ME, MY SUBCONSCIOUS AND I

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ABSTRACT: This Essay postulates, using scientific references from some of the world's leading neurologists, the organic location of 'subconsciousness'. It also postulates, upon the same basis, an original theory on the evolution of language. In doing so, the Essay uncloaks the most fundamental, yet most forgotten component of the human brain.

KEYWORDS: Neurology; Brain Science; Speculative Philosophy

In order for us to have any realistic hope of understanding, or even discussing the human brain, we first need a shared definition of 'the brain' – something that is clearly lacking in today's vast sea of literature on the topic. As defined by Encyclopaedia Britannica, the brain consists of three distinct regions; the hindbrain, the midbrain, and the forebrain:

> The hindbrain is composed of the medulla oblongata and the pons. The medulla transmits signals between the spinal cord and the higher parts of the brain... The pons is partly made up of tracts connecting the spinal cord with higher brain levels, and it also contains cell groups that transfer information from the cerebrum to the cerebellum.
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> The midbrain, the upper portion of which evolved from the optic lobes, is [a] ... centre of sensory integration ... serving primarily as a connecting link between the hindbrain and the forebrain.
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> The forebrain includes the cerebral hemispheres… The cerebrum, originally functioning as part of the olfactory lobes, is involved with the more complex functions of the human brain.

Despite coming from a single source, our working definition of 'the brain' is already flawed: the cerebellum is in fact a fundamental component of the hindbrain. "Relatively large in humans, this 'little brain' controls balance and coordination by producing smooth, coordinated movements of muscle groups"(EB). As per the cerebrum, the cerebellum is also divided into two hemispheres.

Before reading this definition, one could be forgiven for believing that the human brain consisted of no more than our 'forebrain': the cerebrum – often vulgarised even further to only 'the neocortex'. One could also be forgiven for believing that 'the human brain' has two hemispheres, as we so often read today. Instead, 'the brain' more obviously has four quadrispheres, should we acknowledge the fact that both the cerebrum (of the forebrain) and the cerebellum (of the hindbrain) are each made up of two hemispheres. This confusion exists, somewhat surprisingly, despite the fact that the fundamental structure of the brain has remained remarkably stable over time. We read in Carl Sagan's Pulitzer Prize winning *The Dragons of Eden*, of 1977, that "fossil endocasts of the earliest known vertebrates show that the principal divisions of the modern brain (hindbrain, midbrain and forebrain, for example) were already established. Five hundred million years ago, swimming in the primeval seas, there were fishy creatures called ostracoderms and placoderms, whose brains had recognizably the same major divisions as ours".[1]

> "One of the most engaging views of the subsequent evolution of the [human] brain is a story of the successive accretion and specialization of three further layers surmounting the spinal cord, hindbrain and midbrain... The principal contemporary exponent of this view is Paul MacLean, chief of the Laboratory of Brain Evolution and Behaviour of the National Institute of Mental Health".[2] By covering the ongoing work of Dr MacLean, *The Dragons of Eden* popularised his 'triune brain' model as early as 1977; MacLean himself not going on to publish *The Triune Brain in Evolution* until 1990. "The human brain, MacLean holds, 'amounts to three interconnected biological computers', each with 'its own special intelligence, its own subjectivity, its own sense of time and space, its own memory, motor, and other functions'. Each brain corresponds to a separate major evolutionary step".[3]

> "At the most ancient part of the human brain lies the spinal cord; the medulla and pons, which comprise the hindbrain; and the midbrain. This combination of [brainstem/] spinal cord, hindbrain and midbrain MacLean calls the neural

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[1] Carl Sagan, *The Dragons of Eden*, 1st ed., New York, Random House, 1977, p. 51.
[2] Sagan, *The Dragons of Eden*, p. 53-4.
[3] Sagan, *The Dragons of Eden*, p. 57.

> chassis. It contains the basic neural machinery for reproduction and self-preservation, including regulation of the heart, blood circulation and respiration. In a fish or an amphibian it is almost all the brain there is".[4]

Although not clearly identified in this passage either, the cerebellum is, as already stated, a *bona fide* member of the hindbrain, and as such, a member of MacLean's 'neural chassis'.

On top of this archaic 'neural chassis' sits MacLean's holy trinity, the first of which we share "with the other mammals and the reptiles. It probably evolved several hundred million years ago. MacLean calls it the reptilian or R-complex. Surrounding the R-complex is the limbic system, so called because it borders on the underlying brain... We share the limbic system with the other mammals but not, in its full elaboration, with the reptiles. It probably evolved more than one hundred and fifty million years ago. Finally, surmounting the rest of the brain, and clearly the most recent evolutionary accretion, is the neocortex".[5] From this, we understand that in the context of 1970's science, 'the human brain' meant only those things found sitting on top of the midbrain; certainly not the cerebellum.

"The brain of a human fetus also develops from the inside out, and, roughly speaking, runs through the sequence: neural chassis, R-complex, limbic system and neocortex".[6] The components of the neural chassis themselves follow a similar outward-pattern during foetal development; echoing their evolutionary development. We can equally see evolutionary history replayed in the distribution of function across component parts: (1) spinal cord, (2) hindbrain – responsible for sleep and wakefulness, breathing and heart regulation, (3) midbrain – responsible for auditory and visual processing; something that clearly would have evolved after heart regulation, not before.

To close the chapter on 1970's brain science: "The human brain (apart from the cerebellum, which does not seem to be involved in cognitive functions) contains about ten billion switching elements called neurons. (The cerebellum, which lies beneath the cerebral cortex, toward the back of the head, contains roughly another ten billion neurons)".[7] MacLean clearly shared Sagan's views on

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[4] Sagan, *The Dragons of Eden*, p. 57.
[5] Sagan, *The Dragons of Eden*, p. 58.
[6] Sagan, *The Dragons of Eden*, p. 60.
[7] Sagan, *The Dragons of Eden*, p. 41-2.

the cerebellum; at that time considered no more than a lowly member of the 'neural chassis', whose only function was to keep us moving. Indeed, the cerebellum is mentioned only five times in *The Dragons of Eden*.

So how well has MacLean's 'triune brain' model – which considered the human brain to start and finish at the forebrain – stood up against modern science? In 2009, our brain's neuronal distribution was authoritatively declared: "The fractional distribution of neurons in the human brain does not correspond to the fractional distribution of mass among brain structures. Although 82% of brain mass consists of cerebral cortex (including subcortical white matter) and 42% consists of cerebral cortical gray matter alone, the 16.34 (+/- 2.17) billion neurons found in this structure represent only 19% of all brain neurons. In contrast, the cerebellum, which represents only 10% of total brain mass, contains 69.03 (+/- 6.65) billion neurons, or 80% of all neurons in the human brain. Fewer than 1% of all brain neurons are located in the [Rest of Brain] RoB, comprising basal ganglia, diencephalon and brainstem".[8] If we consider that the basal ganglia, midbrain, pons and medulla oblongata together constitute fewer than 1% of all the brain's neurons, then we might consider MacLean as having been fundamentally correct to have excluded the 'neural chassis' from his model of the human brain, with a singular and utterly spectacular exception: the cerebellum – host to 80% of the brain's neurons. Interestingly, "the number of cells in the human cerebellum has been estimated as 70 ... billion neurons [as far back as] Lange, 1975".[9]

Has much been written on the cerebellum since the 1970s? Let's start with the writings of the world's leading authority on the topic, which had its modern renaissance in the 1980s. "It is well established in clinical neurology and neuroscience that the cerebellum is essential for the co-ordination of movement (Flourens, 1824; Luciani, 1891...). Less attention has been directed to the observation that behavioural anomalies occur in association with cerebellar

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[8] Frederico Azevedo, Ludmila Carvalho, Lea Grinberg, José Farfel, Renata Ferretti, Renata Leite, Wilson Filho, Roberto Lent, Suzana Herculano-Houzel, 'Equal Numbers of Neuronal and Nonneuronal Cells Make the Human Brain an Isometrically Scaled-Up Primate Brain', *The Journal of Comparative Neurology*, vol. 513, no. 5, 2009, p. 535.

[9] Azevedo et al., 'Equal Numbers of Neuronal and Nonneuronal Cells Make the Human Brain an Isometrically Scaled-Up Primate Brain', p. 533.

disorders (Combettes, 1831; Andral, 1848…)… The early reports were generally anecdotal and not pathologically verified, and the possibility of a cerebellar contribution to non-motor function was largely dismissed".[10] You might have remarked that "the observation that behavioural anomalies occur in association with cerebellar disorders" dates back to the 1830s; the reason for which I referred to 1980s as the cerebellum's modern renaissance – some 150 years later.

> "Our results indicate that there is a pattern of behavioural abnormalities, [which we have] termed the 'Cerebellar Cognitive Affective Syndrome', that includes impairments of executive function (planning, set-shifting, abstract reasoning, verbal fluency, working memory)...; visual-spatial disorganization and impaired visual-spatial memory; personality change with blunting of affect or disinhibited and inappropriate behaviour; and difficulties with language production".[11] The demonstration of integrated "cerebrocerebellar circuitry has led to the suggestion that the cerebellum is incorporated into the neural systems that subserve such higher order behaviour as working memory, executive function, visual spatial abilities, linguistic processing, memory, attention and emotional modulation (Schmahmann, 1991, 1996). The neuropsychological and affective disorders in patients with cerebellar lesions are likely to be a consequence of disruption of these anatomical connections".[12]

As such, it seems clear that the cerebellum finally entered its golden age at the dawn of the twenty-first century. Given this, rather than further considering MacLean's 1970s model of the forebrain, let us now consider how contemporary authorities on the human brain are addressing our centuries-old neglect of the cerebellum. Let's consider as an example, *The Master and His Emissary: The Divided Brain and the Making of the Western World*, an influential Book first published in 2009, and most recently updated in 2019. In the fourth sentence of the updated 2019 Preface, we read: "I believe in discovering the truth about hemisphere difference".[13] What? Which two hemispheres is Iain McGilchrist actually referring to in his very recently updated tome on 'the human brain'? In reality, we can be quite sure that he is referring to the cerebral hemispheres, given that

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[10] Jeremy Schmahmann, Janet Sherman, 'The Cerebellar Cognitive Affective Syndrome', *Brain*, vol. 121, no. 4, 1998, p. 561.
[11] Schmahmann et al., 'The Cerebellar Cognitive Affective Syndrome', p. 561.
[12] Schmahmann et al., 'The Cerebellar Cognitive Affective Syndrome', p. 575.
[13] Iain McGilchrist, *The Mater and his Emissary*, 2nd ed. paperback, London, Yale University Press, 2019, p. x.

the cerebellum goes almost entirely unmentioned throughout 462 pages, despite its functional role having been first suggested in the 1830s. Should McGilchrist have contemplated the cerebellum – 80% of the brain's neurons – he might naturally have considered 'the divided brain' as having not two hemispheres, but four quadrispheres. Instead, he warns us that "The brain should not be thought of as an indiscriminate mass of neurones: the structure of that mass matters. In particular it has to be relevant that at the highest level of organisation the brain, whether mediator or originator of consciousness, is divided in two"?[14]

In the West, "about 89 per cent of people are broadly right-handed, and the vast majority of these have speech and the semantic language centres in the left hemisphere – let's call this the standard pattern".[15] That's interesting, because "All efferent and afferent pathways between the cerebrum and cerebellum course through the brainstem, and many of them decussate, or cross, within this structure"(EB). This is precisely why "The predominantly left-lateralized cerebral cortical activation during language paradigms is mirrored by right-lateralized posterolateral [cerebellum/] CB activation, reflecting the contralateral connectivity between the CB and cerebral cortex".[16] The vast majority of people have "semantic language centres in the left hemisphere" of the cerebrum perhaps, but they consequently have it in the right hemisphere of the cerebellum; a fact that one might reasonably hope to have seen mentioned in a modern text so haplessly focused on "the truth about hemisphere difference".

> "It has been accepted since the days of the great anatomist John Hunter that structure is at some level an expression of function... Although larger size does not always equate to greater functional capacity, it most commonly does so".[17] It seems that Mr McGilchrist remained unaware in 2019 of the fact – first published in 1975 – that "the cerebellum, which represents only 10% of total brain mass, contains ... 80% of all neurons in the human brain".[18]

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[14] McGilchrist, *The Master and his Emissary*, p. 9.
[15] McGilchrist, *The Master and his Emissary*, p.12.
[16] Georgios Argyropoulos, Kim van Dun, Michael Adamaszek, Maria Leggio, Mario Manto, Marcella Masciullo, Marco Molinari, Catherine Stoodley, Frank Van Overwalle, Richard Ivry, Jeremy Schmahmann, 'The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper', *The Cerebellum*, vol. 19, no. 1, 2019, p. 108.
[17] McGilchrist, *The Master and his Emissary*, p.23-4.
[18] Azevedo et al., 'Equal Numbers of Neuronal and Nonneuronal Cells Make the Human Brain an Isometrically Scaled-Up Primate Brain', p. 535.

Instead, he declares: "Function is reflected in volume throughout the central nervous system, in cerebrum, cerebellum and spinal cord".[19] Absolutely not: brain function is most obviously reflected in neurons, not volume.

It is clearly time to push aside popular BrainLit, and to return to the writings of neurologists. In a lucky coincidence, the original 'Cerebellar Cognitive Affective Syndrome' (CCAS) Paper of 1998 was also revised in 2019, in a new 'Task Force Paper': "Each aspect of the CCAS has been replicated in studies over the 20 years since its description… Recognition of the impact of [cerebellum/] CB dysfunction across multiple task domains has accumulated over the last 30 years".[20] Given that "Lesion-deficit studies in patients with focal injury provide pivotal insights into structure-function correlations",[21] "CB functional topography is [today] often seen in a quadripartite distinction of gross functional regions: the 'vestibular', 'motor', 'cognitive', and 'limbic cerebellum'."[22]

"Evidence from pediatric CB damage and developmental disorders" has led to what has been termed an "anterior 'motor' versus posterior 'cognitive' dichotomy" in the CB, that is "present early in development... CB stroke patients showed that the CB motor syndrome was associated with anterior CB lesions, whereas CCAS resulted from posterior CB damage… Consistent with task-based functional imaging, worse motor symptoms (pegboard, tapping, ataxia scores) resulted from lesions to the anterior lobe".[23] As such, whilst the ancient wisdom of the cerebellum being heavily implicated in motor function has clearly held true over the past two centuries, it holds true only of the anterior CB – its oldest part – in keeping with evolution's standard pattern of accretion.

"Neuroimaging studies in healthy individuals consistently report CB activation during a wide range of cognitive tasks ... consistent with the idea that the CB is part of a network of regions supporting cognitive function. Resting-state fMRI studies demonstrate CB functional connectivity with cerebral cortical

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[19] McGilchrist, *The Master and his Emissary*, p.23-4.
[20] Schmahmann et al., 'The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper', p. 104.
[21] Schmahmann et al., 'The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper', p. 112.
[22] Schmahmann et al., 'The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper', p. 104.
[23] Schmahmann et al., 'The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper', p. 109.

regions involved in cognitive processes";[24] "in agreement with the conceptual notion that the associative cortices [of the cerebrum] are linked with the more recently evolved lateral cerebellar hemispheres (Leiner et al., 1986...)".[25] "High-resolution structural and functional MRI and recent developments in fiber-tracking techniques ... [have] yielded deeper anatomical insight to the CB and its connections to incoming and forwarding signal connections to cerebral areas, among them the prefrontal, parietal, and temporal cortices in accordance with cognitive domains of attention, working memory, and a broad range of executive functions".[26]

Finally, the same Task Force went on to conjecture that the cerebellum "is thought to build motor or mental internal models, which are trained based on error signals and used to predict the consequences of ongoing motor or mental processes. This enables the CB to participate in processes important to optimal cognitive function, including prediction and performance monitoring".[27] Given that the cerebellum so clearly does "participate in processes important to optimal cognitive function", I would like to make a significant conjecture of my own: we have uncloaked the seat of 'subconsciousness'. We are in no way conscious of the many adjustments our cerebellum makes during motor function, so it cannot be reasonably argued, that we should nonetheless be conscious of the adjustments made – by the very same cerebellum – during cognitive function.

"Freud anticipated that making connections between experience and the structure of the brain would be possible once neuroscience became sufficiently evolved. A neurologist first and foremost, he believed that the mental entities that he described, and whose conflicts shaped our world – the *id*, the *ego* and the *superego* – would one day be more precisely identified with structures within the brain".[28] He was right to believe so, and moreover, it seems quite logical that our *id* should be situated amongst the most ancient components of the human brain;

[24] Schmahmann et al., 'The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper', p. 108.
[25] Schmahmann et al., 'The Cerebellar Cognitive Affective Syndrome', p. 575.
[26] Schmahmann et al., 'The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper', p. 111.
[27] Schmahmann et al., 'The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper', p. 110.
[28] McGilchrist, *The Master and his Emissary*, p.7.

those which predate speech. A far more basic question that we should be asking – given that the existence of a human 'subconscious' has been broadly accepted for over a century – is how such a subconsciousness could possibly have cloaked its functions within a singular, wholly-integrated brain?

As thoroughly 'popular' as books such as McGilchrist's *The Master and His Emissary* are, they nonetheless provide some useful brain fodder upon which to develop my conjecture further: "In the brain, unlike in most other human organs, later developments do not so much replace earlier ones as add to, and build on top of, them. Thus the cortex, the outer shell that mediates most so-called higher functions of the brain, and certainly those of which we are conscious, arose out of the underlying subcortical structures which are concerned with biological regulation at an unconscious level".[29] You might have noticed that MacLean's 'neural chassis' is referred to by today's authors as our 'subcortical structures'. As was the case with MacLean, these "underlying subcortical structures … [operate] at an unconscious level". Should McGilchrist one day consider the key role of the cerebellum in managing the "so-called higher functions of the brain", he will doubtless agree that as part of our 'subcortical structures', the cerebellum must certainly operate "at an unconscious level".

McGilchrist also informed us that "Neuroimaging ... use a variety of techniques to detect where there are changes in the perfusion (blood supply) of the brain... [However] Imaging just shows a few peaks, where much of interest goes on elsewhere... And, what is more, one cannot even assume that whatever 'peaks' is of primary importance, since only effortful tasks tend to register – the more expert we are at something the less we will see brain activity".[30]

In fact, it seems far more likely that we simply haven't been scanning the correct 'brain' during the execution of effortless tasks. After all, wouldn't effortless tasks most likely be managed by our 'subconscious brain'? Isn't that precisely why so few people – consciously – remember driving their cars home from work of an evening (so-called 'highway dissociation')?

Finally, McGilchrist reassures us that "Descartes was right: the one undeniable fact is our consciousness".[31] Yet isn't our sub-consciousness an equally

[29] McGilchrist, *The Master and his Emissary*, p.8.
[30] McGilchrist, *The Master and his Emissary*, p.35.
[31] McGilchrist, *The Master and his Emissary*, p.20.

undeniable fact? Don't we see evidence of it everywhere we look? For example, we read from other popular authorities, such as bestselling Daniel Goleman, that the human brain has a 'low road' and a 'high road'. "The low road operates on automatic, outside our awareness, and with great speed. The high road operates with voluntary control, requires effort and conscious intent, and moves more slowly".[32] "One helpful summary has been made by Matthew Lieberman of UCLA. Lieberman calls the automatic mode the 'X-system' (it includes the amygdala among other neural areas) and the control mode the 'C-system' (it includes the anterior cingulate cortex and areas of the prefrontal cortex, as well as others)".[33] It's not immediately clear how this summary is helpful, but it is once again suggestive of distinct conscious and subconscious brains. "Ordinarily they mesh seamlessly. Our social lives are governed by the interplay of these two modes".[34]

It is once again tempting to return to the writings of neurologists: "More recently, the CB role in social cognition has gained increasing recognition. A meta-analysis showed that about one third of all studies on social cognition engaged the CB when the tasks involved social mirroring (e.g., observing others' intentional body movements) or mentalizing (e.g., inferring others' intentions, beliefs, and personality traits on the basis of behavioral descriptions)... Functional connectivity analyses on social cognition confirmed task-related connectivity between the anterior CB and activation in mirror cortical areas, while the posterior CB ... showed task-related connectivity with cortical areas involved in mentalizing".[35] But what purpose can these – more recently evolved – 'mirror cortical areas' of the cerebrum possibly serve, we might ask, if not a necessary prerequisite to the 'smoke and mirrors' show that is human consciousness?

Further evidence of our primordial dichotomy can be found in the writings of Matthew Walker, in his international bestseller of 2017, *Why We Sleep*. Unlike Carl Sagan, Iain McGilchrist and Daniel Goleman, Matthew Walker is a Professor in Neuroscience; not a 'popular authority' on the human brain. "The

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[32] Daniel Goleman, *Social Intelligence*, 1st ed. paperback, New York, Random House, 2007, p. 321.
[33] Goleman, *Social Intelligence*, p. 321.
[34] Goleman, *Social Intelligence*, p. 16-7.
[35] Schmahmann et al., 'The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper', p. 107.

concept of lucid dreaming was once considered a sham. Scientists debated its very existence... Four years ago, an ingenious experiment removed all such doubt. Scientists placed lucid dreamers inside an MRI scanner. While awake, these participants first clenched their left and then right hand, over and over. Researchers took snapshots of brain activity, allowing them to define the precise brain areas controlling each hand of each individual. The participants were [then] allowed to fall asleep in the MRI scanner, entering REM sleep where they could dream. During REM sleep, however, all voluntary muscles are paralyzed... Yet, the muscles that control the eyes are spared from this paralysis... Lucid dreamers were able to take advantage of this ocular freedom, communicating with the researchers through eye movements… When participants signalled the beginning of the lucid dream state, the scientists [again] began taking MRI pictures of brain activity. Soon after, the sleeping participants signalled their intent to dream about moving their left hand, then their right hand, alternating over and over again... Their hands were not physically moving... But they were moving in the dream… The same regions of the brain that were active during physical right and left voluntary hand movements observed while the individuals were awake similarly lit up in corresponding ways during times when the lucid participants signalled that they were clenching their hands while dreaming!"[36] No, not the same regions of 'the brain', but the same regions of 'the cerebrum' were active "during times when the lucid participants signalled that they were clenching their hands while dreaming"; yet their hands did not physically move despite being instructed to do so by the cerebrum! Is this possibly because it is the cerebellum that pilots motor function – as recognized for two centuries – and not the cerebrum? Is the cerebrum just the smoke, to our lived smoke and mirror show?

As a Professor in Neuroscience, we should certainly expect Mr Walker to be fully conscient of the writings of the past twenty years on the key role of the cerebellum in normal brain function, yet it is hard to be sure: the cerebellum is never mentioned in his Book. Despite the Professor, evidence of the cerebellum can be easily unveiled in his writings:

"An obvious challenge to testing the brain when it is asleep is that … individuals

[36] Matthew Walker, *Why We Sleep*, 1st ed., London, Penguin Random House, 2017, p. 232-3.

> cannot engage in computerized tests nor provide useful responses… I and my colleague ... designed a solution to this problem … [exploiting] sleep inertia... The dramatic alterations in brain activity during NREM and REM sleep, and their tidal shifts in neurochemical concentrations, do not reverse instantaneously when you awaken… By restricting the length of whatever cognitive test we performed to just ninety seconds, we felt we could wake individuals up and very quickly test them in this transitional sleep phase… Upon awakenings from NREM sleep, participants did not appear to be especially creative, solving few of the anagram puzzles. But it was a different story when I woke them up out of REM sleep, from the dreaming phase. Overall, problem-solving abilities rocketed up, with participants solving 15 to 35 percent more puzzles when emerging from REM sleep compared with awakenings from NREM sleep or during daytime waking performance! Moreover, the way in which the participants were solving the problems after exiting REM sleep was different from how they solved the problems both when emerging from NREM sleep and while awake during the day".[37]

One might suggest to Professor Walker that the reason that "the way in which the participants were solving the problems after exiting REM sleep was different" is not because of "tidal shifts in neurochemical concentrations", as he suggests, but more logically because it was a different 'brain' doing the calculations; the cerebrum being largely shut down during REM sleep, as is clear to even non-scientists. What's more, had Professor Walker mentioned the cerebellum a single time in his 340 page treatise, he would likewise have had the occasion to mention that it is host to 80% of our brain's neurons. "There is perhaps no better illustration highlighting the smarts of REM-sleep dreaming than ... the dream of Dmitri Mendeleev on February 17, 1869, which led to the periodic table of elements... For years he pondered the riddle of nature. For years he failed... Succumbing to exhaustion, and with the elements still swirling in his mind and refusing organized logic, Mendeleev lay down to sleep. As he slept, he dreamed, and his dreaming brain accomplished what his waking brain was incapable of: 'I saw in a dream a table where all the elements fell into place as required. Awakening, I immediately wrote it down on a piece of paper'."[38] To be more scientific: Mendeleev's cerebellum accomplished (during sleep) what his cerebrum was incapable of (whilst awake).

If the cerebellum does indeed play such a powerful problem-solving role

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[37] Walker, *Why We Sleep*, p. 223-4.
[38] Walker, *Why We Sleep*, p. 220.

during REM sleep, it would doubtless require unhindered access to our full database of facts: "For fact-based information … the hippocampus offers a short-term reservoir... Analyzing ... electrical brainwaves ... [during] lighter, stage 2 NREM sleep, … we observed a strikingly reliable loop of electrical current pulsing throughout the brain that repeated every 100 to 200 milliseconds. The pulses kept weaving a path back and forth between the hippocampus, with it's short-term, limited storage space, and the far larger, long-term storage site of the cortex ... shifting fact-based memories from the temporary storage depot (the hippocampus) to a long-term secure vault (the cortex). In doing so, sleep had delightfully cleared out the hippocampus, replenishing this short-term information repository with plentiful free space".[39] It would seem from this dazzling electric show that we can now be quite confident that our short-term memory is situated in the hippocampus, and our long-term memory in "the cortex [sic]". "What came as a surprise" to Professor Walker and his team however, was that unlike in NREM sleep, REM sleep led to "a pronounced deactivation of ... circumscribed regions of the far left and right sides of the prefrontal cortex… This region ... manages rational thought and logical decision-making, sending 'top-down' instructions to your more primitive deep-brain centers... And [yet] it is this CEO region of your brain, which otherwise maintains your cognitive capacity for ordered, logical thought, that is temporarily ousted each time you enter into the dreaming state of REM sleep".[40]

If it is not the cerebellum, but our prefrontal cortex that fulfils the demonstrated problem-solving role during REM sleep, then it seems quite strange that this very-same 'CEO region' which "manages rational thought and logical decision-making", is "ousted each time you enter into the dreaming state of REM sleep"? Additionally, if the neocortex is indeed the home of our 'long-term secure vault' – and not our far older subconscious brain (as though long-term memory is a recently evolved need) – then it seems strange that the neocortex suffers such a "pronounced deactivation" at precisely the time it would need to be accessed for problem solving.[41] Finally, if the hippocampus is indeed our 'temporary storage depot' – so delightfully wiped clear during NREM sleep

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39 Walker, Why We Sleep, p. 109-1.
40 Walker, *Why We Sleep*, p. 195-6.
41 Walker, *Why We Sleep*, p. 195.

– then what possible role can it serve during REM sleep; yet we read that the "autobiographical memory regions of the brain, including the hippocampus, are [still] so active during REM sleep".[42] Could it instead be the true REM problem-solver – the cerebellum – that is making such frenetic use of this 'short-term reservoir', at the very time the prefrontal cortex is deactivated? Perhaps relevant in this regard, is that a recent "study on neurodegenerative conditions disclosed CB atrophy in Alzheimer's disease ... discussed in relation to CB-hippocampal functional connectivity".[43]

> "Previous MRI studies established that key emotion- and memory-related structures of the brain are all reactivated during REM sleep, as we dream: the amygdala and emotion-related regions of the cortex, and the key mnemonic center, the hippocampus. Not only did this suggest the possibility that emotion-specific memory processing was possible, if not probable, during the dreaming state", it also helped Professor Walker to develop his 'theory of overnight therapy', which "postulated that the process of REM-sleep dreaming accomplishes two critical goals: (1) sleeping to remember the details of ... valuable, salient experiences, integrating them with existing knowledge ... (2) sleeping to forget, or dissolve, the visceral, painful emotional charge that had previously been wrapped around those memories… You have not forgotten the memory, but you have cast off the emotional charge... You can accurately relive the memory, but you do not regurgitate the same visceral reaction… I argued that if REM sleep did not perform this operation, we'd all be left with a state of chronic anxiety in our autobiographical memory networks".[44]

As such, and rather confusingly, we read only a few pages later that it is REM sleep – and not necessarily stage 2 NREM sleep – that helps us "to remember the details of ... valuable, salient experiences, integrating them with existing knowledge". Given that the neocortex experiences a "pronounced deactivation" during REM-sleep dreaming, despite having been previously nominated as our 'long-term secure vault', one must ask the question as to how and where "the details of ... valuable, salient experiences" are therefore being integrated "with existing knowledge"? Even more worrying, is that Professor Walker seems to be prepared to deny the existence of subconsciousness altogether: if you will never

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[42] Walker, *Why We Sleep*, p. 203-5.
[43] Schmahmann et al., 'The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper', p. 107.
[44] Walker, *Why We Sleep*, p. 208-9.

have "forgotten the memory", and can thus "accurately relive the memory" at any time of your choosing, then it would seem that all is remembered; that nothing is ever hidden from us by a subconscious brain whose central role must surely be to prevent "a state of chronic anxiety" – survival? Let's rework Professor Walker's postulation to bring it more into line with the lived human experience: NREM-sleep facilitates (1) sleeping to remember, and REM-sleep facilitates (2) sleeping to forget. If our long-term secure vault of – conscious – memories is indeed our neocortex, then it can only be our subconscious brain that "delightfully cleared out the hippocampus" of excessively-painful memories during REM sleep; locking them away instead in our subconscious memory – a filing-system that has gone largely unchallenged since the times of Freud.

In *The Interpretation of Dreams*, of 1899, we learnt of Freud's "nonscientific theory of dreams as wish fulfillment", which "dominated psychiatry and psychology for an entire century".[45] "According to his theory, repressed desires, which he termed the 'latent content', were so powerful and shocking that if they appeared in the dream undisguised, they would wake the dreamer up. To protect the dreamer and his sleep, Freud believed there was a censor, or a filter, within the mind. Repressed wishes would pass through the censor and emerge disguised on the other side. The camouflaged wishes and desires, which Freud described as the 'manifest content', would therefore be unrecognizable to the dreamer".[46] What contemporary sleep scientists can instead tell us today, is that "the two stages of sleep – NREM and REM – play out in a recurring, push-pull battle for brain domination across the night. The cerebral war between the two is won and lost every ninety minutes".[47] In reality, I am not sure that Freud would be particularly reassured – well over a century of science later – to read that there is a push-pull battle in our cerebrum every night between two verbs? Should we instead avoid such nonscientific narratives, we might go some way towards satisfying Freud's search for an organic basis to dreams. In a maverick attempt to do so, I will make a second conjecture: Every night, the hippocampus is cleared of its 'day residue'. Memories are dispatched either to the cerebrum – our conscious brain – during NREM sleep, or to the cerebellum – our subconscious

45 Walker, *Why We Sleep*, p. 194.
46 Walker, *Why We Sleep*, p. 200.
47 Walker, *Why We Sleep*, p. 43.

brain – during REM sleep. As it is evidently beyond the remit of our conscious brain to decide for itself which memories it shall or shall not be privy to, it is for the cerebellum to censor those memories that are to remain in the hippocampus for eventual integration by the cerebrum – why the cerebrum is deactivated during REM sleep, and why Stage 2 NREM sleeps starts short but gets longer through the night. This filtering role of the cerebellum is precisely why "the deep emotional centers of the brain … are up to 30 percent more active in REM sleep compared to when we are awake".[48]

A "recent link with deficient REM sleep concerns autism spectrum disorder (ASD)... Autism, of which there are several forms, is a neurological condition that emerges early in development... The core symptom of autism is a lack of social interaction… Most notable, however, is the significant shortage of REM sleep. Autistic individuals show a 30 to 50 percent deficit in the amount of REM sleep they obtain".[49] If indeed autistic individuals do suffer from a 30 to 50 percent deficit in REM sleep, wouldn't that suggest that their cerebellums are being robbed of the time necessary to perform the emotional house-cleaning each night? Once again, we must return to the writings of neurologists: "Recent resting-state fMRI studies in ASD reveal ... decreased volume in right Crus II [of the CB/cerebellum] that correlates with the degree of autistic traits… It therefore appears likely that dysfunction reported within neural circuits engaged in social cognition in ASD is related, at least in part, to impaired interactions between focal CB regions and critical cerebral cortical nodes of the social brain".[50] Given this, there is an already established link between the cerebellum and REM sleep: "decreased volume in right Crus II ... correlates with the degree of autistic traits", which themselves correlate with significantly reduced REM sleep.

In order for our cerebellums to correctly fulfil their role of 'subconscious guardian', there is a very practical *sine qua non*: our subconsciousness must remain hidden from our consciousness. Were its machinations to enter into conscious awareness, it could no longer function as a sub-consciousness. This leads to an interesting dilemma: how can our subconscious brain communicate with our

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[48] Walker, *Why We Sleep*, p. 195.
[49] Walker, *Why We Sleep*, p. 81-2.
[50] Schmahmann et al., 'The Cerebellar Cognitive Affective/Schmahmann Syndrome: a Task Force Paper', p. 116.

conscious brain, whilst at the same time remaining hidden from it?

In Geoffrey Miller's brilliant Book, *The Mating Mind: How Sexual Choice Shaped the Evolution of Human Nature*, we learn that: "More has been written about language evolution than about the evolution of any other specific human mental ability. However, very little of this writing has been genuinely adaptationist in the sense of assessing particular fitness benefits that could have driven the evolution of language".[51] "To explain language evolution, then, we need to do the same things we did for morality: find a hidden survival or reproductive benefit in the apparently altruistic act of speaking".[52] As you might have noticed after reading only a few otherwise intelligent-sounding sentences, Geoffrey Miller – an evolutionary psychologist – reasons that language and speech must necessarily have evolved in unison. This is in fact a logical fallacy that can be easily destroyed with his own writing: "The average adult human English-speaker knows 60,000 words. The average primate knows only about 5 to 20 distinct calls… Unusually intelligent bonobos ... can be taught about 200 visual symbols in ape language experiments".[53] Unless I am mistaken, this means that intelligent bonobos have a capacity for "about 200 visual symbols in ape language", but no capacity whatsoever for speech? Doesn't this mean that language evolved in our nearest primate before speech, and separately from it? This is far from a minor point. If language did not evolve in the first place for communication with external entities – via the medium of speech – language must therefore have initially evolved for internal use – for which speech was redundant.

Before advancing on the subject of 'language', it is necessary – as it was for the 'brain' – to provide a working definition (taken from the Cambridge Dictionary): "*a system of communication* consisting of sounds, words, and grammar". It is well understood that words – symbols – are necessary for communication, but why, as you are reading these words, are they being read 'out loud' within the confines of your head? Most of us do this unconsciously of course, but try reading without–forming—each–individual—word–in—your–***d. The same is also true of our ideas and our conclusions. Stop thinking with words, and you will stop 'thinking'. Given that words are necessary for us to form our thoughts, and given

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[51] Geoffrey Miller, *The Mating Mind*, 1st ed., New York, Random House, 2001, p. 345.
[52] Miller, *The Mating Mind*, p. 349.
[53] Miller, *The Mating Mind,* p. 369.

that thought necessarily precedes – and has always preceded – all purposeful communication, did language first evolve for communication with others, or for the communication between our two brains that is apparently requisite to each of our conclusions? Were there only one component actively reasoning inside our heads at any given time, the use of language – "a system of communication" (between entities) – would be redundant, and unnecessary to thought.

This is perhaps why "It is being increasingly recognized that the cerebellum is involved in many cognitive processes including language processing… In the current [2007] study, we looked at effective connectivity (the influence that one brain region has on another) of the cerebellum and basal ganglia with regions [of the cerebrum] thought to be involved in phonological processing, i.e. left inferior frontal gyrus and left lateral temporal cortex. We analyzed functional magnetic resonance imaging data (fMRI) obtained during a rhyming judgment task in adults... The results showed that the cerebellum has reciprocal connections with both left inferior frontal gyrus and left lateral temporal cortex"[54] of the cerebrum. Moreover, the "study is the first to look at effective connectivity of the cerebellum and basal ganglia during a language processing task. Both of these structures have [their own independent] connections with frontal regions and temporo-parietal regions [of the cerebrum] thought to be involved in language processing".[55]

Given these findings, it would appear that the cerebellum can not only communicate directly with the cerebrum via "reciprocal connections with both left inferior frontal gyrus and left lateral temporal cortex", but also indirectly via the basal ganglia; which likewise "have connections with frontal regions and temporo-parietal regions" of the cerebrum. This flagrant 'modular redundancy' – somewhat reminiscent of our 'mirror cortical areas' – is particularly revealing in the context of theories of language evolution: "If a human mental trait evolved through natural selection for some specific function, it is supposed ... to be modular and specialized for solving a particular problem, because modular specialization is the efficient way to engineer things".[56] Nonetheless, aren't the mentioned "reciprocal connections" between the cerebellum and cerebrum

[54] James Booth, Lydia Wood, Dong Lu, James Houk, Tali Bitan, 'The role of the basal ganglia and cerebellum in language processing', *Brain Research*, vol. 1133, no. 1, 2007, p. 136-137.
[55] Booth et al., 'The role of the basal ganglia and cerebellum in language processing', p. 137.
[56] Miller, *The Mating Mind*, p. 132.

suggestive of 'a two-way street' between peers? "Based on research in the motor planning and control literature, we argue that the putamen engages in cortical initiation while the cerebellum amplifies and refines this signal to facilitate correct decision making".[57]

This last statement by expert neurologists bears repeating, at the same time as serving as a conclusion: the cerebellum "facilitate[s] correct decision making" – 'correct thought'. As such, the cerebellum has its own capacity to decide upon what is "correct", independently of the cerebrum; this it does from the shadows of subconsciousness. And yet, despite representing 80% of our brain's functional capacity, the cerebellum has been excised from most modern literature on 'the human brain'. When we consider that the cerebellum is at the same time our best candidate for 'seat of subconsciousness', one can only wonder if it isn't our collective subconscious itself, that is facilitating our collective unconsciousness of the cerebellum and its functioning.

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