2012

An investigation into the neural substrates of virtue to determine the key place of virtues in human moral development

Andrew P.L Mullins
University of Notre Dame Australia

Publication Details

Mullins, A. P. (2012). An investigation into the neural substrates of virtue to determine the key place of virtues in human moral development (Doctor of Philosophy (PhD)). University of Notre Dame Australia. http://researchonline.nd.edu.au/theses/78

Chapter 5

The neural bases of virtue.

“A mind of moderate capacity which closely pursues one study
must infallibly arrive at great proficiency in that study.”
Frankenstein; or, The Modern Prometheus
Mary Shelley

5.1 Reflections on the task being attempted.

There is scant literature referring explicitly to the role of neural structures in virtue. The most noteworthy attempt is by William Casebeer in an article published in *Nature Reviews Neuroscience* in 2003. Casebeer’s paper provides a most valuable, broad brush endorsement of the task of identifying the neural bases of virtue. He considers the various approaches to ethics and in the broadest of terms suggests neuroscientific implications. He finds that because virtue is experience-based it is not only more suited to scientific investigation but also the ethical theory most likely to find correspondence in reality:

> The current evidence allows us to draw a tentative conclusion: the moral psychology required by virtue theory is the most neurobiologically plausible.[1247]

He suggests that the neural “solution” will involve rich interconnectivity between the cognitive and affective resources of the brain, and recruiting aspects of the brain implicated in memory and TOM.

> Empirically successful moral cognition on the part of an organism requires the appropriate coordination of multi-modal signals conjoined with appropriately cued executive systems that share rich connections with affective and conative brain

[1247] Casebeer, “Moral cognition and its neural constituents,” 840-847.

> structures that draw on conditioned memories and insight into the minds of others, so as to think about and actually behave in a maximally functional manner. There is clear consilience between contemporary neuroethics and Aristotelian moral psychology.[1248]

Despite an ostensibly Aristotelian view of virtue, his focus is limited to "moral reasoning", and the role of virtue in supporting rationality remains implicit without either elaboration or explanation. "Virtue" remains undefined, and effectively there appears to be no appreciation of "habitus" nor of how good habits may be acquired or in what they might consist, nor is any any differentiation of the roles of virtue with respect to reasoning and sensitive appetites. Casebeer makes no reference to brain plasticity; and there are only single passing references to basal contribution and to "habit" itself.[1249] In short he demonstrates an impoverished understanding of virtue and consequently his speculation about the neural bases of virtue is unable to account for the actions and operations of virtue.

In addition there is a small but increasing number of studies which consider the neural substrate of isolated behaviours such as honesty, compassion, empathy and contemplation. Of these studies there appears to be none based on the Aristotelian-Thomistic notions of virtue and ensouled body, and therefore offering an articulated position with respect to human personality, autonomous behaviour, and for the capacity of persons to modify behaviours in response to environment, experience and their own choices.

In this chapter, I will argue for the existence of specific neural processes, brain areas, and pathways, constituting a complex of systems that are implicated in the development of virtue. My aim is to present a strong, inductive, empirical case for

---

[1248] Casebeer, "Moral cognition and its neural constituents," 843, suggests that the study of moral cognition can be divided into "three branches: the moral emotions, theory of mind and abstract moral reasoning."
[1249] He refers to "habits of character as informed by conditioned emotion and affect" (844).

the neural bases of virtue; a highly plausible mapping of current knowledge of neurobiology onto the characteristics of virtue identified in **Table 4.1**. Weight of evidence will argue that substantially differing neural bases are incompatible both with the neuroscience and with the Aristotelian and Thomistic notion of virtue. This study stands to make a timely contribution to the field and to give direction to research of an experimental nature.

This task, to my knowledge, has not been previously attempted.

5.1.1 Overview of this chapter.

First I draw insights from contemporary efforts to bridge the disciplines of neuroscience and moral anthropology, with respect to the neural bases of emotion and of morality. I discuss cross-current understandings of the neural bases of emotion in recent explorations of the relationship between emotion and reason by neuroscientists, Joseph LeDoux and Antonio Damasio, and philosophers, Nancy Sherman and Martha Nussbaum. These neuroscientific and philosophical approaches converge in the view that emotion and cognition are interacting, complementary and highly integrated systems.

Second I offer a compact overview of the neural bases of morality, and draw on the contemporary work in the discipline of psychopathology, by celebrated neuroscientist, Michael Gazzaniga. In **Table 5.1** I offer a summary of the neural sites activated in moral activity as many of these must also subserve virtuous activity. I note the increasing quantity of literature on the neural bases of moral behaviour, and tabulate a representative sample of findings which emphasise complexity of processing, and highly predictable centres of activation, results which are consistent with observations about cognitive function offered in **2.7**.

In **5.3** I propose neural bases for virtue.

As a starting point, I propose that the neural bases of virtue must be considered as a complex of interacting systems. I suggest that the neural complexity of the human act, and of virtue itself, is a reflection of the psychological complexity of the human act (as we have seen in **3.1.3**), moving from appetency and motivation at sense level, through evaluative reasoning to choice. I argue that, although particular brain areas are shown to be active in certain tasks, we must describe the neural dispositions of virtue in terms of neural interconnectivity and the activation of multiple brain areas and systems, predisposed by specific plastic development and thus able to work in highly elaborate concert. Only thus can we approach an understanding of the neural bases of the dispositions of virtue. I draw together in **Table 5.2** an outline of the interconnected systems at work in virtuous activity and then, drawing on the content of **Chapter 2**, I discuss the neural bases for the characteristics of virtue offered at the end of **Chapter 4** in **Table 4.1**.

In conclusion in **5.4**, as a model of the neural activity underpinning a specific act of virtue, I offer a neural analysis of Nagai's actions described **Scenario 3.** By analysis of a real life scenario, I demonstrate that the neural schema is highly plausible and readily applicable.

5.2 Insights from contemporary cross-disciplinary studies in emotion and morality.

5.2.1 Understanding emotion.

Neuroscientists and philosophers have focused in recent years on the relationship between emotion and reason/rationality. For the past twenty years, Joseph LeDoux has been at the forefront of research into the neural bases of emotion, most particularly of the emotion of fear.[1250] He shows that emotional reactions may be either regulated by higher cortical function or be direct and impulsive.

[1250] Joseph LeDoux, *The Emotional Brain*, (London: Phoenix, 1998).

Antonio Damasio argues that emotional somatic manifestations assist us in our cognitive response to the world, and that it is a mistake to separate mind and body. In common with philosophers, Nancy Sherman and Martha Nussbaum, these neuroscientists are in agreement that emotion can and should enrich decision making and that both emotion and reason possess biophysical correlates.

5.2.1.1 Joseph LeDoux

The work of Joseph LeDoux has provided some key lines of investigation for this study. He adopts a non-reductive approach, described by Nussbaum as "explicitly cognitive".[1251] LeDoux argues for emotion and cognition as separate but interacting mental functions mediated by separate but interacting brain systems.[1252] His interest is very much as a neuroscientist, and his focus is on the neural bases of emotion and regulation of emotion.

Of particular relevance for this study are these conclusions by LeDoux.

He suggests that reason and emotion should be harmonised; human biology, he argues, supports the view that emotion be moderated but not negated by reason.[1253] Because brain systems generating emotion are highly conserved, he argues that animal studies are valid indicators of the human brain systems associated with emotion:[1254] for example, by means of rat studies, LeDoux had highlighted the central role of the amygdala in fear conditioning and the role of the reciprocal cortico-amygdalic pathway in emotional regulation. [1255]

LeDoux observes that connections from emotion to the cognitive are denser and richer than connections from cognitive to emotional, allowing, he argues, for

[1251] Nussbaum, *Upheavals of Thought,* 105.
[1252] LeDoux, *The Emotional Brain*, 69.
[1253] LeDoux, *The Emotional Brain*, 21.
[1254] LeDoux, *The Emotional Brain*, 17.
[1255] LeDoux, *The Emotional Brain*, 287.

emotions to flood consciousness.[1256] He found that areas of the amygdala project back to a wide variety of cortical areas (all cortical sensory areas, PFC, hippocampus) allowing the amygdala to influence higher order thought process, working and long term memories, ongoing perceptions, attention, mental imagery etc.[1257]

He identifies a "high road" of emotional response whereby the amygdala is informed of emotional content via the cortex, in preference to a "low road" of direct input to the amygdala via the thalamus, [1258] and concludes that cortical emotional regulation of fearful reactions requires reinforcement of this "high road" by means of use dependent plasticities.

He notes that the hippocampus plays a key role when there is cortical regulation of emotion and suggests that these hippocampal pathways require consolidation and reinforcement by means of use-dependent plasiticities. He also notes that the "high road" of cortical afferent to amygdala is informed by hippocampal memory,[1259] consistent with the view that the hippocampus is associated with conscious declarative memory and the implicit emotional memory associated with the amygdala (cf **Chapter 2**).[1260]

While LeDoux discusses pathways of emotional control, he does not directly address habits of emotional control. He does not discuss the interplay of reward pathways and emotion, but he does observe that emotions are powerful motivators of future behaviours.[1261]

5.2.1.2 Antonio Damasio

[1256] LeDoux, *The Emotional Brain*, 19.
[1257] LeDoux, *The Emotional Brain*, 287.
[1258] LeDoux, *The Emotional Brain*, 170.
[1259] LeDoux, *The Emotional Brain*, 199.
[1260] LeDoux, *The Emotional Brain*, 203.
[1261] LeDoux, *The Emotional Brain*, 19.

Another major figure in the contemporary dialogue between emotion and neuroscience is Antonio Damasio. In *Descartes' Error* (1994) he develops his somatic marker hypothesis by which he argues that emotional somatic reactions and consequent qualia assist reason. [1262] Most significantly he argues that emotion enriches cognition, and writes broadly of an integration of "brain systems that are jointly engaged in emotion and decision making" allowing management of social cognition and behaviour.[1263] Descartes' error, he says, was to divide body and mind.[1264]

In his 1999 text, *The Feeling of What Happens*, Damasio pursues this theme of integration of awareness and emotional response. He argues that consciousness and emotion are intimately related: consciousness as the conception that there is both a self and an external object; and emotion as the internal experience of change as a result of interaction with the external object, the "feeling of what happens". [1265]

In a more recent book, *Looking for Spinoza* (2003), Damasio further develops the theme of the unity of the organism. With Spinoza (and, as we have seen, in keeping with Aristotle's metaphysics) he argues that mind and body are manifestations of the same substance.[1266] "The body and the brain form an integrated organism and interact fully and mutually via chemical and neural pathways." [1267] Accordingly Nussbaum states that Damasio presents a non-reductionist, physiological account.[1268] Lacking explicit acknowledgement of the concept of person (for example, he writes only of "organism") his philosophy of mind is arguably impoverished. Damasio relies on assertions such as "(it is) unnecessarily incomplete and humanly unsatisfactory to reduce the mind to brain

---

[1262] Antonio Damasio, *Descartes' Error* (London: Vintage, 1994), 174. Damasio writes, "Somatic markers are a special instance of feelings generated from secondary emotions. Those emotions and feelings have been connected by learning, to predicted future outcomes of certain scenarios."
[1263] Damasio, *Descartes' Error,* xix.
[1264] Antonio Damasio, *Descartes' Error* (London: Vintage, 1994) 249.
[1265] Damasio, *The Feeling of What Happens.*
[1266] Antonio Damasio, *Looking for Spinoza* (Orlando: Harvest, 2003) 12.
[1267] Damasio, *Looking for Spinoza*, 194.
[1268] Nussbaum, *Upheavals of Thought,* 114.

events."[1269] He attempts a non-reductive understanding of the unity of the organism, arguing,

> The truly embodied mind … does not relinquish its most refined levels of operation, those constituting its soul and spirit. … soul and spirit, with all their dignity and human scale, are now complex and unique states of an organism.[1270]

Yet ultimately, these statements are observations without metaphysical justification. "Person" is much richer a concept than "organism", capturing as it does the specific qualities of rationality and of a unifying principle beneath appearances.

Damasio's attempts, therefore, demonstrate the difficulty, perhaps impossibility, of defending specific metaphysiological conclusions about human nature in the absence of a concept of person. They demonstrate the need that mind-body speculation must be supported by a metaphysically rich anthropology.

Nevertheless, the work of Antonio Damasio positively provides assistance to, or verification for, this study in several important ways.

Like Aristotle (see **3.2.1.1**) he argues that all human motivations reduce to pain and pleasure in some form or other. "Pain and pleasure are the levers the organism requires for instinctual and acquired strategies to operate efficiently."[1271] Significantly, within his anthropology he includes the development of habits by which we manage our reactions to pain and pleasure: "our reactions

[1269] Damasio, *Descartes' Error,* 251.
[1270] Damasio, *Descartes' Error,* 252.
[1271] Damasio, *Descartes' Error,* 262. Damasio appears to draw much from Aristotle, albeit indirectly. For example, he quotes another aphorism from Spinoza: we are always moved by love (understood as appetite for what is pleasurable) in some form or other. "An affect cannot be restrained or neutralised except by a contrary affect that is stronger than the affect to be restrained."

to pain and pleasure can be modified by education".[1272] He offers neural substrates for sadness,[1273] and happiness[1274].

He is drawn to a series of insights of Spinoza in an exploration of human motivation and feelings.[1275] Importantly for this study he links pleasure with perfection of function, providing a rich avenue for eudaimonistic exploration. He argues that organisms strive to achieve "a greater perfection" of function and that Spinoza equated that perfection with joy. [1276] [1277] (See **6.2.1**.)

He describes emotion triggering sites as amygdala and VMPFC, and a further "frontal region in the supplementary motor area and cingulate".[1278] He writes of the basal forebrain, hypothalamus and nuclei of the brainstem as execution sites for emotion. He presents a number of significant clinical and research based observations about VMPFC.[1279] [1280] [1281] [1282] [1283] [1284] And he notes that the ACC

[1272] Damasio, *Descartes' Error,* 262.

[1273] Damasio quotes a case of a slightly misplaced electrode in the midbrain, possibly in the SN or the *periaqueductal gray region* PAG, evoking profound sadness.

[1274] Representative studies: Richard Davidson et al., "Reciprocal limbic-cortical function and negative mood: converging PET findings in depression and normal sadness," *American Journal of Psychiatry* 156, (1999): 675-82; Richard Lane et al., "Neuroanatomical correlates of happiness, sadness and disgust," *American Journal of Psychiatry* 154, (1997): 926-33. Damasio also notes that stimulation in SMA (eg in mPFC and dorsal PFC and Anterior cingulate) was shown to evoke "genuine" laughter: Itzhak Fried, et al., "Electric current stimulates laughter," *Nature* 391, (1998): 650.

[1275] Damasio, *Looking for Spinoza*, 12.

[1276] Damasio, *Looking for Spinoza*, 12.

[1277] Damasio, *Looking for Spinoza*, 11. His focus on Spinoza's comment "Love is nothing but a pleasurable state, joy, accompanied by the idea of an external cause" has the potential to connect motivation and pleasure with a role for justice.

[1278] Damasio, *Looking for Spinoza*, 54.

[1279] Hiroto Kawasaki, et al., "Single-unit responses to emotional visual stimuli recorded in human ventral prefrontal cortex," *Nature Neuroscience* 4, (2001): 15-16. Damasio notes the asymmetry is in keeping with Davidson's conclusion that right frontal cortices have a greater association with negative emotions. He points out that single cell studies show how specific different neurons in the right VMPFC in human subjects respond to pleasant and unpleasant visual stimuli.

[1280] Damasio, *Looking for Spinoza*, 152. Damasio argues that the VMPFC and amygdala are critical areas of the PFC for reasoning/decision making and emotion/feeling.

[1281] Damasio, *Descartes' Error,* 61.

[1282] R.W. Sperry et al., "Interhemispheric relationships: the neocortical commissures; syndromes of their disconnection" in *Handbook of Clinical Neurology* Vol4, ed. P. J. Vinken and G. W. Bruyn (Amsterdam: North Holland, 1969), 273-90. Damasio's work confirms the right hemispheric dominance in emotion, and that damage to somatosensory cortices in the right hemisphere compromises reasoning/decision making and emotion/feeling as well as basic body signalling;

provides the location for intimate interaction between systems of reasoning/decision making and emotion/feeling leading to external action (movement) and thought animation and reasoning. [1285]

5.2.1.3 Nancy Sherman and Martha Nussbaum

Aristotle explains in the *Rhetoric* that anger will be towards somebody whom we think has caused us harm. Emotions are directed towards some object, according to the Aristotelian notion. Accordingly Nancy Sherman discusses emotions as "forms of intentional awareness".[1286]

Martha Nussbaum appears to build on this notion in her explorations of emotion in *Upheavals of Thought* which contains insights of significance to this study. She rejects any simplistic or negative view and defines emotions in a positive manner as:

> … appraisals or value judgements which ascribe to things and persons outside the person's own control great importance for that person's own flourishing.[1287]

[1283] Damasio, *Descartes' Error,* 71. Damasio confirms that DLPFC damage compromises reasoning/decision making on a broader scale and that DA driven reward systems are associated with pleasure and with motivation for emotion regulation.

[1284] Damasio, *Descartes' Error,* 180. He links VMPFC to autonomic nervous system effectors, able to trigger chemical responses from brain stem and hypothalamus.

[1285] Damasio, *Descartes' Error,* 72.

[1286] In *Making a Necessity of Virtue,* Nussbaum writes, "Emotions are about something that we represent in thought. Emotions are intentional states. As such they have cognitive content. They are identified by that content, by what we dwell on, whether it be fleeting or with concentrated attention… Such an account need not exclude other features of emotion, such as awareness of physiological and behavioural response or felt sensations. The claim is that these, when present, are dependent on cognitive (i.e. descriptive and evaluative content), and are directed toward that content." Sherman, *Making a Necessity of Virtue: Aristotle and Kant on Virtue*, 55. Insight from Ana C. Santiago, "A Study of Aristotelian Demands for Some Psychological Views of the Emotions" (PhD thesis, Duke University, 2009).

[1287] Nussbaum, *Upheavals of Thought,* 4. Nussbaum writes: "Emotions, I shall argue, involve judgements about important things, judgements in which, appraising an external object as salient for our own well being, we acknowledge our own neediness and incompleteness before parts of the world that we do not fully control."

She presents a eudaimonistic vision in which “Emotions appear to be eudaimonistic, that is, concerned with a person’s flourishing”.[1288] In further extension of this idea, she notes that Aristotle regards pleasure not as a feeling but as unimpeded action. [1289] Flourishing includes, therefore, the concept of mature biological development facilitating ease of action.

Of great value to this study also are a number of additional insights.[1290] She insists that “emotions are, like other mental processes, bodily.”[1291] She also suggests that this vision of emotion offers clarity on the specific roles of the cardinal virtues; if emotion is essentially “thought of an object combined with thought of the object’s salience or importance” this arguably lends a greater role to justice. Secondly, it accords perfectly with an initial presentation of desires and aversions (understood broadly as apprehensions evoking responses disposed by temperance and fortitude or their contrary habits).[1292]

She argues that it was Aristotle himself who integrated emotion into the cognitive world of the person, that Aristotle viewed pain as “pain at”, “as an intentional state with cognitive content”. [1293]

Discussing how particular representations in the mind make possible abstract eudaimonistic conclusions, she notes the significance of “rich particularising detail”, the connection to the imagination that differentiates specific evaluations from abstract judgments. She writes that the imagining is “a vehicle for making a eudaimonistic connection with the object” allowing for example compassion, and downstream the exercise of justice.[1294]

[1288] Nussbaum, *Upheavals of Thought,* 22, 31
[1289] Nussbaum, *Upheavals of Thought,* 63
[1290] Nussbaum, *Upheavals of Thought,* 103 Of note also is her evaluation of Seligman’s work as a non-reductionist account where internal mental representations construct intentionality.
[1291] Nussbaum, *Upheavals of Thought,* 25.
[1292] Nussbaum, *Upheavals of Thought,* 61.
[1293] Nussbaum, *Upheavals of Thought,* 63.
[1294] Nussbaum, *Upheavals of Thought,* 65.

Also of note in this study of virtue, considered as voluntary habit motivated less by external reward and more by intrinsic considerations, are her comments about the need to modify the S-R model to one of "S-Organism-R" [1295] consistent very much with the view raised in **Chapter 2** that voluntary habits can consist of A-O motivations replaced by S-R paradigms that are compatible with voluntary behaviour.[1296]

5.2.2 Research into the neural bases of morality.

5.2.2.1 Gillett's psychopathology.

a) The field of psychopathology.

Research into psychopathology can assist here, as it is a burgeoning field where neurobiology and consolidated moral behaviours, albeit negative behaviours, intersect. If one accepts the premise that through illness, environment or choice such people have underdeveloped dispositions of virtue, insights are possible into the neurobiology of virtue. For example, I have referred above (**4.2.1**.**d**) to studies that suggest an excessive dominance of fear in psychopathic individuals.

Studies emphasise time and again the functional and structural abnormalities of the the OFC, VMPFC and amygdala in psychopathic individuals.[1297] A *Nature* article in 2001 suggested that early imaging studies in this area suggested either that the dysfunctional OFC or dysfunctional amygdala are at the basis of psychopathic behaviour; the views may not be mutually exclusive.[1298] Yang et al. have now identified, by means of structural magnetic resonance imaging, marked deformations, including lower volumes, of the amygdala in individuals with psychopathy. They link these structural data to poor fear conditioning and poor

[1295] Nussbaum, *Upheavals of Thought,* 94.
[1296] Yin and Knowlton, "The role of the basal ganglia in habit formation," 465.
[1297] Walter Glannon, "Moral Responsibility and the Psychopath," *Neuroethics* 1, (2008): 158; Kiehl, et al., "Limbic abnormalities in affective processing by criminal psychopaths as revealed by fMRI".
[1298] Alison Abbott, "Into the mind of a killer," *Nature* 410 (2001): 296-298.

facial emotion recognition that are also present.[1299] Note the potential link between poor fear conditioning, and an inability, in developmental years, to develop normal emotional responses from the faces of parents.[1300] [1301]

"Empathetic dysfunction is one of the major features of psychopathology."[1302] James and Blair find that the empathetic dysfunction of psychopaths is associated with impaired processing of emotions of fear, sadness and possibly disgust, and manifest multiple signs of amygdala dysfunction. [1303] Most interestingly they argue that the lack of emotional empathy appears linked to dysfunction in "cortical and sub-cortical face processing routes" involving amygdala, insula and OFC and VMPFC. [1304] Potential for learning refined dispositions to pain and pleasure from the face of one's parents.

Another common thread of discussion in the literature is that of the apparent "rationality" of psychopaths. However Maibom finds that her studies affirm Damasio's argument for the essential role of emotion in practical rationality.[1305] She argues that the practical reason of psychopaths is impaired and that the basis of this appears two fold: an emotional impairment, with abnormal responses to fear, pain, guilt and empathy; and that are incapable of choosing means appropriate to ends. They are "constitutionally incapable of adopting and carrying out plans that affect the course of their lives in a pervasive and profound

---

[1299] Y.Yang, et al. "Localization of deformations within the amygdala in individuals with psychopathy," *Archives of General Psychiatry* 66, 9 (2009), 986-994.

[1300] This is consistent with my argument that children learn and embody refined attitudes to pain and pleasure from the example of parents first of all. Psychopathic deficits possibly heightened by environmental factors, appear to impair this process in early years.

[1301] Other studies identify abnormalities in the corpus callosum: Adrian Raine et al. "Corpus Callosum Abnormalities in Psychopathic Antisocial Individuals," *Archives of General Psychiatry* 60, (2003): 1134-42.

[1302] R. James and R. Blair, "Empathic dysfunction in psychopathic individuals," in *Empathy in Mental Illness*, ed. Tom F. D. Farrow, (Cambridge: Cambridge University Press, 2007), 12.

[1303] James and Blair "Empathic dysfunction in psychopathic individuals," 12.

[1304] "If we could find means to increase the empathic reaction of children with psychopathic tendencies, we might be able to considerably improve the prognosis of this disorder." James and Blair "Empathic dysfunction in psychopathic individuals," 15.

[1305] Heidi Maibom, "Moral unreason: the case of psychopathy," *Mind and Language* 20, 2 (2005): 251.

manner."[1306] She suggests that psychopaths flout moral and social norms, but "experience no guilt or remorse, feel no empathy, and appear to be perfectly rational."[1307]

Lack of behavioural and emotional regulation also enters as an area of study. Corr suggests that deficits of behavioural inhibition are the basis of these aberrant behaviours. These deficits are associated with a consequent inflexibility with respect to cognitive activity, associated also with inattentiveness.[1308] Significantly he argues that there are multiple systems, an "amalgam of processes", that underpin normal behaviour, and that dysfunction in specific processes may account for the wide variations on psychopathology. He highlights for example failure of systems for appetitive anticipation.

An important study utilizing *diffusion tensor magnetic resonance imaging* (DT-MRI) shows neural underdevelopment in the limbic-cortical pathway connecting the OFC and amygdala.[1309] The authors found significantly reduced fractional anisotropy (suggesting reductions in fibre density, axonal diameter and myelination) in the right uncinate fasciculus (the major neural limbic-cortical neural pathway) of psychopaths in relation to matched controls.[1310]

In summary, studies into psychopathology appear to confirm dysfunction in several of the principal candidate systems and regions appearing to be at the basis of virtue. They draw attention to the role of attention, of regulation of emotion and appetency, of imitation, and in particular of the high level of mutual interaction required between limbic and cortical areas. Furthermore studies highlight the necessity of a multi-systemic approach in order to describe the neurobiological contribution to moral behaviour.

1306 Maibom, "Moral unreason: the case of psychopathy," 243.
1307 Maibom, "Moral unreason: the case of psychopathy," 237.
1308 Philip J. Corr, "The The psychoticism–psychopathy continuum: A neuropsychological model of core deficits," *Personality and Individual Differences* 48, (2010): 695–703.
1309 M. C. Craig, et al. "Altered connections on the road to psychopathy," *Molecular Psychiatry* (2009), 1–8.
1310 Craig, et al. "Altered connections on the road to psychopathy," 5-6.

b) Gillett's work.

Grant Gillett's work builds on the clinical studies of psychopathology. In one recent paper, he introduces neo-Aristotelian notions of character, agency, and moral responsibility (in a consideration of Aristotle's account of practical reason in the light of Kant and Wittgenstein) and concludes "the will of the psychopath is pathological (in Kant's sense) because it is dominated by appetite and not truth...".[1311] This is a fascinating insight drawing on the internal features of the human act (**Table 3.1**) and emphasizing the importance of the virtues of prudence and justice. By the neurobiological features characterising the absence of the virtues, Gillett provides important insights about their neural bases.

Gillett presents a theory of action for psychopaths accounting for manifestly intentional behaviour that is disconnected from prudence and moral consideration.[1312] Ultimately, he finds that the psychopath is moved by self-oriented goals, and, lacking responsivity to others, lacks also responsibility. Often seeing others as less clever than himself, he suffers from a "pathologically restricted horizon of motivations" and "lacks the co-feeling and human connectivity that lie at the heart of moral voice and moral orientation."

Gillett suggests that moral responsibility according to a neo-Aristotelian understanding involves the subject choosing, using his rational powers, to obey or not to obey moral rules, and he sees these rules as pertaining not only to one's actions in the world in isolation from others, but also according to the demands

[1311] Grant Gillett, "Intentional action, moral responsibility and psychopaths," (2012 publication pending), 10. Gillett's work on criminal psychopathology adopts a classic approach of neuroscience, that of learning about the brain by linking deficits of behaviour with anatomical observation.

[1312] A theory of action links psychology of the individual with an understanding of individual human beings as moral agents. The author suggests that action may be explained either by a Millean tradition, relying on prior causal events, or in the Nietzschean (neo-Aristotelian) vision of the individual acting on the world to enact his life story. The latter he combines with the identity-structure view of intention and action that sees action as the outward manifestation of the conception of the agent.

that arise from relationships with others. Within this framework, the role of pain in the form of disapproval, punishment, correction and discipline, is reviewed. Gillett notes that, during the acquisition phase of virtue, virtuous acts are not typically pleasant. Further he distinguishes between the cleverness of acting to achieve one's desired end, from the motivational sensitivity towards others that normally accompanies ethical formation.[1313]

His findings, drawing on various physiological and fMRI studies typified in the section above, highlight brain function in relation to poor choices, impulsivity, and lack of regard for others:

- Defective psychopathic response to fear based and aversive conditioning is situated (in the "limbic prefrontal circuit - amygdala, orbito-frontal cortex, insula, and anterior cingulate" areas of the brain.
- Severe social deprivation and abuse are consistent with unimpaired executive function and emotional intelligence.[1314] (His thesis is that deprivation and abuse impact most of all on practical reason.)
- Psychopathic activity appears unimpaired by secondary emotions of embarrassment and guilt.[1315]
- Certain amygdala dysfunction appears in studies of criminal psychopathic individuals.[1316]
- Defective responses in sensorimotor cortices as well as limbic and para-limbic structures appear implicated in pathologically diminished empathy.[1317] [1318]

[1313] Both are forms of rationality, but only the second contains a moral incentive. He argues that the psychopath acts with self-directed interest as opposed to "the natural human propensity for empathy and sensitivity to the suffering or negative emotions of others".
[1314] A. Raine, "Biosocial Studies of Antissocial and Violent Behaviour in Children and Adults: A Review," *Journal of Abnormal Child Psychology* 30, 4 (2002): 311-326.
[1315] A. Damasio, "A neural basis for sociopathy," *Archives of General Psychiatry* 57, (2000): 128-9.
[1316] K. A. Kiehl, et al., "Limbic abnormalities in affective processing by criminal psychopaths as revealed by fMRI" *Neuroimage* 11, 5 (2000), 677-684.
[1317] T. Singer, "The neuronal basis and ontogeny of empathy and mind reading: Review of literature and implications for future research' *Neuroscience and Biobehavioural Reviews* 30, (2006) 855-863.
[1318] Deely Q et al., "Facial emotion processing in criminal psychopathy," *British Journal of Psychiatry* 18 9, (2006): 533-539. Gillett also discusses psychopathic insensitivity to distress and negative emotion shown in other's faces.

Gillett concludes that “the physiological and fMRI studies show the findings that might be expected from the analysis of virtue and moral development found in Aristotle and Kant...”,[1319] that “our natural tendencies are transformed by socialisation in which we learn to moderate our tendencies by instruction and correction”.[1320]

Moreover he suggests that the advantageous pain, normally signalling undesirability of actions is somehow deficient in the psychopath. He suggests that “learned patterns of moral behaviour” can compensate for this deficiency.[1321] Moral education consists in this. “Necessarily, then, the character must be good or bad by its pursuit or avoidance of certain pleasures and pains.” [1322]

Gillett’s work is a cross disciplinary study reconciling aspects of Aristotelian psychology with neuroscience, and as such, serves as a useful precedent for this study. Furthermore, his identification of the involvement of specific neural structures in moral behaviour/psychopathology provides a valuable point of reference.

5.2.2.2 Gazzaniga and the neural bases of free will.

In the 2009 Gifford Lectures, neuroscientist Michael S. Gazzaniga explores the notion of free will. This topic is of importance to this study because a degree of freedom of agency is a necessity for the development of virtue, and for the operation of a rational being. Gazzaniga adopts a non-reductionist “strong emergent” paradigm in which the emergent “is more than the sum of its parts”.[1323] A number of aspects of his analysis of free agency are particularly useful for this study.

[1319] Gillett, “Intentional action, moral responsibility and psychopaths,” 13.
[1320] Gillett, “Intentional action, moral responsibility and psychopaths,” 14.
[1321] Gillett, “Intentional action, moral responsibility and psychopaths,” 14.
[1322] Aristotle, *Eudemian Ethics*, 1121b33.
[1323] Michael S. Gazzaniga, *Who’s in charge. Free will and the science of the brain* (NY: Harper Collins, 2011), 124. See my response to “emergent rationality” in **Appendix 1. A Response to the Claims of Emergent Rationality by Non-reductive Materialism.** However, because both

He argues that the integration of multiple brain systems underpins complex aspects of personality. “It is becoming increasingly clear that consciousness involves a multitude of widely distributed specialised systems and disunited processes.” [1324] I argue and summarise in **Table 5.2** that virtue may be seen as a type of macro system, a complex of systems, requiring multiple integrated brain systems for activation. Gazzaniga, by applying the concept to consciousness, provides a useful, highly credentialed precedent for such a view. It is the view of this study that such a “systems view”’ of virtue is appropriate to the extent that virtue is understood as a *biological* facilitation for rationality.[1325]

Secondly he offers an alternative model for brain activity, springing from his own research. He argues that “rampant” lateralisation of circuits is a mark of the human brain, and that within the left brain is the “interpreter module” that makes sense out of the literal view of reality presented by the right hemisphere. [1326]

He writes of studies that demonstrate that suppression of the right DLPFC increases self interest and self centred responses, and that VMPFC lesions impair moral judgement. This is consistent with views of the role of the DLPFC that have already been presented in **Chapter 2** and in **Table 5.1**.[1327]

5.2.2.3 Neural subdivisions implicated in moral behaviour.

In this section I note commonly identified neural bases activated in situations demanding a moral response, and complete the section with some comments also about the neural bases of immoral, psychopathic behaviour, as well as of spiritual

hylomorphic and emergent rationalist approaches propose a single agent with rational and biophysical qualities, the conclusions of Gazzaniga, LeDoux, Damasio and others (with respect to neural bases, but not to anthropology nor metaphysics) transfer most readily to this study.

[1324] Gazzaniga, *Who’s in charge. Free will and the science of the brain*, 102.

[1325] That such a view should be applied also to consciousness is not so evident but discussion of this issue is well beyond the scope of this study.

[1326] Gazzaniga, *Who’s in charge. Free will and the science of the brain*, 35 and 86. This appears consistent with the notions in **2.3.4.1** and **2.5.3.1** that affect arousal is preferentially in areas of the right cortex, while emotional regulation pertains more to left VMPFC.

[1327] Gazzaniga, *Who’s in charge. Free will and the science of the brain*, 170 and 177.

and mystical experiences. These moral bases will further inform discussion in **5.3.3.2**.

Green and Haidt in a major review paper note that moral judgement appears to be based both on affect and reasoning, and that many brain areas contribute to moral judgement.[1328] Moll et al. find a "remarkably consistent network of brain regions … involved in moral cognition",[1329] far more consistent than the variability of activations for basic emotions of happiness, sadness, disgust, fear, and anger. He finds that complex emotions (compassion, embarrassment, indignation, guilt) show consistently to activate the same areas: ACC, aPFC, aTL, OFC , and STS.[1330] [1331]

A great number of studies have sought neural bases for social behaviour. A typical study, by Rilling et al., focused on altruistic cooperation. By means of fMRI scanning of 36 women playing the Prisoner's Dilemma Game a neural network associated with reciprocal altruism was identified.

> Mutual cooperation was associated with consistent activation in brain areas that have been linked with reward processing: nucleus accumbens, the caudate nucleus, ventromedial frontal/orbitofrontal cortex, and rostral anterior cingulate cortex.[1332]

Other studies have identified the key role of the *medial PFC* (MPFC) in studies concerning empathy, understanding for others, and the self-knowledge seen as a

---

[1328] Joshua Green and Jonathan Haidt, "How (and where) does moral judgement work?" *Trends in Cognitive Sciences* 6, 12 (2002): 517-123.

[1329] Jorge Moll, et al., "The neural basis of human moral cognition," *Nature Reviews Neuroscience* 6, (2005): 799. Moll looked at the various models for moral cognitive neuroscience, and proposed the "EFEC (event–feature–emotion complex) framework", a model based on the integration of event knowledge, social perceptions, and basic emotional states. The authors argued that moral phenomena emerge "from the integration of contextual social knowledge, represented as event knowledge in the prefrontal cortex (PFC); social semantic knowledge, stored in the anterior and posterior temporal cortex; and motivational and basic emotional states, which depend on cortical–limbic circuits."

[1330] Jorge Moll, et al., "The neural basis of human moral cognition," 805.

[1331] Jorge Moll, et al., "The neural basis of human moral cognition," 799- 808.

[1332] James K. Rilling et al., "A Neural Basis for Social Cooperation," *Neuron* 35, (2002): 395–405.

prerequisite to moral responsibility. Furthermore, empathetic response to the pain of others appears to be mediated by the mPFC.[1333] [1334] [1335] Other studies consider the roles of memory and imagination in moral activity. It appears our judgements to trust others are processed on two different pathways, one bypassing memory and simply assessing the face, and the other accessing memory of behaviour of that person in the past.[1336] Some people draw on the personality trait information when judging trustworthiness others prefer to use facial information.

Self-control disorder studies in children using electroencephalogram (EEG) as well as fMRI of normal subjects, are consistent in linking the VMPFC and moral behaviour, in finding that the OFC cues for moral behaviour and also the acquisition of moral knowledge. ACC is linked to regulation of attention and emotion, and (with the NAc, caudate, and OFC) for cooperation respecting the rights of others.[1337] Moral cognition systems appear modulated by DA, 5-HT, NA and ACh. But "the proper operation of the system as a whole is crucial for effective moral judgement." [1338]

Persistent antisocial behaviours have long been a subject of interest. Forensic psychiatry like psychopathology is a large field offering insights into the neural bases of moral behaviour. Studies of violent offenders have demonstrated that

---

[1333] Philip L. Jackson, Pierre Rainville, Jean Decety, "To what extent do we share the pain of others? Insight from the neural bases of pain empathy," *Pain* 125, (2006): 5–9.
[1334] Arnaud D'Argembeau and Eric Salmon, "The neural basis of semantic and episodic forms of self knowledge. Insights from Functional Neuroimaging," in *Sensing Systems in Nature*, ed. Carlos López-Larrea (Landes Bioscience and Springer Science+Business Media, 2011). The mPFC has been identified as playing "a key role in creating the mental model of the self that is displayed in our mind at a given moment."
[1335] Ruby P., Collette F., D'Argembeau A. et al., "Persons with Alzheimer disease did not recruit the mPFC when making judgments about themselves in perspective taking to assess self‐personality: what's modified in Alzheimer's disease?" *Neurobiology of Aging* 30, (2009): 1637‐1651. In persons with Alzheimer disease the mPFC appears inactive in judgements about self.
[1336] J. D. Rudoy and K. A. Paller, "Who can you trust? Behavioral and neural differences between perceptual and memory-based influences," *Frontiers of Human Neuroscience* 3, (2009): 1-6.
[1337] Casebeer, "Moral cognition and its neural constituents," 844.
[1338] Casebeer, "Moral cognition and its neural constituents," 843.

subjects have reduced grey matter in the PFC and patterns of abnormal limbic, prefrontal and temporal brain activation.[1339] (See also above, **5.2.2.1**.)

It is demonstrated that emotions play a role in moral judgement.[1340] A 2007 study by Michael Koenigs of six patients with VMPFC bilateral damage indicated that the subjects were more prone to utilitarian judgements on a certain type of moral dilemma, but that in other types their responses were normal. "The findings are consistent with a model in which a combination of intuitive/affective and conscious/rational mechanisms operate to produce moral judgements." [1341] [1342]

We must bear in mind the observation of Eric Kandel, Nobel laureate, that there is no single neural locus of command and coordination. He writes,

> "There is no single cortical area to which all other cortical areas report exclusively, either in the visual or in any other system. In sum, the cortex must be using a different strategy for generating the integrated visual image."[1343] [1344]

If the brain requires complex coordination strategies to present an "integrated visual image", how much more, then, will complex coordination of systems be needed for an integrated response to the world, for recognition of truth and moral action. Yet, universal human experience is that in moral matters, as in behaviours of moral insignificance, human responses can be unified and

---

[1339] H. Soderstrom, et al., "Reduced frontotemporal perfusion in psychopathic personality" *Psychiatry Res* 114, (2002): 81–94.
[1340] Michael Koenigs et al., "Damage to the prefrontal cortex increases utilitarian moral judgements," *Nature* 446, (2007): 908-911.
[1341] Koenigs et al., "Damage to the prefrontal cortex increases utilitarian moral judgements," 910.
[1342] Darcia Narvaez, "Triune ethics: the neurobiological roots of our multiple moralities," *New Ideas in Psychology* 26 (2008): 95-119. Narvaez provides a useful summary of the neural bases of moral behaviour within her "triune ethics theory". She draws together neuroscientific evidence in support of the three stages: security, engagement and imagination. Rather than a top down, cognitively initiative view, she adopts a bottom up approach based on motivational orientations, and so her work is complementary to this study; she understands appetitive systems in the body as fundamental, a view consistent, as we shall see with the Aristotelian understanding of motivation. The article also provides an excellent overview of key literature on the role of affection in gene transcription.
[1343] Eric R. Kandel and Robert H. Wurtz, "Constructing the visual image" in Eric R. Kandel et al. *Principles of Neural Science*, 4th ed. (NY: McGraw, 2000), 340.
[1344] Bear, *Neuroscience. Exploring the Brain,* 731.

purposeful despite the varied systems involved. Again, let us remind ourselves that neural excitation cannot make moral decisions, persons do.

Table 5.1 draws together findings from some dozen authors whose work involves the neural bases of moral responsibility. The listing of areas and roles is by no means exhaustive, but it is representative of the complex integration of neural areas in moral action.

5.3 Neural bases.

5.3.1 A complex of systems.

The complexity of the brain is inescapable: the sheer extension of the neural network, the intricate cooperation of mechanisms at the molecular, genetic and cellular levels underpinning a grand collaboration of systems, and the possibilities for connectivity blessed with the potential for a virtual infinitude of subtle variations of synaptic strengths and neuromodulation. Indeed in 1949 Donald Hebb had suggested that thoughts and memories were dependent on "cell assemblies", networks of neurons. He postulated that changes in cell connections were the basis of learning, and that memory is both localised and distributed. Commonly in the current literature we meet terms such as "vast neuronal array"[1345], and "neural pools"[1346] to discuss the means by which networking complexity of the brain contributes to mental processes. Susan Greenfield proposes that "subsecond assemblies of 10s or 100s of millions of neurons lasting a fraction of a second determine *depth* of consciousness."[1347] One need not fully accord with the conclusion to appreciate the complexity of neural operations.

[1345] Susan Greenfield, *I.D. The Quest for identity in the 21st Century* (London: Sceptre, 2008).
[1346] Saladin, *Anatomy and Physiology*, 5th ed., 471.
[1347] Susan Greenfield, *I.D. The Quest for identity in the 21st Century,* 127. "Determine" however is a word that carries unwanted connotations; use of "contribute to" or "subserve" would avoid the suggestion that materiality could be the ultimate cause of free action. (See **6.4.2.2**.)

There is recognition that individual systems in the brain operate with astonishing breadth and complexity. Note for example this recent description of the motivational system:

> All of this being said, what should a *neural* mechanism of motivation look like? According to the account pieced-together in this dissertation, motivational mechanisms should look like pulsating synaptic cascades across vast breadths of neural tissue. From a seed of rhythmic activity, perhaps in orbitofrontal cortex and the hypothalamus, motivation would reach through planning mechanisms in dorsolateral prefrontal cortex, posterior parietal cortex, the cerebellum and motor cortex, and all of the loops connecting these areas through the basal ganglia and thalamus. Basically a motivation mechanism should extend through most of the brain.[1348]

Other brain systems offer similar complexity.

Neuroscientist Mario Beauregard in *The Spiritual Brain* argues that various brain systems are integrated in the performance of the highest rational functions, an intricate cooperation of neural systems, areas and mechanisms facilitating actions of the person. He says that transcendent experiences are

> …implemented via a spatially extended neural circuit encompassing brain regions involved in attention, body representation, visual imagery, emotion (physiological and subjective aspects) and self consciousness.[1349]

LeDoux makes an important point that the contribution of components in a system is derived from the fact that the system exists. Individual components are of this conditional value. Hence he writes of the system of emotional

---

[1348] Anthony Landreth, "Far Beyond Driven: On the Neural Mechanisms of Motivation" (PhD thesis, University of Cincinnati, 2007), 186.

[1349] Mario Beauregard and Denyse O'Leary, *The Spiritual Brain. A Neuroscientist's Case for the Existence of the Soul* (New York: Harper One, 2007), 37. Beauregard writes, "The brain has a neurological substrate that enables it to experience a spiritual state". (39)

management, “The amygdala is certainly crucial, but we must not lose sight of the fact that its functions exist only by virtue of the system to which it belongs.”[1350]

Something analogous happens with respect to virtue. By applying this principle to the systems underpinning virtue, we gain a greater appreciation of the whole. There is no doubt that the PFC and the BG, and numerous other individual brain regions are intimately involved in the expression of virtue, but the whole is greater than the parts. It is the soul that is the principle of unity and the principle of virtuous action; when the soul departs the orchestra falls silent. The performers go their separate ways. The music ends. Virtue may be understood as a complex integration and orchestration of organic elements.

George Orwell said that good prose is like a window… you see straight through it to the ideas it communicates; it does not draw attention to itself. Analogously, for all the complexity of the underlying neural orchestration, it is the beauty of virtue that is seen. We have seen that it is in his actions that the greatness of soul of Takashi Nagai shines out.

The state of virtue will be underpinned at the neurobiological level by mechanisms and pathways within the multiple systems of the brain that integrate neural function under the agency of the person. These neurobiological bases dispose for rational virtuous activity.

5.3.2 The principal brain systems contributing to the development and exercise of virtue.

Our focus is not only on systems operating in isolation, but on “multiple neural systems” which in turn are integrated in a highly coordinated manner. Grossberg and Versace offer an fascinating integrative view of brain function accounting for

[1350] J. LeDoux, “Emotion, Memory and the Brain,” *Scientific American* 270, (1994): 50-57. 56

cortico-thalamic learning.[1351] Furthermore parallel systems operate and compete.[1352] Pollak develops the idea of grand neural systems made up of contributory systems; he writes,[1353]

> Attachment, attention, emotion regulation, are likely to be constellations of processes that emerge as output from multiple neural systems… (and so it is necessary to seek) biologically plausible models of the mental processes in question. [1354]

Such a level of integration and coordinated complexity suggests that the state of virtue itself may be understood as complex of other systems, or several complexes of interlinked systems (pertaining to the different virtues), operating across the whole organism. It is the position of this study that the state of virtue may be classified as a system because numerous somatic areas and subsystems contribute, the process may be described scientifically, and results are replicable. Ultimately it is a system that is ordained to the flourishing of the human person, not only at the personal level, but at the biological level as well. This macro system however, does not operate beyond personal control (such as autonomic systems); rather it is a system over which the individual exercises considerable

---

[1351] Stephen Grossberg and Massimiliano Versace, "Spikes, synchrony, and attentive learning by laminar thalamocortical circuits," *Brain Research* 1218 (2008): 278-312. In their Synchronous Matching Adaptive Resonance Theory (SMART) model they argue that there is high level of coordination between brain regions, dependent upon arousal, attention, memory, learning, and expectation brain systems, and mediated by plasticities generated by resonance and synchrony.
[1352] A. J. Gruber and R. J. McDonald, "Context, emotion, and the strategic pursuit of goals: interactions among multiple brain systems controlling motivated behavior," *Frontiers in Behavioural Neuroscience 6, (*2012): 50. "Multiple brain systems acquire information in parallel and either cooperate or compete for behavioral control. We propose a conceptual model of systems interaction wherein a ventral emotional memory network involving ventral striatum (VS), amygdala, ventral hippocampus, and ventromedial prefrontal cortex triages behavioral responding to stimuli according to their associated affective outcomes."
[1353] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology," 735.
[1354] Cf. Gruber and McDonald, "Context, emotion, and the strategic pursuit of goals: interactions among multiple brain systems controlling motivated behavior," 50. Adding a new degree of complexity, Gruber and McDonald (2012) comment on their finding that multiple brain systems appear to compete in pursuit of goals. They discuss a ventral emotional memory network that is constituted by ventral striatum (VS), amygdala, ventral hippocampus, and VMPFC.

autonomous control (directly, and through participatory systems such as the attentional systems and systems for learning).

It is reasonable to suggest that neural systems operate in support of moral actions. Casebeer notes multiple cognitive sub-processes involved in moral cognition, “a highly distributed, whole brain affair”.[1355] Greene and Haidt also draw attention to the distributed nature of the neural bases of moral cognition.[1356] In a perceptive analysis of self reports of loss of will power by EL patients Paul Foley argues that it is necessary to view the brain as “an integrated whole” rather than separating out the psychic and the neurological elements. Within that view he finds that the biological basis of the loss of willpower in EL patients appeared to derive from dysfunction in the affective and motor centres of the BG, with interference to connection between thalamus and pallidum.[1357]

Notably there is evidence that developmental maturation is associated with the phenomenon of increased connectivity and coordinated systems in the brain. Converging evidence suggests that, during development to adulthood, there is a lessening of immediate functional connections to adjacent regions, and an increase of connection between regions distant in the brain. “These novel network-level findings bolster the claim that cognitive maturation occurs not in unitary structures but in the connectivity and interactions between structures.”[1358]

[1355] Casebeer, “Moral cognition and its neural constituents,” 841 and 846. **“**Socio-moral behaviour is rooted in the brainstem/limbic axis and PFC, with input and recurrent connections to and from sensory and multimodal cortices and frontal lobe areas: so it involves more-or-less the entire brain.”

[1356] Greene and Haidt, “How (and where) does moral judgment work?” 517–523.

[1357] Foley, “The Encephalitis Lethargica Patient as a Window on the Soul,” 184-214.

[1358] Somerville and Casey, “Developmental neurobiology of cognitive control and motivational systems,” 236-241; see also M. C. Stevens, et al., “Age-related cognitive gains are mediated by the effects of white matter development on brain network integration,” in *Neuroimage* 48, (2009): 738–746; Beatriz Luna et al., “What has fMRI told us about the Development of Cognitive Control through Adolescence?” *Brain and Cognition* 72, 1 (2010): 101. The authors write: “The transition from adolescence to adulthood therefore can be seen as a change in *mode of operation* from initially relying on more regionalized processing, such as in the PFC, earlier in development to relying on a broader network of regions that share processing in an efficient and flexible manner at the systems level.”

And what are the neural systems that subserve the state of virtue? At the most elemental level we find the systems and mechanisms of plasticity and learning. Learning may be understood as our capacity to change in response to experience. We can be conscious of some of these changes, and even direct them by our choices; others will be at a subconscious level. The state of virtue denotes the conscious possession of learned moral habits. Plasticity and learning, then, are the two foundational systems for the construction of virtue. We have seen that mechanisms of plasticity are virtually ubiquitous across all areas of the brain.[1359] Plasticity is triggered by a wide array of developmental, environmental and experiential factors, and these mechanisms of plasticity are acknowledged to be decisive in all learning and memory. We have seen that plasticities associated with intracellular calcium and gene expression underpin structural changes resulting in long term memory, consolidated learning of new behaviours, etc. The brain's capacity for plastic change is at the core of a neural explanation for the phenomenon of habit, [1360] and, this study suggests, of virtue itself.

Higher "component" systems of the state of virtue utilise the mechanisms of plasticity and learning. These are the systems of memory, attention, reward and motivation, emotion regulation, habit formation, goal election, executive execution of motor commands and cognition, consideration of consequences, planning, and executive direction. In addition there are various subsystems assisting specifically in the development of virtue: systems for empathy and imitation, and systems disposing to sensitive periods of development.

Table 5.2 summarises the principal brain systems and mechanisms contributing to the state and exercise of virtue, referring to summary tables associated with neuroscientific systems discussed in **Chapter 2.**

5.3.3 The neural substrates of virtue. The state of virtue reflects a state of neural and systemic maturity.

[1359] Butz, et al.,"Activity dependent structural plasticity," 287-305.
[1360] Typical of the literature: Graybiel, "Habits, Rituals, and the Evaluative Brain," 359-87.

Having proposed that the state of virtue may be understood, at the neural level, to operate as a system perfecting the various associated systems of the brain (in **5.3.1** and **5.3.2**), and having identified the principal brain systems contributing to the development and exercise of virtue (in summary form in **Table 4.2**, and in more detail throughout **Chapter 2**) it now remains to set out the neural substrates of virtue in some detail.

I do this in two stages. In **5.3.3.1** I lay out systematically the argument for what I call the "neural excellence" view of virtue in the brain noting in summary form the neural bases; in **5.3.3.2** I draw on neuroscientific understanding to account for the 17 characteristics of virtue identified in **Table 4.1**.

5.3.3.1 A "neural excellence" understanding of the neural bases of virtue.

a) **A successful identification of the neural substrate of virtue and of the individual cardinal virtues requires clarification of the terms virtue, prudence, justice, fortitude, and temperance**. The virtues of prudence and justice are materially manifested as perfections of certain neural structures that are necessarily associated with rationality and choice in the embodied life. The virtues of fortitude and temperance are perfections of certain biological structures constituting dispositions of the irascible and sensitive appetites to endure appropriate difficulties and to seek appropriate pleasure; thus we can say they are <u>pre</u>dispositions for rationality and choice. In simple terms, the practical reason is understood, as the human capacity to elect appropriate means and ends for action; the rational appetite chooses what is good for oneself taking into account the good of others; the irascible appetite chooses goods that are difficult to pursue; the sensitive appetite chooses what is pleasurable. 'Appropriate' and 'good' refer to choices that are in keeping with the needs of human nature. The view of this study, in line with Aristotelian and Thomistic notions, is that all mental activity in the embodied life has a biophysical correlate, and therefore the dispositions of these four capacities have neural substrates. These substrates may be identified. (For detailed argumentation see **Chapters 1, 3 and 4**.) Furthermore the notion of the unity of the virtues has been argued: in all virtuous human actions the dispositions corresponding to all four virtues will be active. The fact that acts disposed by fortitude and temperance require rational guidance disposed by prudence and justice serves to clarify the distinctive neural tasks of each of these virtues. (For detailed argumentation see **Chapters 1, 3 and 4**.)

b) **Virtue is a state of neural and systemic maturity**. (See **Chapter 5.3.1** and **5.3.2**) It is evident that this maturity corresponds to the biological flourishing of the organism. (See **Chapter 6**.) The state of virtue is revealed as a macro system: the result of a highly complex interplay of systems, brain areas, mechanisms and pathways (neural, neurotransmitter and neuromodulatory, etc). The flourishing of the organism as a consequence of virtuous dispositions is seen in the mature development and integration of organic "components". The high levels of specific interconnectivity and cooperation between systems, and fine tuning of mechanisms make possible, as material causes, the rational operations of knowing reality and loving other persons. In fact every experience leaves a trace of neural changes in our brain; it will only be neural modifications serving these deepest goods of our nature, of knowing and loving, that are associated with virtue.

c) **Virtue consists, structurally, in the constellation of neural modifications reflecting maturity, at the genetic, synaptic, and cellular levels, in areas of the brain and in its pathways, across all neural systems serving rational action**. These neural modifications facilitate, at a material level, conscious and intentional action carried out for reasons of intrinsic motivation, and include receptivity for neuromodulation associated with reward pathways associated with pleasure inherent in virtuous action.

d) We have seen in **Chapter 2** and **Tables 5.1**, and **5.2** that **a great range of brain areas and structures are involved in the formation of virtue**.

Developmentally-dependent (initially) and use-dependent plastic changes in these areas and structures bring into being a material facilitation for rational activity; they are the neural signature of the state of virtue. Knowledge of the brain, while still advancing rapidly, has reached the point that it is possible to discuss with some clarity the contribution of discrete brain areas and how discrete areas contribute to the functioning of the whole.[1361] Principal areas of the brain in which will be found the mature modifications of virtue include most areas of the PFC, areas of the other cortical lobes associated with memory, deliberation, goal election, consideration of consequences of action, moral judgement, attention, imitation, response and delivery of affectivity, and for motor execution. The BG, limbic and paralimbic structures, the neural pathways between interconnecting these areas with the cortex, and the pathways for neuromodulation reaching cortical and subcortical areas are also intimately involved. In particular the pathways of emotional regulation, of reward, motivation and goal election, and of habit formation are of great significance.

e) Analysis of the exercise of virtue, or more properly of the various virtues, is additionally complex because of its integration into the steps of the human act itself. (See **Chapter 3.1.3**.) **The analysis of the human act assists in identifying the distinctive roles of fortitude and temperance (disposing rationally appropriate appetitive representations prior to the commencement of the act) and the roles of prudence and justice (disposing the deliberations between intellect and rational appetite that constitute the act itself)**.

f) Virtue is acquired by experience. "The human brain is inscribed (or carries traces) that make its microprocessing structure the record of an unfolding reality" writes Gillett.[1362] (See **Chapter 3.1.3**.) **The various mechanisms of**

[1361] Owing to advances in imaging techniques, the last two decades have brought a great increase in knowledge of the functioning brain. Furthermore, as many neural mechanisms and systems are highly conserved across species, animal studies add greatly to knowledge of the human organism.

[1362] Quoted in: Stephen Lyng, "Brain, body, and society: bioethical reflections on socio-historical neuroscience and neuro-corporeal social science," American Journal of Bioethics 9, 9 (2009): 25-6.

plasticity, making possible learning from sensory experience: explicit tuition, environment, experience (guided and otherwise), and repetition,[1363] bring about the requisite neural changes. Plasticity explains the capacity for the human neural system to modify structurally, and functionally, disposing to new behaviours in a stable way. (**Chapter 2 and 5.3**.)

g) The material manifestion of the state of virtue may be described as the sum of the perfections of neural structures necessarily associated with rationality and choice in the embodied life.

h) We have seen that human motivation may reduce to seeking pleasure and avoiding pain. The practice of virtue then is closely supported by a healthy reward system, assisting motivation and goal election; a system that is balanced with rationally cued, aversive responses when appropriate: "Much of our behaviour is shaped by learned associations between stimuli, our responses to them, and the rewards and punishments that result."[1364] Virtuous action is motivated by pleasures appropriate to our rational nature, and by the forbearance of difficulties for the sake of a noble reason. (See **Chapters 1, 3 and 4**.) In fact, **the virtues of fortitude and temperance dispose the human reward systems, and closely associated systems of emotional regulation, to good health**. It is patently not healthful for the organism to pursue rewards and exercise emotional responses which are detrimental to the wellbeing of the whole organism; therefore it is necessary that reward choices and emotional regulation are subject to cognitive processing. Fortitude and temperance dispose, at the neural level, the reward and emotion systems towards cognitive processing. Reward systems in the brain commence with sensory and somatosensory feedback to the OFC and limbic areas which are interconnected. Centres for both gratification and aversion are present in most limbic system structures. Aversional stimulation, for example in the

[1363] D. Narvaez and J. L. Vaydich, "Moral development and behaviour under the spotlight of the neurobiological sciences," *Journal of Moral Education* 37, 3 (2008): 289-312.
[1364] Saladin, *Anatomy and Physiology*, 6th ed., 540.

amygdala, produces unpleasant sensations such as fear and sorrow, consciously registered through the amygdalic pathways via medial thalamus to the cortex, and by somatosensory cortices registering bodily reactions triggered by amygdalic output to the hypothalamus; [1365] in contrast a sense of pleasure or reward is associated with gratification, notably mediated by the NAc,[1366] pallidum and amygdala, and associated with μ-opioid and phasic DA signalling. [1367] Furthermore, limbic structures and the OFC inform the ventral striatum and the hypothalamus as well as the VTA and SN which reciprocally deliver DA to the OFC, amygdala, ventral striatum and hypothalamus.[1368] Directly, and in a second pathway through the ventral pallidum, the ventral striatum also inputs the medial thalamus via a pathway returning to the OFC.[1369] (See **2.6** for more detail.) This reward system is triggered in the OFC and amygdala by sense input. Arguably the due calibration of these areas is a major focus of the virtues of fortitude and temperance; but, as a system is only as strong as its weakest link, a healthy reward system requires all components and linkages to be calibrated to respond to pleasures with moderation and maintain a degree of equanimity in the face of dangers of one form or another.

i) **Maturity in virtue is evidenced by implicit motivation as opposed to extrinsic rewards**. In the development phase of virtue, neural reward systems (mediated principally by DA) are implicated as goals for A-O paradigms. This shift from A-O to S-deliberation-R paradigms involves increased activity in the dorsal BG, a transition to intrinsic motivation and ease of action, and decreased cortical activity. [1370]

> Some types of instrumental learning result in a strong association between a stimulus and an action that becomes resistant to reward devaluation. This kind of

[1365] Saladin, *Anatomy and Physiology*, 6th ed., 540.
[1366] Saladin, *Anatomy and Physiology*, 6th ed., 534.
[1367] Leknes and Tracey, "A common neurobiology for pain and pleasure," 317-8.
[1368] The ventral striatum is reciprocally connected also to the VTA and SN.
[1369] Saladin, *Anatomy and Physiology*, 6th ed., 428.
[1370] Yin and Knowlton, "The role of the basal ganglia in habit formation," 472.

> associative memory, in which the stimulus becomes stronger than the outcome to trigger the response, is called habit….The more this associative memory becomes represented by a larger number of associative units, the more difficult it will be to erase them when the reward outcome or the novelty decreases. [1371]

Note that outcome devaluation affects neither habit nor virtue. [1372] (See **2.6.4**)

j) The exercise of virtue requires cortical emotional regulation. Emotional regulation is closely associated with the conscious perception of reward expectations. **Training in temperance and fortitude** (see below **p**. and **q.**) **consists in what could be described as the "plastic calibration" of the amygdala, and other limbic, basal and cortical structures associated with aversion and reward, in line with Aristotle's insistence that children be trained to seek appropriate pleasures**. A further aspect of emotional regulation is the reinforcement of pathways from amygdala to the PFC.[1373] [1374] Cortical processing alone, however, is insufficient for virtue. **Cortical processing, in turn, must be disposed by prudence and justice**. (See below **n**. and **o.** and also **Table 5.2**)

k) The practice of virtue requires explicit involvement of systems for goal election, a consequence of effective presentation and processing of rewards, and of emotion regulation. **Goal election, in its final phases, is a cognitive process disposed by prudence and justice**. (See **Table 5.2**) Neural modifications during the acquisition of virtue will be dependent upon goals that are self-elected, or goals, as in the case of a young child for example, that are elected by another. In both cases, virtuous goal election

---

[1371] Da Cunha, et al. "Learning processing in the basal ganglia: a mosaic of broken mirrors," 166.
[1372] Da Cunha, et al. "Learning processing in the basal ganglia: a mosaic of broken mirrors," 166.
[1373] Saladin, *Anatomy and Physiology*, 6th ed., 540.
[1374] LeDoux, *The Emotional Brain*, 170. Sense input received in the amygdala is infused with emotional content. Thence, output will be either to hypothalamus (for bodily reactions to emotional stimulus), which is "the low road" identified by LeDoux, or areas of PFC implicated in conscious control and emotional expression, aspects of "the high road".

is a task of rationality, therefore disposed either by one's own prudence and justice, or by the prudence and justice of the guide whom one obeys.

l) Virtue is a form of learning characterised by the acquisition of habits. **The development of habitual behaviours is attributable to mechanisms of plasticity in brain areas and in brain pathways. Certain habits associated with virtue initially appear cognitively based (eg a habit of deliberation before acting), while others appear more procedural in the strict sense, with a striatal basis (eg the habit of courteously smiling to each new person one meets).** Cognitive habits however will not simply be mediated by cortical plasticity. Striatally mediated habits are not restricted to subconscious procedural activities; automaticity may develop in formerly goal directed actions mediated by striatal changes. [1375] Cortically elicited DA release (from VTA and SN), in both PFC and striatum, reinforces goal election and mediates, by repetition, striatally based habit learning: "Habit learning is achieved after overtraining in the striatum."[1376] Graybiel suggests that oscillatory activity in the cortico-basal loops is involved in establishing the habit, and that that chunking of behaviours, of action repertoires, is evidence for a neuronal shift from limbic to regions of motor and cognitive output. "Thus the relation between habits and the evaluative brain is that habits are an endpoint in the evaluation process."[1377] (See **2.4.5**) Note that as habits are acquired, reward mediation in the ventral striatum gives way to dorsal automatisation. (See above **i.**)

m) **Systems responsive to sensitive periods and to affection, and systems of imitation play significant roles** in acquiring behaviours particularly during developmental periods. (See **Table 5.2**)

n) **Prudence** is characterised by rich and reciprocal connectivity primarily between the DLPFC and other with cortical areas serving memory and somatic and sensory input, with the OFC, DMPFC, BG, and amygdala

---

[1375] Wickens, "Synaptic plasticity in the basal ganglia," 125.
[1376] Da Cunha, et al. "Learning processing in the basal ganglia: a mosaic of broken mirrors," 166.
[1377] Graybiel, "Habits, Rituals, and the Evaluative Brain," 378.

serving emotion regulation, with the ventral striatum assisting in goal setting and motivation. (For more detail see **Tables 5.1** and **5.2,** and **5.3.2**)

o) **Justice** is characterised by habitual understanding for others, consideration of the impact of one's actions on others, empathy, and considerations of fairness, capacities mediated primarily by the aPFC, mPFC, VMPFC, OFC (especially medial OFC), ACC (especially rostal ACC), insula, limbic and paralimbic areas, and the BG. (For more detail see **Tables 5.1** and **5.2,** and **5.3.2**)

p) **Fortitude** is mediated first of all by the BG-thalamo-cortical loop and enriched connectivity between the OFC and the amygdala. At its most elementary level, the expression of fortitude may be understood as a capacity for rational, habitual suppression of debilitating responses to fear or pain. The various pathways of emotional regulation are also implicated. Various brain regions are shown to be active including OFC, DLPFC, VMPFC, areas of the amygdala and of the BG. The close association of pain and pleasure systems in the brain allowing balanced cognitive judgements has also been noted. (For more detail see **Tables 5.1** and **5.2,** and **5.3.2**).

q) **Temperance** is mediated primarily by the DLPFC and ACC, and by the various pathways of emotional regulation associated with the OFC, DMPFC, BG, with the ventral striatum assisting in goal setting and motivation. (For more detail see **Tables 5.1** and **5.2,** and **5.3.2**)

r) Exercise of these four virtues will also be subserved by ready access to memory. Many forms of plasticity dependent learning and memory are implicated in the development of virtue. **Deliberations implicit to cognition, consideration of consequences, planning, and goal election require activation of both long and short term declarative memory, as well as procedural memory and emotional memory.** (See **Table 5.2**.) Consolidation and plasticity in memory pathways is a necessity for virtuous judgement. Activation of declarative memory is necessary in evaluating the value of actions.

s) **Acquisition of the four virtues will be served particularly by mechanisms of imitation** priming responses in accord with the exemplar. (For more detail see **Tables 5.1** and **5.2,** and **5.3.2**)

t) The state of virtue should be seen as the endpoint of neural development, of a developmental sequence of behaviours associated with the ordered biological dispositions of fortitude and temperance informing right judgement. It involves an ongoing interplay between biological development, practical reason, experience, consideration for others, and the repetition of positive goal directed behaviours. The state of virtue makes use of the constellation of mechanisms and processes operating in across the various brain regions and pathways between them. Habit provides a mechanism for the organism to act more efficiently at the neuronal level, allowing the diversion of attention elsewhere and absorbing fewer cerebral resources. During the period of acquisition, both implicit procedural memories and virtue, move from the explicit to the automatised. [1378] Both are acquired by a process initially involving attentive, voluntary and repetitive action and explicit knowledge. During the human act and therefore the process of acquisition of virtue, concrete representations are present in mind.

u) Finally, **happiness as 'the reward of virtue'**[1379] **can be identified on various levels**.

   i. Choices associated with appetite are rewarded indiscriminately by the body's hedonic reward systems. As we have seen this is a normal concommitant to human acts. In biological terms this will be reflected in mechanisms of μ-opioid and phasic DA signalling and 5-HT uptake inhibition.

   ii. Pleasure enjoyed with self control is more enjoyable because it is longer lasting, and because it is enriched by the joy of knowledge of benefits to others, and is free of any bitter aftertaste of self interest.

[1378] See **Chapter 2** for referencing.

[1379] *NE*, 1099b16.

Such reward satisfaction following upon intrinsic motivations has been discussed. This will also be reflected in DA and opioid signaling.

iii. Via thalamic pathways from the striatum to the OFC that allow cognitive modification of PFC to upregulate DA release, rewards are modified to reflect the conviction to that proposed virtuous actions are rationally desirable; a source of reward reserved for what is perceived as a rational choice.

iv. Virtue empowers the functional flourishing of the organism. (See **b.** immediately above.) This state requires the efficient interconnection of the cortical, sub cortical, limbic, and brain stem regions, and the mature development of the full array of biophysiological attributes of the human being.

v. Virtue empowers the functional flourishing of the person, facilitating openness to reality and the capacity to love other persons.[1380] (See **b.** immediately above.) This is facilitated not only by rich connectivity between sensory cortices and the PFC but enriched brain activity supporting just action (see **p.** above), and prudent action (see **o.** above), supported by effective emotional regulation at the service of rationality.

vi. Virtue empowers the teleological flourishing of the person. The endpoint is *eudaimonia*, a state of general flourishing marked by effective self-management mediated by the neurophysiological dispositions of prudence, justice, temperance and fortitude. It satisfies two conditions for the presence of virtue – on the one hand mature neurobiological development, integration of systems, efficiency and an emotionally enriched life; and on the other a rationality that is disposed to seek and recognise truth and to love others. The wellbeing of the human person requires effective integration of the rational and physiological, the complete harmonisation of body and soul. This is the

[1380] Affective experience in turn feeds back into the paradigm of virtue development, facilitating peace of heart and motivating further positive behaviours.

ultimate meaning of *eudaimonia*. (There will be further discussion of flourishing in **Chapter 6**.)

5.3.3.2 The neural bases of virtue

I will now map the neural substrates of virtue to the characteristics of virtue established in **Chapters 3** and **4**. The state of virtue is understood as a state of excellence at the neural biophysical level for each of the characteristics.

This section proposes neural features for the 17 characteristics of virtue identified in **Table 4.1**. These 17 characteristics are divided, as per the original table, into three categories according to their association with the acquisition of virtue. For each point I offer brief philosophical clarifications of the characteristic under discussion (relating findings of **Chapters 3** and **4** to the neurological domain) and then I summarise the proposed neural signature for the characteristic under discussion. Finally, for each characteristic, I list the neural systems (see **Table 5.2**) associated, thus emphasizing the underpinning systemic integration. Tables summarizing discrete neural systems and their *prima facie* linkage to virtue are included in the endnotes.

….

A. CHARACTERISTICS PERTAINING TO THE STATE OF VIRTUE

1. The virtues of prudence and justice dispose the practical reason and the intellectual appetite facilitating rationality and appropriate choices.

Philosophical clarifications.

- **The different virtues exhibit distinctive biological features.** In the Aristotelian/ Thomistic understanding, the human person *is* the animated body. Rational activity is conducted by a body animated by a human soul. As has been reviewed in **Chapter 4**, four cardinal virtues are necessary to account for operations and activities of an embodied soul. On this basis it is necessary for the four cardinal virtues to have distinctive neural signatures. Hence, the virtues of prudence and justice are materially manifested as perfections of certain neural structures that are necessarily associated with rationality and choice in the embodied life.

- **Prudence**[1381] **and justice**[1382] contribute habits perfecting the rational faculties,[1383] and therefore directing choices consequent upon the presentation of arduous goods and pleasurable goods to the intellect and will by the habits of the sensitive appetites.[1384]
- **Rationality** and **rational choice** as we have seen in **Chapters 1, 3 and 4**, while not reducible to the biological, possess and are manifested by means of sensible, neurobiological concomitants.
- Furthermore, (as has been argued in **Chapter 4**) in a state of virtue the unity of the virtues holds: **all virtues are present and their action is fully integrated**. Not only will the virtues of prudence and justice, here described, be enlisted in the direction of actions disposed by fortitude and temperance, but the self-dominion accompanying fortitude and temperance (described in the section immediately

[1381] The virtue disposing the practical intellect is prudence**.** As we have seen in **Chapter 4**, prudence may be understood as the habitual disposition of the practical intellect to be of right counsel, to judge well and to command well. Aquinas argues that prudence is needed "to perfect the reason, and make it suitably affected towards things ordained to the end". (*ST*, Ia-IIae, Q.57, Art.5.) It is "right reason about things to be done," (*ST*, Ia-IIae, Q.58, Art.3.1) the habitual disposition of the practical intellect to be of right counsel, to judgement well and to command well. The starting point of prudence is knowledge of reality. Furthermore, "memory, experience, tact, good judgement, and sagacity" all either arise from prudence or accompany it. (Aristotle *De Virtutibus et Vitiis*, 1250a30-37) It is "well trained reason, capable of working out the particulars of a problem, of foreseeing the probable consequences of an act, of using powers of circumspection, of weighing the individual circumstances of a situation, of exercising caution lest good intentions ultimately do more harm than good. Reasoning, foresight, watchfulness, precaution are all essential elements of prudence, and there is no real prudence without them." (Gilson, *The Christian Philosophy of St Thomas Aquinas*, 288.)

[1382] As we have seen in **Chapter 4**, Justice is the virtue which disposes the rational will to act with due respect to the rights of others. Aquinas argues that justice is the state of character that makes people disposed to do what is just, and makes them act justly and wish for what is just. (*NE*, 1129a7ff.) Strict reciprocity of duty but also extending to duties of religion and of filial gratitude.

[1383] Aquinas writes of virtue as the "perfection of reason" in *ST*, II-II, 51,1.

[1384] The intellectual appetite is understood as the attraction to abstract pleasurable goals brought about by reward mechanisms in the brain responding to particular representations of goods associated with those abstract goals.

below) make prudent and just action possible. Hence, the neural signature of the virtues disposing a single human act will reflect the presence not only of the virtues disposing the intellect and rational appetite, but also those disposing the irascible and sensitive appetites.

- **We must keep present that it is the person who is rational, not particular brain cells.** Although it is the case that the PFC, and higher cortical areas in general, are more active in supporting the dispositions of prudence and justice, it would be an unwarranted conclusion that man's intellectual life, his capacities to grasp the truth of things or to love rationally, have their bases solely in activity in the higher cortical areas. This position would have no philosophical justification in keeping with the views of Aristotle and Aquinas. Beyond the highly complex integration of all brain areas, including limbic and basal structures, accompanying all activity in the cortex, activity in the brain itself is supported by the organic life of the organism, respiration, nutrition and circulation. Our microfocus on neural structures and pathways and mechanisms must be balanced by acknowledgement of the functional, existential, and objective unity of the person.

Neural bases

At the neurobiological level, prudence and justice are perfections of specific biological structures that are necessarily associated with rationality in the embodied life. They are established by plasticity-elicited changes to neural structures, which optimise neural and biological efficiency and are essentially mechanisms for use-induced establishment and reinforcement of neural pathways.

These perfections of bodily structures are essentially neuronal facilitations of the following biophysical tasks. These tasks together account for the roles of counsel, judgement, command, and the disposition to accommodate the good of others, as required by the virtues of prudence and justice.[1385]

- A facilitation for (hereafter described as "capacity for") **processing of sensory data** as a prerequisite for grasping the reality of the context for decision making. This processing will be directed by the lateral PFC informed by the accurate cortical somatosensory feedback via PNS and lower brain areas that is required for effective cortical processing.
- Capacity for planning and foresight, and for **consideration of consequences** of impact on others. This latter role is primarily a task of the VMPFC,[1386] [1387] the ACC and the OFC. Areas of the PFC are active in consideration of possible future outcomes.[1388] [1389] [1390] Contribution of the right DLPFC has been noted. It is believed that the PFC, and in particular the OFC, is the site of appreciation of moral consequences of behaviour.[1391]
- Capacity for cognitive **processing of emotional content, and particular reward representations** reaching PFC via OFC (input from cortico-striatal, and cortico-limbic pathways). Clinical studies show time and again that frontal cortical inhibitory zones suppress lower

---

[1385] Counsel may be understood as a having a sound grasp of reality and duty in both physical and ethical dimensions. Judgement implies the capacity to evaluate the intrinsic and extrinsic benefits of an action taking into account the good of others. Command implies the executive capacity to carry decisions into action.

[1386] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214. It was the medial PFC that suffered damage in the case of Phineas Gage.

[1387] Lee, et al., "Regulation of human behaviours," 190.

[1388] J. M. Fuster, *The prefrontal cortex*, (New York: Raven Press, 1989).

[1389] J. Grafman,"Alternative frameworks for the conceptualisation of prefrontal functions" in *Handbook of Neuropsychology*, ed. F. Boller and J. Grafman (Amsterdam: Elsevier, 1994), 187.

[1390] R. Passingham, *The frontal lobes and voluntary action*, (Oxford: OUP, 1993). Passingham is recognised as a decisive pioneer of an understanding of PFC function and its role in support of decision making.

[1391] Note that damage to the medial PFC and frontal cortex leads to socially inappropriate behaviour, disinhibition, emotional impairment, difficulty in planning, and impaired working memory, as noted above in the celebrated case in 1848 of Phineas Gage but borne out by many animal studies and human case studies. Cf Gazzaniga, *Who's in charge. Free will and the science of the brain*.

order behaviours. [1392] [1393] Emotional and reward representations are generated in the medial PFC in conjunction with the BG via reciprocal pathways. BG are also active in concert with the PFC, enlisting limbic structures for processing emotional content and memory. [1394] Cognitive processing of emotional representations channeled through the OFC via limbic-cortical pathways is primarily in DLPFC, VMPFC, and OFC itself. [1395] [1396] [1397] This will be assisted by generation of representations in the memory (primarily distributed in cortex and in amygdala), as required for the representation of the anticipated goods. Note that, via striatal pathways, the medial PFC is capable of upstream modification on ACh and DA release, further modifying reward and emotional representations. [1398] [1399] Plasticity in spindle cells understood to facilitate goal directed behaviour and self control.[1400] There is evidence that emotional and reward election management requires the PFC areas to be in rich reciprocal communication with the amygdala and striatum. [1401]

- Capacity for **associated deliberation about abstract goods** (again primarily in the PFC) represented by the above particular reward representations. This cognitive activity directed by the lateral PFC will be facilitated by recruitment of memory (principally cortical-declarative, emotional memory via the limbic pathways, and hippocampal memory) which "supports the capacity to make

---

[1392] M. R. Bennett, "The prefrontal-limbic network in depression: Modulation by hypothalamus, basal ganglia and midbrain," 483.
[1393] Zotev et al., "Self-Regulation of Amygdala Activation Using Real-Time fMRI Neurofeedback".
[1394] Koch, "Consciousness," 1220.
[1395] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[1396] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 57.
[1397] Balbernie, "Circuits and circumstances. The neurobiological consequences of early relationship experiences and how they shape later behavior," 237-255.
1398 Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,"747.
[1399] Yin and Knowlton, "The role of the basal ganglia in habit formation," 470.
[1400] Arden and Linford, *Brain-based therapy with children and adults*, 104-105.
[1401] Ray and Zald, "Anatomical insights into the interaction of emotion and cognition in the PFC," 479-501.

generalisations and inferences from memory".[1402] [1403] Recruitment of various forms of short and long term memory at cortical, limbic, and striatal sites in particular, facilitate recall of contextual particular information, emotional cues, and also abstract rules of right and wrong. The BG also play a direct role in the task of deliberation: areas of BG interconnected with PFC are implicated in intentional behaviour, learning and decision making. [1404]

- Capacity for **consequent generation of an intention** is supported by mechanisms of reward and goal election. As we have seen, goal election and cognition of reward representations appear to be closely associated functions. Rational intention will be informed by medial PFC emotional processing balanced by laterally directed deliberation.[1405] [1406] Input from the BG, modifying the PFC via thalamic pathways, is also considered a key regulator of voluntary behaviour.[1407] Capacity for deliberation is an integrating cognitive task directed by the lateral cortex. [1408] [1409] Active brain areas are diverse but feature strong connectivity. [1410] Memory in the striatum not only appears to instruct the PFC with respect to procedural patterns of behaviour,[1411] but the striatum contributes to an

[1402] Manns and Hichenbaum, "Learning and memory: brain systems," 1165.
[1403] Marieb, Elaine N. and Katja Hoehn. *Human anatomy and physiology*. 8th ed. San Francisco: Pearson, 2010, 459. Declarative memory pathways involve sensory input carried to the association cortex; information is then sent to the medial temporal lobe, including the hippocampus and proximate temporal cortical areas that link to the PFC and the thalamus. ACh from the basal forebrain released into the PFC and the medial temporal lobe is believed to trigger memory formation.
[1404] Wickens, (2009) "Synaptic plasticity in the basal ganglia,"119.
[1405] Markowitsch, et al., "Brain circuits for the retrieval of sad and happy autobiographic episodes," 643-665.
[1406] Arden and Linford, *Brain-based therapy with children and adults*, 104-105.
[1407] Yin and Knowlton, "The role of the basal ganglia in habit formation," 464.
[1408] Miller and Wallis, "The prefrontal cortex and executive brain functions," 1201.
[1409] Arden and Linford, *Brain-based therapy with children and adults*, 88.
[1410] Lee, et al., "Regulation of human behaviours," 189-199.
[1411] Pasupathy and Miller, "Different time courses of learning related activity in the prefrontal cortex and striatum," 873-876.

emphasis on intentional behaviour, learning and decision making. [1412] [1413]

- **Executive command** is a task of the lateral cortex enlisting motor cortices, the cortico-BG-thalamocortical loop, the BG, and the cerebellum. [1414] [1415] [1416] [1417] [1418] (See **No. 7** in this section.) This will be complemented by the **capacity to carry through executive commands to appropriate execution**.
- **Capacity to utilise language** as a vehicle for thought. For this the PFC links extensively to Broca's Area also in the frontal cortex.
- **See also n. – q.** in **5.3.3.1** outlining the particular neural features of each of the four cardinal virtues considered individually.

Note that in the performance of a single human act, these tasks are seamlessly **integrated**.[1419]

Prudence consists in appropriately formed neural structures that assist the intellect in reaching correct conclusions about ends and means. The lateral PFC is the principal site active in deliberation about consequences and means, planning and foresight. Lateral and medial PFC are densely interconnected and facilitate human volitional activity,[1420] and cognitive deliberation about emotional content.[1421]

1412 Wickens, (2009) "Synaptic plasticity in the basal ganglia,"119.
1413 Yin and Knowlton, "The role of the basal ganglia in habit formation," 465.
1414 Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 62.
1415 Kaas and Stepniewska, "Motor cortex," 159.
1416 Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 73.
1417 Wickens, (2009) "Synaptic plasticity in the basal ganglia,"119.
1418 Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 473.
1419 The analysis of the constituent parts of the human act (**3.1.3**) provides essential knowledge for the correct sequencing of activities at a somatosensory level and at the rational level. It provides a clear understanding of the distinctions between counsel, judgment and command, and of the roles of prudence and justice in informing these actions. Importantly also, it provides an understanding of the reciprocating deliberation between the intellect and the rational appetite prior to command. For example, an appreciation that particular reward representations precede to-and-fro deliberations between parts of the cortex prior to a single completed human act is essential the if the neural signature of the virtues disposing that human act are to correctly be identified.
1420 Lee, et al., "Regulation of human behaviours," 189-199.

Justice consists in appropriately formed neural structures that assist the rational will in choosing correctly. Neural structures include aspects of those aspects of **b-e** which are related to affective appreciation and evaluation, and emotion-cued reward representations. In particular, areas of medial and orbital PFC are centrally implicated. These are the principal cortical sites for emotional processing, reward evaluation, deliberation about positive and negative affective consequences and means, and planning and foresight, most particularly with respect to the impact proposed actions will have on others. Recruitment of systems for empathy (including mirror neurons) to assist in understanding consequences of actions on others is also required. Areas of BG also, interconnected with amygdala, and PFC assist in deliberation about rewards with emotional content. Furthermore, a habit of expectations of cortical (ie conscious) DA reward in response to appropriate consideration for the impact of actions on others will be a further indicator of possession of the virtue.

In summary, the PFC should be considered the most significant brain area associated with the virtues of prudence and justice, although various other brain areas are directly implicated, most significantly other cortical areas, the BG, the limbic system, and the pathways connecting these. The neural activity associated with prudence and justice takes place in a highly integrated and coordinated manner across multiple areas of the brain.

Associated systems

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit

[1421] Source for information in this section on the frontal cortex is, unless otherwise specified: Lee, et al., “Regulation of human behaviours,” 190.

formation. Cognition, consideration of consequences, planning, goal election, and executive direction.

2. **The virtues of fortitude and temperance dispose the irascible and sensitive appetites to endure appropriate difficulties and to seek appropriate pleasure.**[1422]

Philosophical clarifications.

- Virtue consists in appropriate (ie rational) response in respect to pleasure and pain. Regulation of emotion is at the heart of virtue. Fortitude and temperance dispose for the effective management of emotion. Rational guidance systems, disposed by prudence and justice, then are able to act.
- **Fortitude**[1423] **and temperance**[1424] are essentially perfections of biological structures of the body, directly associated with management of emotional life, which facilitate the presentation of appropriate arduous goods and pleasurable goods to the intellect and will. It has been argued that fortitude and temperance are, in total, ordered biophysical qualities of the human person; they facilitate rational action in the same way that a well-trained animal obeys the rationality of its master, eg by eating only when permitted, defending the master's interests by fighting, etc.

[1422] The irascible and sensitive appetites, are understood as the attraction to concrete pleasurable goals brought about by reward mechanisms in the brain responding to particular representations or sensory input. Fortitude disposes the irascible appetite to endure difficulties in pursuit of difficult goods. Temperance disposes the sensitive appetite to obey reason in moderating pursuit of pleasures.

[1423] Fortitude is a particular quality of self management; the right management of one's fear and its concomitant sorrow is at the heart of the virtue. The essence of the virtue of courage is mastery over one's emotions of fear with readiness in necessity to put one's life knowingly and calmly on the line. "The man of fortitude relinquishes, in self forgetfulness, his own possessions and his life." Pieper, *Fortitude and Temperance*, 54.

[1424] Temperance is "the virtue whose particular function is to restrain and check passion" (Gilson, *The Christian Philosophy of St Thomas Aquinas*, 263). It is "a virtue of the appetitive part, by which men cease to desire bad sensual pleasures" (Aristotle *De Virtutibus et Vitiis* 1250a30-37). In the strict sense it is "a mean with regard to the bodily pleasures of touch" (*NE*, 1117b24ff). "To temperance belongs absence of admiration for the enjoyment of bodily pleasures, absence of desire for all base sensual enjoyment, fear of just ill repute, an ordered course of life, alike in small things and in great. And temperance is accompanied by discipline, orderliness, shame, caution."

- We have seen that with respect to temperance Aristotle understood that virtue consists in finding pleasure in the right things for the right reason to the right degree. Thus we should look for the temperance in the changes and dispositions in the pathways triggering pleasure as well as in the cognitive reassessment and adjustment of sense pleasure, a reassessment of fitting sources of pleasure.
- We have seen that with respect to fortitude Aristotle understood that virtue consists in enduring difficulties in the right things for the right reason and to the right degree. Thus we should look for the fortitude in the changes and dispositions in the pathways triggering fear as well as in the cognitive reassessment and adjustment of fear, a "recalibration" of what makes us fearful.
- Note that, the points which follow should be read most particularly in conjunction with the **No. 1** in this section outlining the common neural bases of prudence and justice, and **n. – q.** in **5.3.3.1** outlining the particular neural features of each of the four cardinal virtues considered individually. This is discussed in **No. 1**, immediately above, according to the understanding of the unity of the virtues.[1425]

<u>Neural bases</u>

At the neurobiological level, the virtues of fortitude and temperance consist in plasticity elicited changes to neural structures. These changes are brought about by mechanisms for use-induced establishment and reinforcement of neural pathways and they serve to optimise neural and biological efficiency. These perfections of bodily structures are essentially neuronal facilitations, plasticity elicited predispositions for rationally consistent responses to pain and to pleasure. They serve to enable rational action. In the restricted sense they consist of habitual responses, which when acquired, allow a person more easily to manage

[1425] Note that an understanding of the unity of the virtues leads to the conclusion that the work of the virtues is highly integrated, and points to the difficulty of precisely delineating at what point the work of fortitude and temperance is completed, and where the work of prudence, most particularly, commences.

fear of bodily danger and inappropriate attraction to sense pleasures of touch. In a broader sense they refer to habitual responses of patience and determination in the face of difficulties, and to habitual responses of appropriate moderation of pleasurable activities.

They are constituted by integrated activity in neural bases below. Activity is primarily in interconnected areas of the PFC, limbic system, and BG, dedicated to emotional regulation, bearing in mind that the various emotions are represented, as would be expected, at differing locations in the brain.

Fortitude and temperance, as we have seen, are brought about by “training” according to Aristotle, in a way analogous to training an animal. As such they may be viewed as varieties of “conditioned response”, itself a broad term denoting learning brought about by some form of incentive. These conditioned responses are compatible with, and facilitate, conscious rational goal election.

The points below must be read in conjunction with **No.1** above. In the light of the above proviso, **the common neural bases** for fortitude and temperance follow.

- **Areas of the PFC (OFC, medial PFC, and lateral PFC) and areas of the amygdala and of the BG** are the key structures in management of fear and pleasure. The capacity of the PFC to elicit conscious representations of emotion, and to assess affective consequences of actions is at the heart of this emotional regulation.[1426] The PFC has projections to and from the forebrain systems associated with sensory data, with voluntary motor movement, with long term memory, and with systems processing affect and motivational state.

[1426] Davidson, “Affective style, psychopathology, and resilience: Brain mechanisms and plasticity,” 1196-1214.

It is also interconnected to brain areas processing external information (linked to sensory systems/cortical and subcortical motor systems), as well as internal information (limbic and midbrain involving affect, memory and reward).

- Cognitive processing of emotional representations reaching the OFC via limbically modified thalamocortical pathways is primarily in **DLPFC, VMPFC and OFC**, those areas of the cortex adjacent to the limbic areas, and are believed to regulate emotional response.[1427] [1428] [1429] [1430] Conscious regulation of emotion utilizes both the DLPFC and VMPFC. It is believed that the DLPFC recruits input from the VMPFC (which includes the OFC) when there are conflicting emotional situations.[1431]
- The **OFC** is regarded as the limbic gateway to the cortex. OFC inhibition of subcortical areas such as the amygdala is a key to affect regulation.[1432] Neuroplastic remodelling of the frontal lobes is at the core of improved affect regulation in the PFC, allowing the OFC to effectively inhibit activation of subcortical areas such as the amygdala.[1433]
- The **ACC**, within the medial PFC, has been called the "major outflow of the limbic system" and is active in the experience of pain and distress. [1434] With the OFC it plays a central role in cortical regulation of emotion.[1435] The ACC appears to play a role in inhibiting impulsive

---

[1427] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 738.
[1428] Arden and Linford, *Brain-based therapy with children and adults*, 88.
[1429] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 57.
[1430] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[1431] Arden and Linford, *Brain-based therapy with children and adults*, 88.
[1432] Arden and Linford, *Brain-based therapy with children and adults*.
[1433] Arden and Linford, *Brain-based therapy with children and adults*.
[1434] Posner and Rothbart, "Developing mechanisms of self regulation," 429.
[1435] Balbernie, "Circuits and circumstances. The neurobiological consequences of early relationship experiences and how they shape later behavior," 237-255.

behaviours and in generating goal-directed behaviours.[1436] There is evidence that it plays a role in analysing conflicting options.[1437]

- **The BG** informs the limbic loop of emotional management and plays a significant role in regulation of emotional responses.[1438] [1439] [1440] This finding supported by clinical observation that dysfunction of basal ganglia-limbic circuitry leads to schizophrenia and severe anxiety.[1441]
- The **amygdala** projects back to virtually all areas of the cortex influencing not only responses to fear, but higher order thought process, working and long term memories, ongoing perceptions, attention, mental imagery, principally in assistance to emotional regulation. [1442] [1443]
- **Pathways for emotional regulation** are found in the BG-thalamo-cortical loop importantly already associated with habit formation, and in the limbic-OFC-ACC loop. [1444] Limbic modulation requires rich reciprocal connections with the OFC. [1445] [1446] Significantly, the NAc in the BG is adjacent to the OFC and rich interconnections exist between them. Limbic modulation also requires interconnectivity to memory centres. OFC links to other cortical memory centres and to subcortical memory centres including amygdala and hippocampus. The lateral OFC, the OFC, and medial PFC are interconnected and

---

[1436] Markowitsch, et al.,"Brain circuits for the retrieval of sad and happy autobiographic episodes," 643-665.
[1437] Arden and Linford, *Brain-based therapy with children and adults*, 88.
[1438] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 347.
[1439] Heatherton and Wagner, "Cognitive Neuroscience of Self-Regulation Failure," 132-139.
[1440] Michael W. Shiflett and Bernard W. Balleine, "Molecular substrates of action control in cortico-striatal circuits," *Progress in Neurobiology* 95, 1 (2011): 1–13. "How the striatum controls the influence of reward learning on the cognitive control of action selection and initiation at a cellular and molecular level is an area of active research."
[1441] Tortora and Derrickson, *Principles of Anatomy and Physiology,* 11th ed., 493-494.
[1442] LeDoux, *The Emotional Brain*, 287.
[1443] Hamann, et al., "Ecstasy and agony: activation of the human amygdala inpositive and negative emotion," 135–141.
[1444] Pare et al., "New vistas on amygdala networks in conditioned fear," 1-9.
[1445] Heatherton and Wagner, "Cognitive Neuroscience of Self-Regulation Failure," 132-139.
[1446] Somerville and Casey, "Developmental neurobiology of cognitive control and motivational systems," 236-241. Cortico-striatal pathways appear crucial for cognitive control.

play a critical role in cognitive and emotional processing and in the formation of motivation for the selection of behaviours.[1447] DA modulation of reward pathways is well established. [1448] [1449] [1450]

- **Various forms of memory** are recruited in support of emotional regulation. Consideration of the perceived good of emotional regulation is associated with recruitment of memory (principally by hippocampal-cortical memory systems informed by the amygdala) the generation of reward representations associated with a pleasurable good, and associated DA and opioid signaling.

Fortitude consists in appropriately formed neural structures that assist the irascible appetite to obey rationality. These are essentially learned dispositions at the neural level regulating fear responses and aversive responses to pain.

As fortitude involves the rational management of fear, it is necessary to describe the neural bases of the experience of fear in order to better understand the neural bases of fortitude. To describe the **neural bases of the experience of fear** I draw, among others, from the work of Joseph LeDoux:

- The PFC is active in conscious representations of emotion, and in assessing affective consequences of actions.[1451] The presence of fear, the capacity to experience fear, indicates the maturation of working memory and in particular the OFC, linking temporal lobe limbic areas (amygdala and temporal pole cortex), the subcortical drive centres (in hypothalamus), and the DA neurons in reward

[1447] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 57.
[1448] Pine, et al., "Dopamine, Time, and Impulsivity in Humans," 8888-8896.
[1449] Buitelaar, "Adolescence as a turning point: for better and worse," 357.
[1450] Floresco, "Dopaminergic regulation of limbic-striatal interplay," 400–411.
[1451] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.

centres of VTA.[1452] ACh is responsible for the mediation of vivid fearful memories. [1453]

- The amygdala is active in the experience of fear, mediates emotional influences on attention and perception, and regulates emotional responses. Mechanisms of synaptic enhancement are linked to emotional memory in studies of amygdala circuits that mediate fear. [1454] Emotional memory seems associated with the BLA which includes the lateral, basolateral, and basomedial nuclei, and the CEA.[1455] The lateral nucleus area tags memories with emotional "markers".[1456] Recall of these memories is mediated by hippocampus.[1457]
- The BLA seems key in development of an aversion, of fear conditioning. BLA draws input from widespread cortical areas, and from the sensory nuclei of the thalamus, with reciprocal connections to hippocampal and striatal memory systems. Outputs also extend from BLA to CEA and thence to subcortical areas controlling fear related responses such as heart rate, blood pressure, sweating, hormone release, etc. [1458]
- Emotional arousal appears to promote synaptic plasticity (for memory and learning) by various mechanisms including release of NE.[1459] The emotional circuitry is also modulated in an excitatory way by ACh from the gigantocellular neurons of the reticular excitatory area.[1460] [1461]

[1452] Schore, "Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health," 7-66.
[1453] LeDoux, "Emotion circuits in the brain," 155-184.
[1454] Byrne, "Learning and memory: basic mechanisms," 1141.
[1455] LeDoux, "Emotion circuits in the brain," 155-184.
[1456] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[1457] McGaugh, "The amygdala modulates the consolidation of memories of emotionally arousing experiences," 1-28.
[1458] LeDoux, "Emotion circuits in the brain," 155-184.
[1459] Kessels and Malinow, "Synaptic AMPA Receptor Plasticity and Behaviour," 344.
[1460] Bear, *Neuroscience. Exploring the Brain,* 581.
[1461] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 730.

- Cortisol, adrenaline, and noradrenaline are triggered from the adrenal glands in times of stress that may or may not accompany fear.[1462]

Neural regions associated with the apprehension of pain are widespread and include the lateral PFC, anterior and posteria insula, the OFC, the MPFC, the anterior cingulate gyrus, areas of the BG, the thalamus, amygdala, hippocampus and various other subcortical regions. [1463]

It is proposed that **the specific neural bases of fortitude** are essentially to be found in neural modifications in the above pathways, most particularly in the following ways:

- Cortical processing of pain and fear responses is facilitated by the cortico-basal ganglia-thalamocortical loop which permits complex cognitive-emotional interaction, and offer insights into processes of planning, goal selection, self-regulation, attention and motivation. There are dense interconnections between the OFC and the amygdala, and between the amygdala, the hippocampus, and the ventral striatum.[1464] Furthermore, it is shown that motivation and meaning are analgesic factors. [1465] Therefore plastic modification of reward and goal setting pathways can effect changes in the pain threshold.
- The VMPFC and the amygdala are the key brain areas implicated in fear and its management. The VMPFC, the DLPFC, the hippocampus, and amygdala constitute the core elements of the neural circuit (the

---

[1462] Sunderland, *The Science of Parenting,* 40. "Brain scans show that early stess can cause the HPA axis (the stress response system in the body) to become permanently wired for oversensitivity." "When a child experiences prolonged, uncomforted distress, the hypothalamus releases *corticotrophin releasing factor* (CRF)", which in turn stimulates the pituitary gland to release the hormone *adrenocorticotropin* (ACTH) which travels to the adrenal glands (on top of each kidney) which produce cortisol which in the short term "can help us to respond to stress by boosting the level of glucose in the blood." However continued exposure to high levels of cortisol is detrimental to neurons. (p87)

[1463] Leknes and Tracey, "A common neurobiology for pain and pleasure," Figure 2, 317.

[1464] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469.

[1465] Leknes and Tracey, "A common neurobiology for pain and pleasure," Figure 2, 317.

cortico-amygdalic pathways) critical for deactivating conditioned fears. [1466]

- Neurotransmitters modulate the individual's emotional responses,[1467] We have seen, for example, 5-HT released into the hypothalamus and limbic structures inhibits aggression. [1468] [1469]
- Emotional inhibition makes use of inhibitory pathways in the brain. GABA is the major inhibitory transmitter in the mammalian brain further modified by the presence of steroids (denoting stress) and testosterone. [1470] [1471] GABA and GABAergic genes are seen as key mediators of learning and memory in anxiety, and in specific in the amygdala and hippocampus, regions of the brain involved in memory and anxiety. [1472]
- Consciousness of wellbeing and inner peacefulness as a consequence of release of opioids from the hypothalamus,[1473] and release of cortical (ie conscious) DA reward in response to appropriate endurance of difficulties will be further possible indicators of virtue.

Temperance consists in appropriately formed neural structures that condition the sensitive appetite to obey rationality. These are

---

[1466] Morgan et al., "Extinction of emotional learning: contribution of medial prefrontal cortex". In rats it is the mPFC that plays a significant role for fear extinction in rats; this area corresponds to the DLPFC in humans.

[1467] Depue andCollins, "Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion," 514.

[1468] Bear, *Neuroscience. Exploring the Brain,* 581.

[1469] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 730.

[1470] Siegal and Sapru, *Essential neuroscience*, 124. Note that inhibitory refers to the effect at the synapse and that therefore inhibitory pathways do not necessarily result in inhibition of actual behaviours. Sometimes the opposite result is obtained by the mechanism.

[1471] Arden and Linford, *Brain-based therapy with children and adults*. 204. Note reference to the work of LeDoux in this area. Sunderland writes that GABA naturally inhibits high levels of cortisol and calms the amygdala. "Research shows that if young mammals are left alone or in a prolonged state of distress, this can have a marked influence on how the genes for GABA unfold in the brain. This can alter the brain's sensitivity to stress, resulting in an agitated attitude to life for much of the time." Sunderland, *The Science of Parenting,* 44.

[1472] Kalueff, "Neurobiology of memory and anxiety From genes to behaviour. (Review)".

[1473] Sunderland, *The Science of Parenting,* 87. Endorphins for the relief of pain are "endogenous morphine"; oxytocin, released in the pituitary gland brings about feelings of comfort and well being and inhibits the triggering of the body's stress response system. Opioid receptors are ubiquitous in the brain.

essentially learned dispositions at the neural level regulating formation of pleasure representations, and response to these representations.

The **neural bases for the experience of sense pleasure** consist in:

- Basic sexual drives associated the hypothalamus in association with somatosensory feedback pathways trigger neurochemical and hormonal release. DA, originating in the VTN and SN, is sent via reward pathways, to the striatum, medial PFC and some twenty other locations.
- Equivalent pathways associated with sense pleasures with respect to food and drink.
- Emotional memories are laid down in the BLA, reward and procedural memories in the striatum, and associated declarative memories distributed through the cortex.

It is proposed that **the specific neural bases of temperance** are essentially to be found in certain neural dispositions. Hence the neural bases for temperance consist in the following:

- The facilitation of cortically moderated responses to basic sexual drives associated the hypothalamus, and reward representations in the medial PFC and the striatum, following pleasurable stimuli. Reinforcement of appropriate emotional memory, procedural memory and declarative memories will be take place in association with this.
- Facilitation for conscious management of lustful feelings in DLPFC and ACC, which have been shown to be activated in suppression of sexual response.[1474] The DLPFC, interacting with VLPFC and ACC, becomes active in choosing to resist feelings deemed inappropriate.[1475]

[1474] Beauregard, et al., "Neural correlates of Conscious Self-Regulation of Emotion," 1-6. Noted in Nolte, *The human brain. An introduction to its functional anatom* , 6th ed., 605.
[1475] Lee, et al., "Regulation of human behaviours," 190.

- Established pathways of habituated responses to pleasure in keeping with rational choice, in association with cognitive pathways regulating reward responses, assessing impact on others, and assessing proposed behaviours against moral learning.
- DA modulation of appropriate reward representations in the striatum exerts in turn a major modulatory effect on cortical output via the cortico-striatal connection and the via the thalamolimbic pathway. [1476] Cortico-basal-thalamic loops lead to further modulation and reinforcement of appropriate pathways.
- Consciousness of wellbeing and inner peacefulness as a consequence of release of opioids from the hypothalamus,[1477] and release of cortical (ie conscious) DA reward in response to appropriate sense pleasure, will be further possible indicators of virtue.

In **4.2.6** I asked why fear has the capacity to obliterate reason more easily than sense pleasure. The neural bases for these two responses are distinct, and it would appear possible that the central role of the amygdala, and direct interconnectivity with the hypothalamus, offer an explanation for this enhanced function.[1478] The studies of LeDoux demonstrate that fear responses are highly phylogenetically conserved; for evolutionary reasons, the sympathetic, fight or flight responses triggered by the amygdala, have an override capacity.**[1479]** Cortical processing comes second. It would seem too that pathways for the experience of sense pleasure to some extent are more cortically driven, a result of choice rather than of chance encounter in the environment requiring split second response. For this evolutionary reason too, it would seem that response to fear is more dominating and subrational.

<u>Associated systems</u>

[1476] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 158.
[1477] Sunderland, *The Science of Parenting,* 87. See also preceding Sunderland note.
[1478] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469.
[1479] For an introduction to the anatomy and physiology of the brain: Larry W. Swanson, "Basic plan of the nervous system" in Squire, Larry et al. *Fundamental Neuroscience*. 3rd ed. Burlington, MA: Elsevier, 2008. Chapter 2.

Plasticity. Systems for learning. A-O paradigms giving way to S-R paradigms. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for imitation and empathy.

3. A capacity for rational goal election is evident.

<u>Philosophical clarifications.</u>

In this section we look more closely at the neural basis for cognitive management of goal election. Cognitive management of goal election is a necessary but insufficient condition for the presence of virtue. Cognitive choices must not only be present but also disposed by prudence and justice (as discussed in **No.1** above). Vice is none other than the deliberate choice of harmful behaviours.

We have seen in **No.2** that fortitude and temperance may be developed by incentive learning. In such a paradigm will be found rational goal election, supported by reward incentives for appropriate behaviours.

In addition what can be called an **intellectual or spiritual joy** is effected by harmonious rational activity. This may be understood as the peace, comprehended rationally, and further rewarded by the body's reward systems, derived from due order in one's emotional and passionate life, and from an appreciation of the good accruing to others because of one's virtuous activity.

The **pleasure associated with virtuous action** is first of all a consequence of the reward systems and pathways. These reward systems operate at two levels: as a motivation to act, and as a further reward for virtuous action.

Neural bases

Our focus in this section is on the reward systems of the human organism, associated with goal election and motivation; our focus is on how these, in themselves, are subject to the neural facilitation of virtue. Reward systems may either be subject to cognitive direction, or (in the case of impulsive behaviour) over-ride effective cognitive direction. It is shown for example, that subcortical sensory inputs to the amygdala can drive emotional responses that precede cortical awareness, thereby circumventing executive direction. [1480]

Neural modifications associated with virtue will dispose reward systems to cognitive deliberations thereby offering the satisfaction of greater self management attuned to the integrated flourishing of the entire organism.

The **neural bases for the human reward systems** involve:

- The exciting DA driven, and the blissful endorphin driven systems. DA release is the principal mechanism of reward activation and, as we have seen, is interdependent on opioid signalling. The hormone oxytocin manufactured in hypothalamus provides specialised reward incentive, upregulating mood. A further type of reward activation involves 5-HT release into the limbic area and hypothalamus. [1481] [1482]5-HT receptors are found in nerve endings throughout brain. [1483]
- Areas of the amygdala, BG, and OFC are major reward "centres" of the brain. [1484] [1485] They are richly interconnected. Cue-reward learning and synaptic plasticity in the amygdala, more particularly,

[1480] Pare D, Quirk GJ, and LeDoux JE 2004 New vistas on amygdala networks in conditioned fear. *Journal of Neurophysiology* 92:1-9
[1481] Bear, *Neuroscience. Exploring the Brain,* 581.
[1482] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 730.
[1483] Deutch, Ariel Y, and Roth, Robert H. "Neurotransmitters" Chapter 7 in Squire, Larry et al. *Fundamental Neuroscience*. 3rd ed. Burlington, MA: Elsevier, 2008.
[1484] Schultz and Tremblay, "Involvement of primate orbitofrontal neurons in reward, uncertainty and learning," 194.
[1485] Wagner and Silber, *Physiological Psychology*, 193.

the LA appears to be a decisive mechanism underpinning goal directed behaviour. Note that goal directed behaviour does not necessarily imply consciously elected action.

- Hedonic reward has been long believed to be mediated by DA projections from the VTA of the basal forebrain.[1486] Midbrain DA systems appear to provide reward signals to the PFC strengthening specific connections for particular behaviours.[1487] [1488]
- We have seen that there are two major DA systems in the brain: one projecting from the SNpc to the caudate and the putamen in the striatum and in a minor way to the NAc;[1489] another, the mesocorticolimbic DA system originating in the VTA and innervating the NAc, the amygdala and the various parts of the cortex, particularly the PFC. [1490] This second system is regarded as central to the brain's reward circuit,[1491] [1492] and critical in facilitation of incentive motivation.[1493]
- These DA systems, triggered by cortico-limbic afferents,[1494] in response to novel reward stimuli are the principal reward signals acting on the PFC to strengthen specific connections for particular behaviours.[1495] [1496]

[1486] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"116.
[1487] Miller, E. K., and Cohen, J. D. "An integrative theory of prefrontal function" *Annual Review of Neuroscience*. 24 (2001): 167-202.
[1488] Wagner and Silber, *Physiological Psychology*, 213.
[1489] Linked to laying down of procedural memory, and possibly to higher order personality traits
[1490] McCormick, David A. "Membrane potential and action potential" Chapter 6 in Squire, Larry et al. *Fundamental Neuroscience*. 3rd ed. Burlington, MA: Elsevier, 2008. DA is diffused in cortex with 80% of the DA concentrated in the corpus striatum. DA release is the condition for synaptic plasticity in the BG synapses between corticostriatal neurons and MSNs, possibly involving reverberation in the cortico-striatal loop.
[1491] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 390.
[1492] Bear, *Neuroscience. Exploring the Brain,* 526.
[1493] Depue andCollins, "Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion," 500.
[1494] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,"747.
[1495] Miller, E. K., and Cohen, J. D. "An integrative theory of prefrontal function" *Annual Review of Neuroscience*. 24 (2001): 167-202.
[1496] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 166.

- The BG play a major role in learning owing to their plasticity, presence in the reward and emotional regulation pathways, and efferent neuronal pathways to sensory cortices allowing somatic and sensory feedback.[1497] Closed cortical (lateral PFC, OFC, and the premotor cortex) - striatal loops appear to enable PFC to link complex anticipated behaviours with rewards, relying on rapid plasticities of the striatum.[1498]
- The NAc is topographically linked to basolateral amygdala and is a major terminal area for DA release in the reward pathways. The role of the striatum is essential in reward and motivation, organising somatosensory representations in a topographic manner. It draws cortical inputs from many areas of cerebral cortex.[1499]

T**he neural bases facilitating virtuous activity in association with the human reward systems** will facilitate activity in the following structures and pathways.

- **Plasticity in the OFC** enables cortical processing of reward representations. The OFC is the key area for volitional goal election. Reward representations in the OFC are associated with goal-directed, conscious choices of action.[1500] The OFC permits association information to access representational memory promoting "voluntary, cognitive, and goal directed (not stimulus driven) behaviour and facilitating new learning."[1501] It is activated by tasks where processing of rewarding or emotional information is required,[1502] [1503] [1504]and where information about rewards and punishments is integrated with their predictors to select goals for

[1497] Squire et al., *Fundamental Neuroscience*. 3rd ed.
[1498] Koch, "Consciousness," 1220.
[1499] Manns and Hichenbaum, "Learning and memory: brain systems," 1165.
[1500] O'Doherty and Dolan "The role of the human orbitofrontal cortex," 276.
[1501] Roesch and Schoenbaum, "OFC as gateway," 229.
[1502] Wagner and Silber, *Physiological Psychology*, 193.
[1503] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[1504] Roberts and Parkinson, "Functions of primate orbitalfrontal cortex, 250.

action. [1505] [1506] Medial OFC appears implicated in reward and the lateral OFC in punishment. [1507]

- The OFC through its rich reciprocal connections to the limbic system and to the striatum plays a major integrating role. [1508] The OFC (particularly area MOC13) integrates both stimuli and responses with complex associations of reinforcement.[1509] MOC 13 is believed to integrate appetitive and aversive factors that are environmentally dependent."[1510]
- **Plasticity in the DA pathways and uptake in the PFC** facilitates cortical processing of reward representations. A large proportion of PFC neurons assisted by DA release, encode rewards linking behaviours to goal directed consequences. [1511] It is postulated that DA neurons in the midbrain respond when a reward seems imminent. [1512]
- **Plasticity in areas of the BG** facilitates conscious reward processing. [1513] Like the OFC, the striatum is activated in association with movement for an expected reward. [1514] [1515] The BG contain inhibitory GABAergic neurons, [1516] requiring strong and coherent excitatory cortical inputs from almost all cortical areas to become

1505 Roesch and Schoenbaum, “OFC as gateway,” 201.
1506 O'Doherty and Dolan “The role of the human orbitofrontal cortex,”266.
1507 O'Doherty and Dolan “The role of the human orbitofrontal cortex,”269.
1508 Price, “Connections of the orbitofrontal cortex,”39 and 52.
1509 Depue andCollins, “Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion,” 501.
1510 Depue andCollins, “Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion,” 491-517.
1511 Miller and Wallis, “The prefrontal cortex and executive brain functions,” 1217.
1512 Miller and Wallis, “The prefrontal cortex and executive brain functions,” 1217.
1513 Yin and Knowlton, “The role of the basal ganglia in habit formation,” 465. Animal studies have offered much light about the role of the BG in reward systems. Lesions of the BG affected the instrumentality of actions so that tested animals have been no longer able act for reward to avert adverse outcome.
1514 Barbas and Zikopoulos, “Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex,” 64.
1515 Wickens, “Synaptic plasticity in the basal ganglia,” 120.
1516 95% of neurons in striatum are GABAergic MSNs according to Da Cunha, “Learning processing in the basal ganglia: a mosaic of broken mirrors,” 159.

active. [1517] Over time A-O behaviours activating the ventral striatum give way to S-R behaviours.[1518] [1519] As has been discussed, S-R behaviours can also be volitional.[1520]

- **Plasticity in connectivity between the BG and the OFC is crucial** to the body's reward system, and hence to systems for goal election. Cells of the striatum become active in anticipation of reward, mirroring reward coding in the OFC.[1521] [1522] DA is released into the striatum leading to further limbic modification of neural transmission. DA modulation in the BG in turn brings about a decisive modulatory effect back on the cortex via the cortical-BG-cortical pathways. Striatal DA depletion is shown to lead to severe disruption of learned movement sequences.[1523] This further supports the view that there is an interconnection, at the level of the BG, between reward pathways and learned sequential behaviours. The DA system acts as a learning signal for behavioural reinforcement but also may well be involved in attention and motivation before all important events, both positive and negative. Its action is facilitated by neural loops. [1524]

[1517] Yin and Knowlton, "The role of the basal ganglia in habit formation, " 464.
[1518] Wickens, "Synaptic plasticity in the basal ganglia," 125.
[1519] Graybiel, "Habits, Rituals, and the Evaluative Brain," 364. Ventrally based limbic reward becomes less significant; the dorsal striatum characterised by habit formation and addictions becomes associated with management pathways of actions.
[1520] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 349. Activities carried out with the ease of habit, either of a purely motor variety such as a tennis forehand, or with an ethical dimension such as habitual courteous greetings to strangers, may of course be fully intended and free, despite their intrinsic motivation.
[1521] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 133.
[1522] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 133. There is a close association between the striatum and the OFC by observation of differences between the sustained activity in striatal cells in comparison with the hundreds of millisecond activations of DA cells of the midbrain. The striatal-cortical reciprocal pathways connect reward centres in the BG and PFC and play a major role in goal election. DA, a principal mediator of plasticity, is decisive in development of habits of goal directed action.
[1523] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 135.
[1524] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology," 747. In relation to this point, Pollak cites Schultz (1998), and Pruessner et al. (2004).

- Consciousness of wellbeing and inner peacefulness as a consequence of release of opioids from the hypothalamus,[1525] and release of cortical (ie conscious) DA reward will be further possible indicators of virtue.

Associated systems

Plasticity. Systems for learning. Attentional systems. Memory systems. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction.

4. "Virtues change us." The acquisition of virtue creates a state of character, a way of being that tends to be permanent..

Philosophical clarifications.

At a secondary level, it is universally recognised that **the habits we develop change us as people**: good habits, virtues, change us for the better; bad habits, vices, for worse. Habit formation may be seen to consist in, at the neural level, of plasticities that facilitate certain ways of acting and thinking.

Here I look at character, understood as a stable way of being that is associated with and denoted by qualities that have been acquired or developed. My focus is on habits that are acquired, the stable behaviours that define character.

Neural bases

- Explanation for the quasi permanent nature of character changes in the virtuous state is found at its foundation in the brain's capacity to incorporate **use-induced structural plasticities** which elicit

[1525] Sunderland, *The Science of Parenting,* 87.

permanent structural changes at the neural level, predisposing thereby to changed behaviours.[1526]

- **Cortical and BG plasticities** appear central to the stable, characteristic ways of acting and thinking that constitute personality and that are evident in emotional management systems, reward evaluation, systems for cognition and deliberation, and in the facility to act.
- The cumulative effect of genetically transcripted changes on personality is profound.[1527] In fact structural plasticities may have more permanent and lasting forms. For example, hippocampal plasticity is supplanted by cortical plasticity over time that is mediated by the striatum. [1528] [1529]
- There is a compelling case supporting the view that the BG are a key component in the development of **stable voluntary habits**.[1530] [1531] In conjunction with the PFC, the BG are now increasingly regarded as a key brain area for reward and emotion processing, cognition and voluntary goal election, and for behaviour changing modulatory input to the cortex. BG are now seen as a centre, not only for subconscious facilitation of habits, but also mediating deliberate attention, and limbic modulation of cognition and action.[1532] (see **2.6**)
- **The BG are now recognised as an area critical for learning, cognition and behavioural control**. [1533] [1534] Furthermore, the role of the BG,

---

[1526] Butz, et al., "Activity dependent structural plasticity," 287-305. As we have seen, plasticity is now known to be virtually ubiquitous in the human brain.
[1527] Malenka and Bear, "LTP and LTD: an embarrassment of riches," 5-12. This is despite the fact that LTD is the mechanism whereby LTP can be reversed in the neocortex.
[1528] Pasupathy and Miller, "Different time courses of learning related activity in the prefrontal cortex and striatum," 873-876.
[1529] For distinct forms of memory systems and the story of their discovery, the principal source of material that follows: Manns and Hichenbaum, "Learning and memory: brain systems," 488.
[1530] Manns and Hichenbaum, "Learning and memory: brain systems," 1165. The role of the BG in modifying cortical motor representations is well documented.
[1531] Floyer-Lea and Matthews, "Distinguishable Brain Activation Networks for Short- and Long-Term Motor Skill Learning," 517.
[1532] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 327.
[1533] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 327.

and of the cortico-striatal pathways, in conscious goal election is increasingly well understood. [1535]

- It has become clear in recent years that the PFC-basal pathways sustain voluntary movement, whereas the motor cortex-basal ganglionic modules underlie more automatic movements.[1536] The role of the BG in instructing the cortex in S-R situations is well understood.[1537] Now it is becoming clear that S-R habituation need not necessarily be subconscious nor, per se, non-volitional. BG pathways appear integral to the pursuit of complex, purposeful, behaviour patterns,[1538] It may be argued that individual goal directed behaviours on repetition become automated and less reward dependent, but nevertheless they remain purposeful, thereby fulfilling requirements for virtuous action.[1539]

Associated systems

Plasticity. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy.

5. The virtuous state is in keeping with our human nature.

Philosophical clarifications.

[1534] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 349. "It is well known that the cortico-striatal network controls functionally heterogeneous decision making processes, including goal directed actions, susceptible to reward feedback, and stimulus linked actions, largely automatic or habitual."

[1535] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 349.

[1536] Wise and Shadmehr, "Motor control," 153.

[1537] See for example: Yin and Knowlton, "The role of the basal ganglia in habit formation"; Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors".

[1538] Beretta, Nicola et al. "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions" in *Progress in Neurobiology* 84 (2008): 345-346.

[1539] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 349.

Virtue assists human beings to flourish by disposing us to rational action.[1540] The virtuous state, in keeping with our human nature, facilitates the fulfilment of our needs as human beings, understood by some as the goods of human flourishing (**6.2**), and promotes the complete realisation of personal potential (ie both at the biological level and at the level of the transcendental fulfilment by truth and love). Virtue offers us the capacity to be open both to the truth of experience and to transcendent truth, to elect reasonable goals for pursuit without interior hindrance, and to respond with love in interpersonal relationships.

<u>Neural bases</u>

- Virtue fosters the complete realisation of personal potential at the biological level. The development of virtue is manifestly a state of integration of brain systems, and a realisation of the capacity to learn most effectively from experience. The integration of the brain systems harnessed for the possession and expression of virtue is suggested by **Table 5.1** and is central to this proposal for the neural bases of virtue. The capacity to learn from experience is a consequence of mechanisms of plasticity in conjunction with the somatosensory system, and systems for imitative learning.

- Biological flourishing of the organism may be understood as the maturity of neural development. It implies the highest degree of development and specialization of individual neural components, mechanisms and systems, together with the development of interconnectivities (of all cortical, sub cortical, limbic, brain stem regions and PNS, together with the full development of

[1540] *NE*, 1106a15. "That which makes its possessor good and his work good likewise". The good may be understood that which is most fulfilling according to one's nature; rationality is ordered to choice of what is good.

neuromodulatory pathways). Thus is enabled the most complete integration and contribution of all elements at the service of emotional direction and enrichment, and which, in turn, is at the service of efficient, rationally directed action that takes the rights of others into full account.

- Virtue offers the complete realisation of personal potential at the transcendental level by fostering an integration of emotional and rational life. Through a disposition to rational action, one is empowered to know and to love in an habitual way.
- See **No. 1** above for an overview of the neural manifestations of rational action.
- Note also that the development of neuronal maturity in the support of rational operations is a gradual process. Neonates manifest little activity in the cerebral cortex and this accords with the Aristotelian view that infants and children, because they do not possess full rationality, are incapable of perfect virtue.[1541]
- See also **6.2.1**.

Associated systems

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

6. In the exercise of virtue intrinsic motivation takes priority over extrinsic motivation. Virtue is motivated by that which is worthy of man's nature.

Neural bases

[1541] Byrne, "Learning and memory: basic mechanisms," 1142.

Intrinsic motivation leading to virtuous activity is present in several ways:

- As has been discussed, once a disposition is acquired, A-O paradigms give way to S-R paradigms (possibly operating below the threshold of consciousness), leading to intrinsic reward associated with μ-opioid and phasic DA signalling in the BG, NAc, pallidum and PFC.[1542] (It is argued that S-R paradigms are compatible with rational action.[1543])
- Actions disposed by virtue will be intrinsically rewarding, a trigger in themselves for the contentment mediated by reward systems.
- By the exercise of the virtue of justice (see **No. 1** above) which is always present in virtuous action, actions are disposed to take into account the good of others. This may be understood as a form of intrinsic motivation because there is no conscious hedonic benefit sought by the protagonist in interpersonal relationships. Persons may never be instrumentalised for personal gain or reward.

<u>Associated systems</u>

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for imitation and empathy.

7. Virtue facilitates effective action.

<u>Philosophical clarifications.</u>

While not all virtuous action need manifest in external activity, external activity that does result is rationally directed, taking the needs of others into account, addressing one's own needs, having both sound intention and prudent selection of means.

[1542] Leknes and Tracey, "A common neurobiology for pain and pleasure," 314-320.

[1543] Yin and Knowlton, "The role of the basal ganglia in habit formation," 465. The speed of development however is striking. In the first four years of life, cerebral neuronal metabolic activity increases to twice adult levels, thereafter declining to adult levels by age 15.

- See **No. 1** for actions originating in the intellectual appetite.
- See **No. 2** above for actions originating in the sensitive appetite.
- The virtue of prudence will underpin selection of ends and means. (See **5.3.3.1.n.**)
- The virtue of justice takes account of the impact of actions on others. (See **5.3.3.1.o.**)

Effective direction of habitual external behaviours is effected by complex pathways involving primarily the PFC, the motor cortices and the BG.

<u>Neural bases.</u>

We have seen in **No.1** above, the role of executive command in the virtue of prudence. This was described as a task of the lateral cortex enlisting motor cortices, subserved by systems for action selection or goal election, and motor pathways utilizing the BG-thalamo-cortical loop, the BG, and the cerebellum, complemented by the capacity to carry through executive commands to appropriate execution. [1544] [1545] [1546] [1547] [1548] Here I focus on the facilitation specifically of these tasks. This is a further characteristic that is necessary, but in isolation insufficient, for the presence of virtue.

The facilitation of execution of intended action requires integration of the various sectors of the frontal lobe (most specifically the lateral PFC, an area oriented to action[1549], and the motor cortices), enlistment of the

---

[1544] Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 62.

[1545] Kaas and Stepniewska, "Motor cortex," 159.

[1546] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 73.

[1547] Wickens, (2009) "Synaptic plasticity in the basal ganglia,"119.

[1548] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 473.

[1549] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 73.

BG and cerebellum (for procedural facilitation), and directed neural activity in subsequent pathways via brain stem to execution in the PNS .

Plasticity in these motor pathways is well documented. ACh is the principal excitatory mediating agent at the neuromuscular synapse, opening ion channels and triggering the phenomenon of muscular memory. Epi also plays a role.[1550] AMPA trafficking is the mechanism appearing to underlie the formation of neuronal pathways, and behaviour modification itself.[1551] Activity at the motor synapse can be self reinforcing with synapse pruning serving to optimise the connection,[1552] [1553] causing the synapse to be responsive to the specific environment of the individual. [1554]

The neural facilitation for effective action will consist in the following aspects:

- The **PFC** itself is richly endowed with connections for conscious motor management to motor cortices, the primary motor cortex, the premotor and supplementary motor areas and Broca's area. In addition to "anatomical loops" between the PFC and the BG , there is rich interconnectivity between the functional sectors of the frontal lobe, the cerebellum, the BG, and lower brain structures enabling execution of cortical commands. The medial PFC "provides goal directed motor plans selected within the NAc on the basis of contextual and emotional associations from both the hippocampus and the amygdala".[1555]

[1550] Bear, *Neuroscience. Exploring the Brain,* 707.
[1551] Kessels and Malinow, "Synaptic AMPA Receptor Plasticity and Behaviour," 340.
[1552] Tapia, Juan C and Lichtman, Jeff W. "Synapse Elimination" Chapter 20 in Squire, Larry et al. *Fundamental Neuroscience*. 3rd ed. Burlington, MA: Elsevier, 2008. p470
[1553] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 610.
[1554] Tapia, Juan C and Lichtman, Jeff W. "Synapse Elimination" Chapter 20 in Squire, Larry et al. *Fundamental Neuroscience*. 3rd ed. Burlington, MA: Elsevier, 2008. p475
[1555] Quoted in Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,"738.

- Multiple **memory** systems are associated with execution of goal directed motor plans.[1556] The **premotor cortex** holds motor activity in memory. [1557] Motor memories and learning are triggered in the premotor cortex by ACh released from the basal forebrain. [1558] The **dorsal striatum** lays down memory for the long-term storage of well-learned movement sequences and motor habits. [1559] The **cerebellum** holds movement programming.[1560] Hippocampal plasticity and memory are evident in the development phase of habits in the striatum, and in the formulation of goal directed motor plans.[1561].
- Long term **storage of explicit motor knowledge is in the PFC and associated parts of the BG**, while storage of intermediate term explicit motor knowledge is in the MTL. [1562]
- The **BG** are most involved not only in cortical management of emotion, and habit formation, but also in motor management. The dorsal striatum lays down memory for motor habits and instructs the PFC in S-R situations.[1563] The putamen receives input from motor and somatosensory cortical areas. [1564] Processing of motor commands takes place here and in the GP.[1565] BG outputs directly affect activity of motor areas in the cortex,[1566] operating "mainly to modify cortical motor representations rather than control behaviour through direct motor inputs".[1567] The GP and the SN of the BG also play a major role

[1556] Manns and Hichenbaum, "Learning and memory: brain systems," 1174.
[1557] Marieb and Hoehn, *Human anatomy and physiology*, 8th ed., 437.
[1558] Siegal and Sapru, *Essential neuroscience*, 124.
[1559] Floyer-Lea and Matthews, "Distinguishable Brain Activation Networks for Short- and Long-Term Motor Skill Learning," 517.
[1560] Marieb and Hoehn, *Human anatomy and physiology*, 8th ed., 458-459.
[1561] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology," 747.
[1562] Wise and Shadmehr, "Motor control," 137-157.
[1563] Squire et al., *Fundamental Neuroscience*. 3rd ed.
[1564] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469.
[1565] Martini, *Fundamentals of Anatomy and Physiology*, 6th ed., 486.
[1566] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469.
[1567] Manns and Hichenbaum, "Learning and memory: brain systems," 1165.

in motor control, [1568] selecting patterns of cortical activity, and ultimately selecting and reinforcing chosen motor programs.[1569]

- The **BG-thalamo-cortical loop** processes subsequent motor commands. Motor learning involves a “functional interplay... between cortico-striatal, cortico-cerebellar, and limbic systems.” [1570]
- The **cerebellum** assists in movement and motor habits and is now recognised to have a likely role in formation of cognitive habits.[1571] [1572] [1573] Furthermore, there is now evidence that the cerebellum and the BG are far more interconnected ,via a cerebello-thalamo-striatal pathway, and are therefore interactive, than has been long thought.[1574]
- **Axonal myelination** facilitates speed of sensory and motor messaging through much of the PNS and CNS.
- See also **6.2.1.2.**

<u>Associated systems.</u>

Plasticity. Systems for learning. Reward and motivational systems. Systems for habit formation. Memory systems. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands.

8. Virtue brings about ease of action.

<u>Philosophical clarifications.</u>

[1568] Kaas and Stepniewska, “Motor cortex,” 159.
[1569] Petersen, *Human physiology,* 205.
[1570] Doyon, et al., “Contributions of the basal ganglia and functionally related brain structures to motor learning,” 62.
[1571] James W. Kalat, *Biological Psychology*, 7th ed. (Belmont CA: Wadsworth, 2001), 238.
[1572] Ito, M. “Cerebellar long term depression: Characterisation, signal transduction, and functional roles” 1143-1195. There is strong evidence that LTD is the mechanism by which learning is encoded in cerebellum.
[1573] Patrick R. Hof, et al., “Cellular components of nervous tissue,” in Larry Squire, et al., *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), Chapter 3. NE is distributed to the cerebellum and other areas from noradrenergic nucleus, the locus coeruleus, within the pons.
[1574] E. Hoshi, et al., “The cerebellum communicates with the basal ganglia,” *Nature Neuroscience* 8, (2005): 1491–93.

The easy repeatability of behaviours associated with virtue is immediately seen, for example in habitual courtesies, habits of getting up when the alarm goes off, habits of reacting to difficulties with patience, etc.

Neural bases.

Here we focus on the development of habit, automaticity, in good behaviours. Ease of action is primarily a result of a number of neuronal mechanisms and loci of facilitation:

- Preferential pathways are established by mechanisms of **plasticity**: in the pathways of the CNS and PNS, in motor, emotional and deliberative areas and pathways, in the various seats of memory, etc.
- Mechanisms of habit learning, of **automatisation,** offer an explanation for the phenomenon of behaviours that appear to remain robust in the absence of immediate rewards. A-O paradigms give way to S-R paradigms with lower cortical demand: action becomes more efficient as action moves from high levels of cortical activation to simpler patterns of activation that are associated with automaticity.
- The **BG** mediate subconscious facilitation of habits, cognition and action.[1575] Hence they are now recognised as areas contributing to conscious control of established behaviours. The putamen, an area of the sensorimotor striatum, [1576] involved in learning and movement initiation and neuromodulated by DA from the SNpc, is also enriched by reward pathways.[1577]
- See **6.2.1.2**.

[1575] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 327.
[1576] Yin and Knowlton, "The role of the basal ganglia in habit formation," 468.
[1577] The BG become increasingly, or at least more efficiently, involved in the process of learning as actions become more automatic. Complex striatal habit formation involves cortical management via the striatal-cortical pathway. The striatum is functionally linked to SN which is richly interconnected to midbrain, STN, and VTA. In the dorsal striatum, which as we have seen is most active once actions are automatized, the caudate nucleus receives inputs from association cortices (and appears more implicated in A-O learning); the putamen has primarily sensorimotor connections (associated more with S-R learning).

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems for habit formation. Systems for effective execution of motor commands.

9. **Virtue facilitates the flourishing of the person. Virtue brings about a state of excellence: an excellence of the person, inclusive necessarily of both neurobiological flourishing and the exercise of rationality. It is a state whereby reason and rationality are empowered to manage activity. Capacity for rationality that is reflective and emotionally enriched and able to be carried through into noble humane behaviours.**

Philosophical clarifications.

- Flourishing, those habits "by which a person acts well",[1578] is in effect the "reward of virtue".[1579] It denotes a state in which autonomy and agency, mastery over one's operations and activities, are enhanced. Autonomy is a consequence of enhanced rationality and an enhanced capacity to bring one's plans to fruition. See also **No.5.**
- See also **6.2.1.2** where I argue that flourishing may be understood on at least three levels: affective, functional and teleological (directly facilitating of the final end of the person).

Neural bases.

- **Nos. 1 and 2** above, focused on the capacity for the person to act in a truly rational and emotionally enriched way are the heart of *eudaimonia*. The high degree of integration of systems required, in support of emotional regulation and cognitive goal selection directed

[1578] *ST*, Ia-IIae, Q.55, Art.3.
[1579] *NE*, 1099b16.

towards moral behaviour, is well established and increasingly acknowleged.[1580]

- **Nos. 7 and 8** above, focused on ease and efficiency of action, enhancing further to the autonomy of the person, contribute further to his functional flourishing. Functional flourishing requires structural maturity at the cellular and systemic levels, as well as functional integration. Essentially these processes are driven by developmental gene transcription triggered by internal processes and appropriate sense inputs. As the person matures after infancy, the subject's own goal choices increasingly direct experiential inputs that consolidate pathways facilitating future behaviours. Development becomes increasingly self regulated, or at least offers the potential for this to be so.[1581]
- Learning pathways need to be both efficient and cognitively directed: a result of plasticity and well developed mechanisms supported by habitual management of attentional systems.

Associated systems.

Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

[1580] A representative sample of supporting papers: Casebeer, "Moral cognition and its neural constituents," 841-849**;** Grossberg and Versace, "Spikes, synchrony, and attentive learning by laminar thalamocortical circuits," 278-312; Greene and Haidt, "How (and where) does moral judgment work?" 517–523; Somerville and Casey, "Developmental neurobiology of cognitive control and motivational systems," 236-241. Also see Stevens, et al., "Age-related cognitive gains are mediated by the effects of white matter development on brain network integration," 738–746; Luna, et al., "What has fMRI told us about the Development of Cognitive Control through Adolescence?" 101.

[1581] The work of Wolf Singer is of relevance. His work focuses on how the brain is modified by experience, and on the synaptic modifications underpinning the neurobiological basis of learning and memory. At the Pontifical Academy of the Sciences gathering of experts in Human Neuroplasticity and Education in October 2010, he spoke of the "massive rearrangement of functional networks" in adolescence, and of the "second chance" to reconstitute one's neural structures in a way more conducive to personal fulfilment. Note reference to Singer in **Table 1.1. A hylomorphic critique of 20th century currents in philosophy of mind.**

B. CHARACTERISTICS OF VIRTUE IN ITS ACQUISITION

Essential features pertaining to virtue in its acquisition.

10. The virtuous state results from habituation and education.

Philosophical clarifications.

Habituation in the Aristotelian sense consists of training from one's earliest years, primarily in the behaviours appropriate to fortitude and temperance. Education, in Aristotelian sense, consists both in the learning of appropriate information (for example, of right and wrong in accord with nature) and the acquisition of appropriate experiences. In both, guided experience, imitation of good example, aspiration to what is good, true, and beautiful, and appropriate correction of erring behaviours are essential. Education also requires explicit ethical and behavioural instruction, carried out in a practical and contextual manner.

Neural bases.

- The neural bases for mechanisms of **habituation** are a result primarily of the plasticities, primarily use-induced, present in mechanisms of learning associated with the virtues of fortitude and temperance (see **No. 2** above). These are complemented by the explicit development of habits and automaticity in specific behaviours (see **No. 8** above.).
- The neural bases for mechanisms of **education** are a result primarily of the plasticities, primarily use-induced, present in mechanisms of learning associated with the virtues of prudence and justice (see **No. 1** above.) These will be complemented by mechanisms of imitation inspired by exposure to what is good, true and beautiful (see **No. 12** below), and explicit ethical instruction (see **No. 16** below).

Mechanisms of attention need to be engaged in order to facilitate learning (see **No. 13** below).

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

11. Repetition, understood as critical practice, plays an essential role in the acquisition of virtue: repetition in appetitive responses, in responses manifesting noble sentiment and attentiveness to others, and in reasoning, deliberation and sound decision making.

Neural bases.

- Use-induced plasticities and pathways operate across most brain areas and pathways, established by Hebbian laws, underpin the synaptic strengthening that results from repetition of neural firing. (See **2.2** and **Tables 2.3** and **2.15**)
- Other forms of learning also contribute. The possibility of self induced and parentally guided conditioning has been discussed.
- DA reinforcement of goal directed activity underpins a broad spectrum voluntary plastic reinforcement of behaviours.

Associated systems.

Plasticity. Systems for learning. Attentional systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

12. Education specifically in wisdom and beauty is necessary in the formation of virtue.

Neural bases.

All experience leaves neural changes. Education in wisdom and beauty is acquired, in the Aristotelian view, by exposure to appropriately true and beautiful experience. Experiences where there is effortful attention, positive emotional association, repetition, or novelty are shown to have greater potential to effect neural change. Mechanisms of cognitive learning and memory, as well as use-induced plasticities, will be implicated.

Neural facilitation of these pathways of learning consists in plastic modification of neural structures associated with:

- Attentional control. (See **No. 13** below, and **Tables 2.9** and **4.2** Attentional Systems.)
- Mechanisms for learning. (See **No. 16** below, and **Tables 2.4** and **4.2** Systems for learning.)
- Pathways for empathy. (See **No. 15** below, and **Tables 2.6** and **4.2** Systems for imitation and empathy.) This will be most relevant in ease of adoption of behavioural example of parents, siblings, mentors and friends.
- Pathways responsive to positive emotional context and affection. (See **No. 17** below, and **Tables 2.2** and **4.2** Sensitive periods of development.)

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for imitation and empathy.

13. Effortful attention plays a significant role.

Philosophical clarifications.

Human beings have some capacity to reflect on the direction and level of attention operating in their sensory systems (most significantly the visual system). They have some capacity to redirect or focus that attention if they so choose. If the activity pursued is virtuous, the choice to focus one's attention must also be virtuous as it is integral and necessary for the intended act. The relationship between willpower (which, if rational and effective, will with due regard to the unity of the virtues involve the spectrum of established virtues) and attention has been noted.

Neural bases.

Effortful attention appears to be a prerequisite for much of the learning associated with the development of virtue. This is so for at least two major reasons:

- The attentional system is a key to self-directed brain plasticity, and as such is a key to free and volitional behaviour.
- Effortful attention would appear to be present in all learning from sensory input (consider for example a small child learning by observing). The nucleus basalis, and the attention system in which it plays a critical part, have the capacity to guide plastic development.[1582]

In the learning stages of habit development there are much higher levels of attention evident in the cortex, than when the behaviour has

[1582] Doidge, *The brain that changes itself*, 84-88.

been incorporated as habit, at which time procedural mechanisms dominate.

Neural facilitation in attentional systems will consist in the following:

- Plasticity in the fronto-parietal attentional control system is the core mechanism for attention. [1583] [1584]
- Learning related and use-dependent plasticities in the nucleus basalis, the parietal lobes, the ACC, and the BG. Each plays a key role in attentional learning. In these cases the actions will be constituted at the neural level by an integrated constellation of neural activities, similar to those outlined in **Nos. 1 and 2** above.
- The BG play an integral role in attention regulation, [1585] [1586] [1587] [1588] and in attentional loops.[1589]
- ACC involvement in attentional systems, appears necessary for learning, and a prerequisite for goal election and executive command. [1590]
- Note that **No. 13** refers to the attention required for learning to take place.

<u>Associated systems.</u>

Plasticity. Systems for learning. Attentional systems.

C. CHARACTERISTICS OF VIRTUE IN ITS ACQUISITION

Features that may not necessarily be present in every case.

[1583] Froemke, et al., "A synaptic memory trace for cortical receptive field plasticity," 425-429.
[1584] Doidge, *The brain that changes itself*, 84-88.
[1585] Hole Jnr., *Human Anatomy and Physiology*. 2nd ed.
[1586] Markowitsch, et al.,"Brain circuits for the retrieval of sad and happy autobiographic episodes," 643-665.
[1587] Doidge, *The brain that changes itself*, 84-88.
[1588] Kaas and Stepniewska, "Motor cortex," 167.
[1589] Doidge, *The brain that changes itself*, 84-88.
[1590] Markowitsch, et al.,"Brain circuits for the retrieval of sad and happy autobiographic episodes," 643-665.

14. Advantage must be taken of the early years both for training and provision of appropriate example.

Philosophical clarifications.

Considerations under this heading will account for the effectiveness of early experience noting Aristotle's dictum: "We like best what we first experience," and his imperative to form habits while children are very young. [1591]

Neural bases.

Mechanisms for enhanced learning in early years take advantage of periods of greater sensitivity, constituted at the neural level by enhanced developmental and activity induced plasticities. Learning in critical periods is comparatively effortless because of activity in the nucleus basalis.[1592]

The relationship between sensitive periods and cortical development is now shown.[1593] [1594] [1595] (See also **No.17.**)

- Attentive mothering leads to gene transcripted cellular changes in the hippocampus reducing basal levels of glucocorticoids, abolishing thereby anxiety and fearfulness, and facilitating learning.[1596]
- Emotional arousal, for example in the positive affect produced by sound mothering, appears to promote synaptic plasticity. This

[1591] Aristotle, 1103b.
[1592] Doidge, *The brain that changes itself*, 84-88.
[1593] In the case of imprinting, neurons in intermediate and *medial mesopalium* (IMM) become responsive and selective for the stimulus; there are local increases in NMDA receptors, an increased size in certain synapses, and a transitory surge in inhibitory activity. While imprinting is not directly a mechanism of virtue development, in a sense it may be regarded as a prerequisite mechanism laying necessary foundations for affection facilitated plasticity, etc. Systems associated with responsiveness to affection are directly implicated in sensitive periods
[1594] Coon, *Essentials of psychology*, 7th ed, 115.
[1595] Laura E. Berk, *Development through the lifespan*, 4th ed. (Boston: Allyn and Bacon, 2007), 126.
[1596] Core content here derived from Knudson, "Early experience and sensitive periods," 525.

promotes learning by various mechanisms including release of NE.[1597]

- The end of sensitive period is triggered sensory input and possibly by myelination.

A wide range of mechanisms are directly involved in the plasticities of sensitive periods and developmental periods. Some of the more significant include:

- As with other occasions when plasticity is at work, NMDA receptors triggering gene transcription associated with LTP and LTD are integral to the mechanisms of the sensitive periods and developmental learning.
- Attentional mechanisms operate in conjunction with the great range of mechanisms of plasticity are associated with sensitive periods of development. Hence attentional learning plays a significant role here also. (See also **No.13**)
- Guidance mechanisms are particularly active during this time: astrocyte, and associated molecular guidance cues of migrating neurons and production of growth (trophic) factors.[1598]
- The amygdala is particularly active in mediating early attachment relationships, and reaction to stress and nonconscious emotional memories.[1599]
- Hypothalamic oxytocin is also implicated; the oxytocin bonding pathways are active in periods of attentive mothering.
- DA plays a key role in cortical information processing around puberty. [1600]

[1597] Kessels and Malinow, "Synaptic AMPA Receptor Plasticity and Behaviour," 344.
[1598] Stevens, "Neuron-astrocyte signalling in the development and plasticity of neural circuits," 278-288. Neurotrophins such as BDNF can also play an essential role in anatomical remodelling.
[1599] Arden and Linford, *Brain-based therapy with children and adults*, 3, 36.
[1600] Rapp and Bachevalier, "Cognitive development and aging," Chapter 45.

- Up to the age of 20, there is a gradual decline in synaptic density, a refinement and clarification of pathways; cortical myelination appears to continue to the fourth decade of life.[1601] [1602]
- It appears that changes in dendritic architecture, and abnormalities in the myelination of axons are at the basis of aging in the prefrontal cortex, rather than neuron death and a simple decline in PFC synapses.[1603]

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Systems for imitation and empathy. Sensitive periods of development.

15. Imitation of example is a key means for acquisition of behaviours.

Neural bases.

- Imitative learning is effective because plastic changes in neuronal structures are triggered, allowing the adoption of new behaviours. Mechanisms for learning behaviours, for learning moral behaviours and attitudes, and for learning empathy, through imitation consist in the activation of mirror neurons present in areas of the cortex, most particularly in the left frontal operculum area (Broca's area), the right anterior parietal cortex,[1604] Imitative mechanisms involve activity in the fronto-parietal and the superior temporal cortex, the amygdala, and insula.[1605]
- An important aspect of imitation is the capacity to empathise, to read the feelings of others. There is widespread association of mirror

---

[1601] Rapp and Bachevalier, "Cognitive development and aging," Chapter 45.
[1602] Principal source for this section: Knudson, "Early experience and sensitive periods," 525.
[1603] A. Peters, et al., "Are neurons lost from the primate cerebral cortex during normal aging?" in *Cerebral Cortex* 8, (1998): 295-300.
[1604] Iacoboni, et al. "Cortical Mechanisms of Human Imitation," 2526-2528.
[1605] Carr, et al.,"Neural mechanisms of empathy in humans: a relay from neural systems for imitation to limbic areas," 5497-5502.

neurons with the development of empathy. In addition, the **OFC** is regarded as having a major role in processing the "interpersonal signals necessary for the initiation of social interactions between individuals". The OFC operates in a limbic circuit comprising OFC,[1606] [1607] AC gyrus, amygdala and temporal pole. It would appear too that right orbitofrontal and right anterior insula cortices are components of a pathway that integrating bodily responses with attentional and emotional states. [1608]

- **VMPFC and OFC** are needed for associating incoming information with existing response contingencies, linking information to motivational importance, and for working memory... plasticity in these areas is necessary for object reward association memory, and contextual fear conditioning. The medial PFC, especially the ACC, has abundant links to limbic system via the hippocampus, the shell region of the NAc and the amygdala. There is a likely contribution of this pathway to DA and 5-HT modulation of cortical socioemotional areas.[1609]
- The **PFC** and the complex integration of brain areas, including lateral and medial PFC, are associated with deliberation about emotional content is also involved. Effective emotional modulation of deliberation is essential for sound reasoning particularly in areas requiring empathy with others, understanding of others' viewpoints etc.[1610]
- The **BG** are known to play a role in anticipating movement.[1611] [1612]

[1606] Nitschke et al., "Orbitofrontal cortex tracks positive mood in mothers' viewing pictures of their newborn infants," 583-592.

[1607] Arden and Linford, *Brain-based therapy with children and adults*, 103.

[1608] Schore, "Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health," 7-66.

[1609] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology," 747. In primate studies, the amygdala has been shown to project directly to medial thalamic nucleus and thence to VMPFC, facilitating involvement in processing social information requiring plasticity dependent learning and memory.

[1610] This is a very strong take home message from Nussbaum, *Upheavals of Thought.*

[1611] Tortora and Derrickson, *Principles of Anatomy and Physiology*, 11th ed., 493-494.

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

16. Explicit teaching and guidance as to right and wrong, are needed.

Philosophical clarifications.

Guidance as to right and wrong will include, when appropriate, appropriate correction to assist in reforming behaviour.[1613]

Neural bases.

Neural facilitation in pathways of cognitive learning consists in plastic modification of neural structures associated with:

- **Attentional control**. (See **No. 13** above, and **Table 2.9** Attentional Systems, and **Table 5.2**.)
- **Imitation** of example is a powerful means of inculcating ethical values. (See **No. 15** above.)
- **Correction** communicating affection and empathy is shown to be more effective in bringing about neural restructuring than methods motivated by fear. A moderate degree of stress promotes neural restructuring; excessive stress paralyses.[1614]
- Cognitive learning requires particularly **intense activation of learning mechanisms** (See **Table 2.4** Systems for learning, and **Table 5.2**.)

[1612] Graybiel, "Habits, Rituals, and the Evaluative Brain," 379. In this way the BG are acknowledged to have a key role in control and modulation of social behaviours and may be integral to a progressive evaluation process of behaviours.

[1613] Correction will normally take the form of admonition that enlightens. Aquinas insists that even punishment must be medicinal – restoring justice, and bringing a wrong doer to the point of recognising his or her error.

[1614] cf Sunderland, *The Science of Parenting,* 38.

Learning usually involves strengthening and consolidation at the synapse, and associated changes in the dendritic tree. Learning associated with LTP and LTD is mediated by NMDA receptors, coexisting with AMPA receptors, activated by L-Glutamate.[1615]

- **Memory** in the cortex is plastically responsive to experience.[1616] (See **Tables 2.5** and **5.2** Memory systems.)
- DA, 5-HT, NA and ACh appear to modulate the **moral cognition** systems. OFC cues for moral behaviour and also moral knowledge acquisition. [1617] Activation of stored memories depends on hippocampus and the PFC – temporal cortex connection.[1618]
- **Declarative memory** features the explicit recall required in cognitive learning**.** Hippocampus initially acts as retrieval system for information in widespread areas of neocortex. Over time, the hippocampus reactivates the neocortical representations (by repetition and rehearsal, etc), bringing about plasticity in cortico-cortical connections. [1619]
- The **PFC** (focusing on acquisition of new rules) and the **BG** (focusing selection of rules appropriate to the situation) play complementary roles in rule learning.[1620]

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Reward and motivational systems. Systems of emotional management. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

[1615] See discussion in Waxham,"Neurotransmitter receptors, " Chapter 9.
[1616] Manns and Hichenbaum, "Learning and memory: brain systems," 1174.
[1617] Casebeer,"Moral cognition and its neural constituents,"843.
[1618] Tomita, et al. "Top down signal from prefrontal cortex in executive control of memory retrieval," 699-703.
[1619] For distinct forms of memory systems and the story of their discovery, the principal source of material that follows: Manns and Hichenbaum, "Learning and memory: brain systems," 488.
[1620] Wise, et al.,"The frontal-basal ganglia system in primates," 317-356.

17. Affection facilitates learning particularly in the family environment.

Philosophical clarifications.

Family and social culture, as well as appropriate laws and rules are needed.

Neural bases.

The capacity to respond to affection is shown to be developmentally sensitive, and is centred in the emotion responsive areas of the PFC: the VMPFC and the OFC. [1621] Furthermore affectionate mothering and affectionate teaching style facilitates learning and associated plasticities.

- Cortical development is shown to positively correlate to the presence of affection, and consequent perfusion of hypothalamic oxytocin.[1622] [1623]
- Attachment and positive maternal affect are linked to DA mediated reward arousal in the right brain of the infant[1624].
- Emotion laden events cause release of Epi and glucocorticoids by adrenal glands leading onto release of NE in amygdala, increasing its activity and thereby consolidating memory in other parts of the brain (direct by connections to striatum, hippocampus or cortex; and indirect by connections with nucleus basalis which innervates much of cortex). [1625]

[1621] Arden and Linford, *Brain-based therapy with children and adults*, 103.
[1622] Core content here derived from Knudson, "Early experience and sensitive periods," 525.
[1623] Arden and Linford, *Brain-based therapy with children and adults*, 8.
[1624] Schore, "Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health," 24
[1625] For distinct forms of memory systems and the story of their discovery, the principal source of material that follows: Manns and Hichenbaum, "Learning and memory: brain systems," 488.

- Unless intense arousal is involved, emotional arousal appears to promote synaptic plasticity in memory promoting learning. [1626] Mechanisms include release of NE.[1627]
- Left side PFC has been shown to play a role in maintaining positive affect. Medial insula and the anterior cingulated cortex also mediate affective feelings. [1628]
- Reduced affect leads to underactive OFC. OFC function is relative to the individual's reaction to emotional laden events in the environment.[1629] [1630]

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for imitation and empathy. Sensitive periods of development.

5.4 A case study: a simplified neural analysis of a virtuous action performed by Takashi Nagai

In conclusion to this chapter the analyses of **5.3.3.2** are applied to one of the case studies from **Chapter 3**, the moment when Nagai reads and rereads an American leaflet claiming that Japan's defeat is inevitable. (See **Scenario 3**)

[1626] Bechara, et al.,"Emotion, Decision Making and the Orbitofrontal Cortex," 295-307. See Cahill et al., "The amygdala and emotional memory," 295-296.

[1627] Kessels and Malinow, "Synaptic AMPA Receptor Plasticity and Behaviour," 344.

[1628] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214; Sunderland, *The Science of Parenting.* Identification with family or culture heightens positive affect and desire to learn, and neural restructuring. Clarity of expectation and communication, with explicit input and positive affection promotes effective cognitive learning.

[1629] Roesch and Schoenbaum, "OFC as gateway," 202.

[1630] Arden and Linford, *Brain-based therapy with children and adults*, 8. We have seen that imaging studies of orphans (See **2.4.4 Early Experience and Sensitive Periods**) reveal abnormalities that are consistent with the behaviours that appear to follow upon being raised in environments of social deprivation, in particular, the manifestation of an underactive OFC in comparison with normal children.

This exercise serves as illustration but also as a form of validation for the results presented in this chapter. It is a demonstration that the proposed model of virtue and neuroscience accommodates a real life case study of a virtuous act, as described in precise psychological observations by the subject himself.

Table 5.3
A simplified neural analysis of Scenario 3.
For complete description of scenario see **Chapter 3.1.2 Scenario 3.**

Action (**3.1.2 Scenario 3**)	**Virtue commentary** (**3.1.2 Scenario 3 Commentary; 3.1.3 Virtue and the human act.**)	**Neural analysis** Note that it can be only the person as the subject of the action when we are considering a human act. However when we are not referring to a human act, but to unconscious responses by parts of the body (eg ACh heightens attentiveness) or to the action of part of the body (eg my eye blinked, my amygdala responded to emotional input) there is no problem specifying non personal subject.
"The chief nurse came running up and handed me a sheet of paper"	Nagai has already demonstrated that he has finely attuned responsibilities to those he leads, and habitual courtesy. He takes the leaflet from the nurse, conscious of his duties towards her. It is reasonable to surmise that this sense of responsibility as well as his training in scientific objectivity assisted him in applying sufficient deliberation before committing himself to judgement. Justice will dispose Nagai to take his duties to the nurse and to the survivors into account, giving appropriate example and reaching a final deliberation in the best interests of the entire community he finds himself leading. An unspoken principle he clearly follows is that	Prior learning of duty and courtesy, both disposed by justice, lead Nagai to respond to the nurse's implicit request to read the leaflet. Nagai is extremely drained and exhausted as it is the day after the bomb has exploded. He has suffered much blood loss and has lost consciousness at least on one occasion. The need to care for the wounded has given him little rest. He is also fatigued from the responsibility of leading the growing group of survivors. Exhaustion will be manifested in lower levels of attention, a heightened capacity for emotionally initiated representations (an overactive imagination), and difficulty in suppressing goal irrelevant sensory inputs. When Nagai is approached by the nurse and becomes aware of the American leaflet, his fronto-parietal attentional system is triggered. ACh from the nucleus basalis is released into the thalamus and into areas of the parietal, frontal and cingulated cortices, heightening attentiveness. Attentional loops between the BG and the cortex are established. DA, a facilitator of attention, is also activated for emotional and reward responses.

	truth, no matter how unpalatable, must be faced… and for a leader to do so is necessary.	
Nagais' initial glance at the leaflet revealed the cause of the catastrophe as an atomic blast. Nagai writes, "In the depth of my being I felt a tremendous shock. The atom bomb has been perfected! Japan is defeated!"	Nagai's description of how his passionate reaction subsides on successive readings of the leaflet gives us a remarkable insight into how deliberation can enable mastery of passion. What is initially less obvious is the interior battle that Nagai has fights in order to respond rationally to the news. There is an initial movement of complacency towards the truth. He comprehends the American claim and reacts initially dispassionately.	As Nagai glances at the leaflet initial visual input is channelled to the BLA from the sensory nuclei of the thalamus which has filtered out other inputs allowing his full attention on the leaflet. A degree of fear conditioning will be evident in the BLA given the suffering that Nagai has endured. There is an initial numbness, a lack of cortical response associated with a welling sadness (perhaps reflecting a left VMPFC that is underactive in managing right side negative affect), but Nagai falls back, perhaps heightened through his training as a scientist, on an established habit of seeking knowledge. He reads in the text a confirmation of his suspicions of a nuclear blast. His scientific knowledge gives him virtually an intuitive grasp of the potential of the bomb. Cortical representations of sadness for his country and people, and disgust at the Americans, flood his cortical memory and a negative emotional state overwhelms reason. Even in a state of physical and psychological exhaustion, Nagai's learned self mastery is sufficient for him to utilise cognitive pathways to gain some management of passionate predisposition, reacting with deliberation, and consideration of consequences.
"… Conflicting emotions churned in my mind and heart as I surveyed the appalling atomic wasteland around me. … A bamboo spear lay on the ground. I kicked it fiercely and it made a dull, hollow sound. Grasping it in my hand, I raised it to the sky, as tears rolled down my cheeks. The	Conflicting emotions well up within him, of frustration, sadness, anger, patriotism and shame at defeat. He deliberates briefly about the prospects of victory for Japan in the face of a nuclear power and concludes there is no hope of victory. At some point there is a rejection of blind passionate assertion. Prudence disposes his readiness to apply himself diligently to assess the truth of the American claims. Justice ensures	We are witnessing a "low road" emotional response unmediated by the cortex. Although there is consciousness in the PFC of the response, there is little cortical processing. A further surge of emotional memory inputs flood into the BLA via reciprocal connections to the hippocampal and striatal memory systems. There are neural activations of fear, sadness, anger and disgust (in the anterior insula). Outputs from the BLA trigger a rage response in the dorsomedial nucleus of the hypothalamus. This hypothalamic response directs rage related motor patterns. The various limbic aversion centres also activate. Limbic afferents to the PFC via the OFC trigger consciousness of the emotional response and provide an initial justification based hippocampal call up of DA mediated conscious short term memories of the

bamboo spear against the atomic bomb! What a tragic comedy this war was! This was no longer a war. Would we Japanese be forced to stand on our shores and be annihilated without a word of protest?”	that does not dismiss the American claims out of hand.	suffering witnessed in association with the bomb. These representations are in the PFC. The reward system is activated and Nagai seeks gratification in the pointless action of kicking the bamboo spear. DA floods the NAc in anticipation. GP and the SN select patterns of cortical activity and motor programs for action drawing on movement sequencers in the dorsal striatum. Hippocampus is enlisted for goal direction. The BG instruct the motor areas of the PFC via the BG-thalamo-cortical loop. PFC and motor cortices deliver executive command. The bamboo is kicked. The BLA is now drawing input from widespread cortical areas, and from, and from cortical, hippocampal and striatal memory systems. Nagai shows a greater awareness of his current state, looking around and reflecting on his situation. Attempts to articulate the situation serve to mitigate his passionate reaction. Nagai indulges in a flight of imagination calling up a succession of cortical representations of future scenarios, and this diverts his attention away from sensory input and into deliberation. Effectively is buying time for cortical processing of the overwhelming emotion. The initial surge of passion, corresponding to a neuromodulating flood of ACh and DA, dissipates somewhat and he is able to adopt a more cognitive response. His training in self-discipline can now take effect. Also he is conscious that he has an audience. His desires to give good example, despite an absence of evident reward, are mediated by overlearned S-R responses in the ventral striatum. His prior training has brought about this mechanism.
“I read the leaflet once and was stunned.”	By learned pathways of reflection Nagai sets about the task of reaching the truth of the situation. Quickly Nagai refocusses on reaching the truth or falsehood of the American claim. Very swiftly has Nagai moved through steps of the human act concerning ends and means (**Table 3.1.** Steps 1-7.). His end is to reach the	Nagai’s self mastery is characterised by habitual obedience of the emotional realm to rational command. Goals and rewards are not needed as incentives. S-deliberation-R pathways have taken over. Input to the PFC via the BG-thalamo-cortical loop reestablishes higher cortical, as opposed to emotion driven, management. Emotional thalamic and limbic centres are now redisposed to cortical override**.** Prior learning of fortitude and temperance have established pathways moderating emotional responses so they are obedient

	truth. The means is to weigh the message of the leaflet with his own assessment. Prior to the commencement of his deliberative reading there is a moment of "election" towards the means to reach the chosen good: by reading and calm consideration he decides he will reach the truth. (**Table 3.1.** Step 8 of the human act. See also **3.1.3 Virtue and the human act**.) Despite his impeding emotion he shows determination to face truth no matter how unpalatable it may be. (**Table 3.1.** Steps 9 to 11.) He makes a judgement that the truth can be reached by suppressing immoderate emotion and then applies himself rereading the leaflet weighing its assertions against his own knowledge and estimations.	to rational direction. The habit of fortitude will be present in preferential pathways in the BG-thalamo-cortical loop, and strengthened top-down connections between the OFC and the amygdala. The prior habituation of temperance will be present in mediation primarily by the DLPFC and ACC. In the past it is likely that this habituation was associated with DA rewards that consolidated the pathways of self control. In this current scenario, with the habit established, it is unnecessary for DA perfusion to take place. Various brain regions now coordinate to regulate emotional reaction: OFC, DLPFC, VMPFC, further areas of the amygdala and of the BG. Emotional regulation leads to cortical direction of reward expectations. Emotional representations are consciously suppressed. Cortical management is consolidated via action plans involving rereading. Even though it is unlikely that this is a conscious strategy, nevertheless it is likely to be a learned strategy… to divert oneself into a cognitive task in order to take the heat out of emotion.
"I read it a second time and felt they were making fools of us."	Nagai's established dispositions to moderate and divert excessive emotional representations and expressions are the result of prior learning. The actions of these dispositions permit cortical deliberation to occupy his attention. Nagai's response in this situation, and his character in general, is built on previously established behaviours and convictions upon which he can draw.	Nagai's habit of application at the task until the desired outcome is achieved is a consequence of prior training. His election of the goal to read and reread involves deliberative evaluation utilising numerous cortical areas, drawing particularly on episodic memory, self knowledge, scientific knowledge and skills of critical assessment. Intrinsic motivations have come to the fore: of commitment to the truth, and that one's duty to others must be fulfilled. These appear to be the result of cortical neuronal pathways established and consolidated by prior experience and DA reinforcement, originating in the VTA and SN and mediated by the ventral striatum, by childhood and military training and in happier times. The prior habituation of prudence will be present in this rich and reciprocal connectivity, primarily to and from the DLPFC, with other cortical areas serving memory and somatic and sensory input, with the OFC, DMPFC, BG, and amygdala

		serving emotion regulation, with the ventral striatum assisting in goal setting and motivation. Similarly the prior habituation of justice consists of consolidated pathways in the aPFC, mPFC, VMPFC, OFC (especially medial OFC), ACC (especially rostal ACC), insula, limbic and paralimbic areas, and the BG. These rich connections serve to give preferential traffic to deliberations about understanding of others, consideration of the impact of one's actions on others, empathy, and considerations of fairness, etc. It is possible to detect in this change of behaviour the classic pattern noted by Graybiel:[1631] a passing from reward mediation in the ventral striatum (Nagai's kicking fruitlessly against the goad), associated with the emotional gratification, to a dorsal automatisation, carrying out duty as he has trained himself to do (Nagai's determination to grapple with the truth and face it). Such an automatisation is consistent with our knowledge of the character of this wonderful man.
"I read it a third time and was enraged at their impudence."	In the analysis of the human act (**3.1.3**) it was noted that sense appetite acts upon the will particularly at Steps 2,4,6, and 8; that "undue sense appetition can negate effective use of the intellect".	In neural terms this means that the person is aware of cortical representations of attractive or aversive sense objects, and that reward systems provide neuromodulatory incentive for preferential attention to, and pursuit of these goals via appropriate action plans. Cognition and the capacity to reach the truth can be overwhelmed by the presentation of attractive or aversive cortical representations. This is the battle that Nagai fights in the first, second and third reading. However by holding to his action plan of rereading he is able to regulate the emotion sufficiently to allow deliberation and a final judgement as to the truth of the American message. As we are discussing aversional content, direct involvement of reward systems is minimal. However, during prior learning the habits of prudence, justice, fortitude and temperance were established; during this time the reward systems were greatly active, leading to DA mediated

[1631] Graybiel, "Habits, Rituals, and the Evaluative Brain," 378.

		reinforcement of regulatory pathways triggered in the OFC and amygdala by sense representations. These pathways are available now for Nagai's use in coping with this particularly difficult situation.
"But when I read it a fourth time I changed my mind and began to think it was reasonable."	Nagai has reached the point a judgement about the trustworthiness of the American leaflet.	In the course of moral evaluations and judgements there is a complex integration of numerous neural subdivisions which show significantly consistent activation across numerous studies. (See **Table 5.1** and **Table 5.2.**) Therefore it is possible to predict that, in this case, Nagai's neural activity is likely to include heightened activation in numerous areas: • DLPFC, ACC, the ventral striatum, and amygdala will reveal principal activation. • Above baseline activation will also be evident in mPFC, VMPFC, OFC, the posterior cingulate/retrosplenial cortex, superior temporal cortex, STS, the temporo-parietal junction, medial hypothalamus, and insula. • LPFC and Right OFC will be active in the suppression of sadness. • Considerations of the social norms of patriotism and of cultural expectations of a leader will involve further integration of areas such as the VMPFC, lateral OFC, and aTL, assisted by storage of social perceptual representations in the temporal lobes, • In addition, reflecting Nagai's frustration at the shame of defeat and empathy with the pain of others, the rostral ACC, and the anterior insula will show activity. • Posterior cingulate, and inferior parietal lobe will show activity during the Nagai's brief catastrophising.
"But when I read it a fourth time I changed my mind and began to think it was reasonable. After reading it a fifth time I knew that this was not a propaganda stunt but the	He gives his assent to the assertion of the leaflet. The word "sober" indicates his attainment of "quies". (**Table 3.1.** Step 12 of the human act. See **3.1.3 Virtue and the human act**.) This achievement of *quies* contrasts with Nagai's fierce kick to the bamboo spear: destructive, impulsive, futile, and	In Nagai's reading of the flyer, in this single human act seeking the truth of the issue, we have witnessed a highly complex interplay of systems (memory, emotional management, deliberation, goal election, consideration of consequences of action, moral judgement, attention, reward to some extent, and motor execution), of brain areas, of mechanisms and of pathways. The end result has been the harmonisation of the emotional life with the rational life. The disorder of actions carried out without

sober truth."[1632]	pointless. Acquiescence to the truth implies also a degree of self mastery.	cognitive approval and direction, is replaced by an admission of the truth and a quieting of wayward passion.

This exercise has also served to clarify certain understandings of virtue in action.

Reason and judgement, and the virtues of prudence and justice, are exercised in what we could call a "biophysical dimension" that incorporates duration. As Nagai explores the truth of the American claims his deliberations are protracted in time.

Examples drawn from actual life argue strongly for the unity of the virtues. Nagai's struggle against his emotional reaction is quietened only when he admits that the American leaflet reflects truth. Emotional management is a necessary though insufficient condition for virtue. Management of passionate responses and the disposition to acquire and accept the truth pertain to different virtues. Virtues that directly dispose rational operations as well as virtues that enable emotions to correctly inform, or respond to, rational command are both needed.

The contributory work of the virtues of fortitude and temperance is prior to the deliberations of the human act. In this case, the contributory involvement is manifested in the rereadings and evaluations of the leaflet's content. The action of these virtues is ongoing during the reading in response to the tenacity of the emotional reactions he experiences. It is fascinating to note that, at the point where Nagai admits the truth, the violent emotional responses subside. (They are replaced by a sadness and lethargy which will require a further virtuous response from Nagai.)

Automatised habituated dispositions for positive action are able to come to the fore once the flood of passion passes. Of course, should there be no habituated

[1632] Nagai, *The Bells of Nagasaki*, 52-3.

positive habits, or should there be vices, the flood of passion will not be diverted but may stand in even greater relief.

5.5 Conclusion.

A highly probable model for the neural bases of virtue has now been described on the basis of an hylomorphic anthropology. I have presented arguments supporting the view that virtue, as understood by Aristotle and Aquinas, is embodied, I have described the distinctive nature of that embodiment as it pertains to the cardinal virtues, and I have identified 17 characteristics that capture the nature of virtue. For each one of these characteristics I have identified processes that account for, at the neurobiological level, the specific contributory task that I have identified. I have noted the capacity of the brain to operate multiple processes, concurrently and in concert, in support of goals of the person's own choosing, and that this view of virtue, as a complex of systems, is highly consistent with that view.

This approach respects the soul as principle of being, unity and function; it accounts for rationality of the person and human freedom; it supports the view that neural bases are necessary for, but alone cannot account for, human operations.

In mapping the discrete characteristics of virtue against the neuroscience, I have identified supporting neural structures, pathways and mechanisms. In summary:

i. Human motivation and goal election are supported by the reward structures of the brain that are in reciprocal communication with cortical structures.
ii. Emotional regulation is supported by limbic-cortical connectivity permitting bottom up modification of cortical "decision making", and top-down direction and regulation. I have argued that neuroscience and philosophy converge in describing the complementary roles of emotion and reason in a balanced happy life. The very presence of reciprocal

substantial neural pathways is firm evidence of both cortical direction and subcortical modification of regulation and decision making. A neural reality, consistently presented in this study, is that neuronal pathways develop when used, but atrophy in disuse. I have distinguished between the relative roles of the OFC, the DLPFC and the VMPFC in emotional regulation, with implications for motivation.

iii. It has been shown that the established <u>cognitive activity of the PFC requires the complement of subcortical structures of the limbic system and the BG</u> for these activities of emotion regulation and goal election. I have further argued that the involvement of the BG is crucial, not only by its implication in emotion and reward pathways but also because the BG are the principal seat of automaticity of actions. It has been shown that such automaticity is not necessarily opposed to conscious, voluntary goal election.

iv. The “second nature”, the ease of use that characterises virtue, is attributable primarily to <u>mechanisms of structural plasticity</u> in both cortical and subcortical regions and in the relevant communicating neural pathways. Plasticity in the structures of the BG underpinning automaticity is a further source of the facility for ready action that we find in actions disposed by virtue.

v. <u>The notion of a complex of systems</u> is supported by a weight of current neuroscientific opinion. I have argued that the systems of reward evaluation, of goal setting, of motivation, and of emotional regulation are supported by “upstream” systems of plasticity, learning and memory, and capacities for attention, critical learning, and imitation and empathy.

vi. In support for the notion of the unity of the virtues and of the <u>distinctive neural “signatures” for each of the cardinal virtues</u> I have reviewed the complexity of the human act and noted the necessary and consequent neural complexity of any virtuous act. In particular, I have noted the activity of the sensitive appetites prior to every rational choice and noted the distinctive pathways involved in each of the cardinal virtues.

vii. Cognition centres in the PFC (assisted by other cortical and lower areas primarily implicated in reward and emotional assessment, sense apprehension, memory, attention, and motor planning and command) support the integrating capacity of rationality and the reflection and reasoning that are manifestations of prudence.

viii. Cortical pathways and brain areas are demonstrably implicated in cortical assessment of the consequences of actions on others. These too are in reciprocal connection both by DA pathways, and BG-thalamo-cortical loops, with the reward systems and centres, providing further incentive for action. I have argued that the virtue of justice resides most typically in the habitual activation of these areas.

ix. I have argued that human actions commence with sensitive appetitive responses to perceptions or imaginative representations in the memory (but not necessarily of specific past events) of pleasure and aversion, and that the essence of virtue is to find pleasure in what is in keeping with our nature, along with a readiness to endure difficulties to obtain those things that we know to be good for us. In essence, neural dispositions in our reward processing and in our responses to fear support temperance and fortitude.

In **Chapter 6** I will turn my focus to a eudaimonic analysis of what we have seen at the neural level. At the beginning of this current chapter, I noted Casebeer's observation that the virtuous life will be characterized by neural elements operating in a "maximally functional manner".[1633] I will focus on this notion of functional fulfilment along with affective and teleological fulfilment. In conclusion, **Chapter 6** will also offer neuroscientific, philosophical and pedagogical conclusions relevant to this study.

[1633] Casebeer, "Moral cognition and its neural constituents," 843.