e.g. no grand 'neurophilosophy' was offered by those who developed vision science as a first-rate science.[170] Yet, Wittgensteinian philosophy is precise. It is the philosopher who monitors so that the future does not perpetuate current confusions.[171]

It can be noted that Bennett and Hacker also criticise Aquinas, claiming that Aquinas reified the intellect, separated form from matter, and "confused the incorporeality of powers (which are abstractions) with the alleged incorporeality of the soul, conceived as a *non-physical part* of a human being). Other scholastic philosophers also contributed to the attempted synthesis of Christianity with Aristotelian philosophy."[172] They also see that Aquinas adopted Aristotelian philosophy but "strove, with questionable coherence, to adapt it to Christian theology."[173]

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[166] Keestra & Cowley, *Foundationalism and neuroscience,* p.532
[167] Keestra & Cowley, *Foundationalism and neuroscience,* p.532
[168] Greg Janzen, "Bennett and Hacker on Neural Materialism," *Acta Analytica* Vol.23 No.3 (September 2008), pp.273-286. Janzen concludes that Bennett and Hacker have "failed to generate any convincing arguments for either the meaningless of or the falsity of NM. Of course, there may be compelling arguments for at least the falsity of the thesis; it's just that Bennett and Hacker's arguments are not among them." (p.285)
[169] If Bennett and Hacker are right, many philosophers, neuroscientists and psychologists are holding false and meaningless views. Janzen, *Bennett and Hacker on Neural Materialism,* p.274
[170] Daniel Robinson, "Still Looking: Science and Philosophy in Pursuit of Prince Reason," in Bennett et.al., *Neuroscience and Philosophy,* pp.171-193 (p.191)
[171] Robinson, *Still Looking,* p.193
[172] Bennett & Hacker, *Philosophical Foundations,* p.24
[173] Bennett & Hacker, *Philosophical Foundations,* p.24.. Bennett &Hacker's one reference to Aquinas' philosophy of psychology is A.J.P.Kenny's *Aquinas on Mind* (1993). But not all Thomists agree with Kenny's account of what Thomas thought about the mind.

Critical Analysis

Neuroscience and its methods are authoritative explanations of the brain, and supply the physicalist grounds for the human mind. However, the magisterial teachings and other Catholic thinking are not typically expressed in neuroscientific language but metaphysically as soul and body, yet more importantly as the unified person.[174] Neuroscience could be perceived as a threat because it appears to account articulately for the human capacities traditionally associated with the soul, e.g. nutrition, sensation, intellect and memory. Or at least if mind-brain causation is questioned philosophically as seen above, then at least there is an indisputable correlation between brain and mental activity in neuroimaging.

Tommaso sees the soul giving the body its organised existence,[175] actuating a body.[176] This sounds very much like the contemporary understanding of the brain. Yet the soul is the "principle of the act of understanding" and the human soul he also calls an "intellect" or "mind."[177] Moreover, understanding goes beyond an ability to comprehend; it is "much more a substance acting through that ability; and so what it understands is not just its own ability but also the substance."[178] Whereas, according to the contemporary science the brain is, like the heart and lungs, a vital organ of the body; however the soul as described by Tommaso is more substantial, is mind or intellect. Neuroimaging reveals brain activity correlated to stimuli, perhaps not enough to qualify to be a medieval 'mind', albeit the human being has intelligence which neuroscience can explore. It is just that neuroscience does not require the soul or the very concept, for its work, except if the experiment involves religious subjects and the investigator is a believer in the soul, as will be seen in the next chapter.

The centrality of the brain is mirrored by Tommaso on the soul, "the ultimate principle by which we conduct every one of life's activities; the soul is the ultimate motive factor behind nutrition, sensation and movement from place to place, and the same holds for the act of understanding."[179] The soul is one with many powers

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174 *Catechism of the Catholic Church,* nos.364-365; p.93
175 Aquinas, *Quaestio Disputata de Anima*, reply to 15, p.191.
176 Aquinas, *Sum.Theol. Vol 11,* I. Q.75 Art.1, p.6-7
177 Aquinas, *Sum.Theol. Vol 11,* I. Q.75 Art.2, p.11
178 Aquinas, *Quaestio Disputata de Spiritualibus Creaturis,* in Aquinas (McDermott), Art.11, reply to 18, p.129.
179 Aquinas, *Sum.Theol. Vol 11,* I. Q.76 Art.1, pp.42-43.

though ordered, eg. vegetative, sensitive, appetitive, locomotive, intellective[180] Tommaso's philosophical account of soul is naturally limited by the knowledge of his times. Thus it may not be valid to compare his philosophy of mind with contemporary neuroscience.

Neuroscience expanded rapidly in the twentieth century and with progress of technological methods, with ever-expanding research that is comprehensive but unintegrated due to its sheer volumes.[181] Neuroscience has been described as a "splintered field," with some 10,000 laboratories worldwide "pursuing distinct questions about the brain across a panoply of spatio-temporal scales and in a dizzying variety of animal species, behaviours and developmental time-points. At any large neuroscience meeting, one is struck by the pace of discovery, with 50,000 or more practitioners heading away from each other in all directions, in a sort of scientific Big Bang."[182] Despite this spacious spread, neuroscientific findings seem to present difficulties for understanding soul in the hylomorphic scheme (although as we shall see in Part III, some Thomists have utilised modern brain/mind ideas).

On the other hand, far from being a threat, the neurosciences can be read as a marvellous confirmation of the wonders of the body (Psalm 139:14), and exemplifying the corporeal nature of persons; and who are unified persons in the Catholic understanding due to the spiritual principle.[183]

For Christians, neuroscience is a new materialist explanation which some have enthusiastically used to inform their thinking.[184] This "progress of the sciences" which throws light on the nature of human beings, opening "new avenues to truth,"[185] can be welcomed by the Catholic Church. Thus neuroscience and its methods provide sound causal explanations to which Catholic thought ought to pay serious attention. Still, for some Christians, those 'Christian materialists' (so to

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[180] Aquinas, *Sum.Theol. Vol 11,* I. Q.77 Art.4, pp.102-103; and Q.78 Art.1, pp.120-121
[181] Steriade, *The Intact and Sliced Brain,* p.65
[182] Christof Koch and R.Clay Reid, "Observatories of the mind," *Nature* Vol.483 No.7390 (22 March 2012), pp.397-398 (p.397); Buzsáki, *Rhythms of the Brain,* pp.109-110
[183] *Catechism of the Catholic Church,* no.363; p.93
[184] Warren S.Brown, Nancey Murphy and H.Newton Malony (eds.), *Whatever Happened to the Soul? Scientific and Theological Portraits of Human Nature*, Theology and the Sciences Series (Minneapolis: Fortress Press, 1998).
[185] Vatican II, "Pastoral Constitution on the Church in the Modern World, *Gaudium et Spes*," in Austin Flannery (Ed.), *Vatican Council II, The Conciliar and Post Conciliar Documents* (Dublin and Clonskeagh: Dominican Publications/Talbot Press, 1975), no.44; p.946

speak) who are sympathetic to Greene's materialist views, the brain explains virtually everything and therefore must replace the traditional soul.

Other Catholic thinkers suggest that perhaps contemporary neurology confirms the Aristotelian notion that 'the mind has no organ', because 'it is not mixed' (*De Anima*, III, 4, 429 a 15; b 23; 29 ff.) and is not the form of any physical structure.[186] M.S.Sorondo explains how different to the senses (sight, taste, hearing, touch, smell) which have their own organs, the brain instead cannot be regarded as the organ of the mind because the intellect thinks its objects via images (phantasms), or something akin to internal representations. These are physically based in the brain and also in the senses distributed through the body.[187]

The mind, says Sorondo, depends on the imagination, and is therefore dependent on the brain and body and has a natural character. The soul confers on the body the unity and the essential quality of the human body. These are reflected in "the dynamic unity of the cognitive (and inclinational) activities which cannot only coexist but also work together with intelligence (and the will) in a participation of the senses with the intellect (and in a participation of the sense inclinations with the will)."[188] There is a working unity of body/soul in the person.

Conclusions

On the autonomy of reason, John Paul II teaches that reason cannot set itself up as an absolute; "reason on its part must never lose its capacity to question and to be questioned."[189] Indeed, today's technological outlook has an inclination to perceive problems and emotions of the interior life from a pure psychological perspective, even to the point of neurological reductionism.[190] Neuroscience and its foundations are subject to philosophical criticism, such as that of Bennett and Hacker. The brain sciences are not ethical systems, though they investigate ethics as neuroethics[191] and moral concepts e.g. free will.[192]

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[186] Various speakers, *Questions For Neurologists and Others,* p.xliii
[187] Various speakers, *Questions For Neurologists and Others,* p.xliii
[188] Various speakers, *Questions For Neurologists and Others,* pp.xliii-xliv
[189] John Paul II, *Fides et ratio* No.79, p.112
[190] Benedict XVI, *Caritas in Veritate,* no.76, p.140
[191] Adina Roskies, "Neuroethics for the New Millenium," *Neuron* Vol.35 No.1 (3 July 2002), pp.21-23; Richard Joyce, "What Neuroscience Can (and Cannot) Contribute to Metaethics," in Walter Sinnott-Armstrong (ed.), *Moral Psychology, Volume 3 The Neuroscience of Morality: Emotion, Brain*

As an empirical discipline, neuroscience can only be neutral on philosophical matters, since its aim, procedures and results are purely physicalist. Its purpose is not to normatively adjudicate on the soul's demise, existence, or its transcendent status. And certainly not on the Catholic view that the human body shares in the dignity of "the image of God": that it is a human body precisely because it is animated by a spiritual soul.[193]

This metaphysical position creates a tension with secular thinkers and some neuroscientifically-minded theologians. The traditional Catholic understanding of the soul is transcendent, theological, and non-scientific, and can partly align with Bennett and Hacker as an ally in their anti-Cartesian critique of neuroscience. Whereas neuroscientific thinking is physicalist and non-theological. There is an opening for the possibility of dialogue. If however the tone is trenchant, like Greene's mission to root out the cancer-like 'soul', then the likely result will be a form of Barbour's first or second types of science-theology relationships, where one dominates the other or where each is completely independent of the other. Yet for neuroscientists, the official Catholic views can also appear to be closed to dialogues. All parties to dialogue need to be well-informed about the other's position.

There are avid secular scientists who see cognitive neuroscience discoveries as claims against the existence of the soul. But others in the profession return findings and interpretation which favour a spiritual alternative. This will be part of the next chapter which applies neuroscience and its methods to matters of science and the soul.

Disorders, and Development (Cambridge, Massachusetts and London: The MIT Press, 2008), pp.371-394.

[192] Benjamin Libet et.al., "Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential): the unconscious initiation of a freely voluntary act," *Brain* Vol.106 No.3 (September 1983), pp.623-642; Patrick Haggard, "Human volition: towards a neuroscience of will," *Nature Reviews Neuroscience* Vol.9 No.12 (December 2008), pp.934-946

[193] *Catechism of the Catholic Church*, no.364; p.93