

Appendix One: DARPA BAA 2005

**STRUCTURAL PRIMITIVES OF THE PRIMATE CENTRAL
NERVOUS SYSTEM**

(An initial list)

I. Limbic System and Related Structures (subcortical)

- A. limbic lobe
 - 1. cingulate gyrus
 - 2. subcallosal gyrus
 - 3. parahippocampal region
 - a. parahippocampal gyrus
 - b. perirhinal cortex
 - c. entorhinal cortex
 - 4. hippocampal complex
 - a. dentate gyrus
 - b. subicular complex
 - i. parasubiculum
 - ii. presubiculum
 - iii. subiculum
 - c. Ammon's horn (hippocampus proper)
 - i. CA1
 - ii. CA2
 - iii. CA3
 - iv. CA4
- B. anterior thalamic nuclei
- C. medial dorsal nucleus of thalamus
- D. habenula
- E. mammillary body
- F. amygdala
 - 1. corticomедial nuclei
 - 2. basolateral nucleus
 - 3. central nucleus
- G. olfactory bulb
- H. prominent hippocampal pathways
 - 1. mossy fiber pathway
 - 2. perforant pathway
 - 3. schaffer collateral fiber pathway
- I. prominent limbic pathways
 - 1. cingulum
 - 2. stria terminalis

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3. stria medullaris
4. dorsal longitudinal fasciculus
5. mammillotegmental tract
6. medial forebrain bundle
7. habenulo-interpeduncular tract
8. mammillary peduncle
9. ventral amygdalofugal pathway
10. lateral olfactory stria
11. anterior commissure
12. mammillothalamic tract
13. fornix

J. hypothalamus

1. lateral hypothalamic area
2. supraoptic nucleus
3. ventromedial hypothalamic nucleus
4. arcuate nucleus
5. median eminence
6. arcuate nucleus
7. lateral tuberal nucleus
8. periventricular nucleus
9. dorsomedial hypothalamic nucleus
10. posterior hypothalamic area
11. pituitary
12. infundibulum
13. supraoptic nucleus
14. lateral preoptic nucleus
15. anterior hypothalamic nucleus
16. medial preoptic nucleus
17. paraventricular nucleus

II. Subcortical Motor Systems: Basal Ganglia and Thalamus

A. striatum (striosomes and matrix)

1. caudate nucleus
2. putamen

B. globus pallidus

1. internal segment
2. external segment
3. ventral pallidum

C. subthalamic nucleus

D. substantia nigra

1. pars reticulata
2. pars compacta
3. pars lateralis

E. ventral lateral nucleus of the thalamus

1. oral portion

- 2. caudal portion
- F. ventral posterior nucleus of the thalamus
 - 1. oral portion
- G. centromedian nucleus of the thalamus
- H. nucleus X of the thalamus

III. Subcortical Motor Systems: Cerebellum

- A. cerebellar peduncles (contain input-output tracts)
 - 1. superior
 - 2. middle
 - 3. inferior
- B. flocculonodular lobe
 - 1. nodulus
 - 2. flocculus
- C. vermis
 - 1. culmen
 - 2. declive
 - 3. folium
 - 4. tuber
 - 5. pyramis
 - 6. uvula
- D. deep nuclei
 - 1. fastigial
 - 2. interposed
 - a. globose
 - b. embiliform
 - 3. dentate

IV. Other Subcortical Motor Systems/Structures

- A. spinal cord
 - 1. lamina VIII
 - 2. lamina IX
- B. brainstem and midbrain
 - 1. pontine reticular formation
 - 2. red nucleus
 - 3. medullary reticular formation
 - 4. superior colliculi
 - 5. vestibular nuclei
 - 6. trigeminal motor nucleus (V)
 - 7. facial motor nucleus (VII)
 - 8. dorsal motor nucleus of vagus (X)
 - 9. hypoglossal nucleus (XII)

V. Cortical Motor Systems

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- A. premotor cortex (area 6)
- B. supplementary motor area (area 6)
- C. primary motor cortex (area 4)
- D. parietal cortex (sensorimotor cortex)
 - 1. area 5 (area PE in von Economo nomenclature)
 - 2. area 7a (area PG in von Economo nomenclature)
 - 3. area 7b (area PF in von Economo nomenclature)
 - 4. area 39 (human)
 - 5. area 40 (human)
 - 6. cortical areas of the intraparietal sulcus
 - a. AIP (anterior intraparietal)
 - b. LIP (lateral intraparietal)
 - c. VIP (ventral intraparietal)
 - d. MIP (medial intraparietal)
- E. prominent tracts
 - 1. lateral corticospinal tract
 - 2. ventral corticospinal tract
 - 3. corticobulbar pathway

VI. Thalamic Nuclei

- A. internal medullary lamina (divides thalamus into six subregions)
- B. medial dorsal
- C. intralaminar
- D. pulvinar
- E. medial geniculate
- F. lateral geniculate
- G. centromedian
- H. ventral posterior medial
- I. lateral posterior
- J. lateral dorsal
- K. ventral lateral
- L. ventral intermediate
- M. ventral posterior
- N. ventral posterior inferior
- O. ventral anterior
- P. reticular
- Q. anterior

VII. Brainstem: Cranial Nerve Nuclei (Sensory and Motor)

- A. mesencephalic trigeminal nucleus (V)
- B. principal sensory trigeminal nucleus (V)
- C. spinal trigeminal nucleus (V, VII, IX, X)
 - 1. oralis

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- 2. interparialis
- 3. caudalis
- C. vestibular nuclei (VIII)
 - 1. superior vestibular nucleus
 - 2. lateral vestibular nucleus
 - 3. inferior vestibular nucleus
 - a. rostral part
 - b. caudal part
 - 4. medial vestibular nucleus
 - a. rostral part
 - b. middle part
 - c. caudal part
- D. cochlear nucleus (VIII)
- E. solitary nucleus (VII, IX, X)
- F. accessory nucleus (XI)
- G. dorsal motor nucleus of vagus (X)
- H. hypoglossal nucleus (XII)
- I. nucleus ambiguus (IX, X, XI)
- J. salivatory nuclei
 - 1. superior (VII)
 - 2. inferior (IX)
- K. facial motor nucleus (VII)
- L. abducens (VI)
- M. trigeminal motor nucleus (V)
- N. trochlear nucleus (IV)
- O. oculomotor nucleus (III)
- P. Edinger-Westphal nucleus (III)

VIII. Arousal / Neuromodulatory Systems

- A. cholinergic system (in basal forebrain)
 - 1. nucleus basalis of Meynert
 - 2. substantia innominata
 - 3. medial septal nucleus
 - 4. diagonal band of Broca
- B. brainstem reticular formation (3 major monoaminergic systems)
 - 1. noradrenergic system
 - a. locus ceruleus
 - b. lateral tegmental neurons (scattered diffusely)
 - 2. dopaminergic system
 - a. mesostriatal system
 - i. ventral part
 - a. ventral tegmentum (area A10)
 - b. retrorubral nucleus (area A8)
 - ii. dorsal part
 - a. substantia nigra (area A9)

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- b. mesolimbic and mesocortical systems
 - i. area A10
 - ii. area A9
- 3. serotonergic system
 - a. raphe nuclei
 - i. nucleus raphe pallidus
 - ii. nucleus raphe obscurus
 - iii. nucleus raphe magnus
 - iv. nucleus raphe pontis
 - v. nucleus raphe dorsalis
 - vi. nucleus paragigantocellularis
 - vii. nucleus centralis superior
 - viii. nucleus tegmenti reticularis pontis and adjacent tegmentum

IX. Olfactory Structures

- A. peripheral structures
 - 1. olfactory epithelium
 - 2. olfactory bulb
- B. cortical structures
 - 1. olfactory cortex
 - a. anterior olfactory nucleus
 - b. olfactory tubercle
 - c. pyriform cortex
 - d. cortical nucleus of the amygdala
 - e. entorhinal area

X. Gustatory Structures

- A. peripheral structures
 - 1. geniculate ganglion (VII)
 - 2. petrosal ganglion (IX)
 - 3. nodose ganglion (X)
 - 4. solitary nucleus (VII, IX, X)
- B. thalamic structures
 - 1. ventral posterior medial nucleus
 - a. parvocellular portion
- C. cortical structures
 - 1. taste area I
 - 2. taste area II

XI. Auditory Structures

- A. cochlea (peripheral sensory apparatus)
- B. auditory nerve (VIII) (fiber tract)
- C. cochlear nucleus (VIII)

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1. dorsal
2. ventral
 - a. three dominant pathways exiting cochlear nucleus:
 - i. dorsal acoustic stria
 - ii. intermediate acoustic stria
 - iii. trapezoid body
- D. medial superior olive
- E. lateral superior olive
- F. spiral ganglion
- G. lateral lemniscus (fiber tract)
- H. Probst's commissure (fiber decussation)
- I. nucleus of lateral lemniscus
- J. inferior colliculus
- K. auditory thalamus
 1. medial geniculate nucleus
 - a. medial division
- L. cortical auditory structures
 1. AI (primary auditory cortex) (areas 41 and 42)
 - a. laminated columnar structure similar to other sensory cortices
 - i. summation columns
 - ii. suppression columns
 2. anterior lateral auditory field
 3. rostral auditory field
 4. posterior lateral auditory field

XII. Visual Structures (cortical areas correspond to Macaque)

- A. retina
- B. superior colliculus
 1. stratum zonale
 2. stratum griseum superficiale
 3. stratum opticum
 4. stratum album intermedium
 5. stratum griseum intermedium
 6. stratum griseum profundum
 7. stratum album profundum
- C. pretectal area
- D. visual thalamus
 1. lateral geniculate nucleus (6 layers)
 - a. parvocellular layers (3,4,5,6)
 - b. magnocellular layers (1,2)
 - c. ipsilateral layers (2,3,5)
 - d. contralateral layers (1,4,6)
 2. pulvinar
 - a. medial
 - b. lateral

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c. dorsal

E. cortical areas – occipital lobe

1. V1 (primary visual cortex) (area 17)
 - a. hypercolumns
 - i. ocular dominance columns
 - ii. orientation columns
 - a. layer 1
 - b. layer 2
 - c. layer 3
 - d. layer 4
 - i. layer 4A
 - ii. layer 4B
 - iii. layer 4C α (magno)
 - iv. layer 4C β (parvo)
 - a. blobs
 - b. interblobs
 - e. layer 5
 - f. layer 6
 2. V2 (secondary visual cortex) (area 18)
 - a. thin stripes
 - b. pale stripes
 - c. thick stripes
 3. V3 (area 18)
 4. V3A (area 18)
 5. V4v (ventral) (area 19)
 6. V4d (dorsal) (area 19)
 7. V4t (transitional) (area 19)
 8. VP (ventral posterior)
 9. VOT (ventral occipitotemporal)
 10. MT (middle temporal, V5) (area 19)

F. cortical areas – temporal lobe

1. FST (floor of superior temporal)
2. PITv (posterior inferotemporal ventral)
3. PITd (posterior inferotemporal dorsal)
4. CITd (central inferotemporal dorsal)
5. CITv (central inferotemporal ventral)
6. AITd (anterior inferotemporal dorsal)
7. AITv (anterior inferotemporal ventral)
8. STPa (superior temporal polysensory anterior)
9. STPp (superior temporal polysensory posterior)
10. TF
11. TH

G. cortical areas – parietal lobe

1. MSTd (medial superior temporal dorsal)
2. MSTl (medial superior temporal lateral)
3. PO (parieto-occipital)

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4. PIP (posterior intraparietal)
 5. AIP (anterior intraparietal)
 6. LIP (lateral intraparietal)
 7. VIP (ventral intraparietal)
 8. MIP (medial intraparietal)
 9. MDP (medial dorsal parietal)
 10. DP (dorsal perlunate)
 11. area 7a
- H. cortical areas – frontal lobe
1. FEF (frontal eye field) (area 8)
 2. area 46
- I. other cortical area designations
1. dorsointermediate visual area
 2. dorsolateral visual area
 3. dorsomedial visual area

XIII. Somatosensory Structures

- A. peripheral structures
1. dorsal root ganglia
- B. spinal cord
1. gray matter
 - a. dorsal horn
 - i. lamina I (marginal zone)
 - ii. lamina II (substantia gelatinosa)
 - iii. lamina III (nucleus proprius)
 - iv. lamina IV (nucleus proprius)
 - v. lamina V (nucleus proprius)
 - vi. lamina VI (nucleus proprius)
 - b. intermediate zone
 - i. lamina VII
 - a. Clarke's nucleus
 - c. lamina X
 2. white matter (fiber tracts)
 - a. dorsal columns
 - b. lateral columns
- C. brainstem
1. principal sensory nucleus (V)
 2. spinal trigeminal nucleus (V, VII, IX, X)
 - i. oralis
 - ii. interpolaris
 - iii. caudalis
 3. dorsal column nuclei
 - i. gracile nucleus
 - ii. cuneate nucleus
- D. medial lemniscus (fiber tract)

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E. somatosensory thalamus

1. ventral posterior medial nucleus (thalamus)
2. ventral posterior lateral nucleus (thalamus)
3. ventral posterior inferior nucleus (thalamus)
4. ventral posterior nucleus (thalamus)

F. cortical areas

1. SI (primary somatosensory cortex)
 - a. area 1
 - b. area 2
 - c. area 3a
 - d. area 3b
2. SII (secondary somatosensory cortex)
 - a. area 2a
3. posterior parietal cortex (sensorimotor cortex)
 - a. area 5
 - b. area 7

G. structures involved in descending pain modulation

1. periaqueductal gray
2. locus ceruleus
3. lateral reticular nucleus
4. nucleus raphe magnus
5. nucleus of the solitary tract

XIV. Association and Polysensory Cortices

A. parietal- temporal-occipital association cortex

1. area 39 (Wernicke's Area)
2. area 40 (Wernicke's Area)
3. portions of areas:
 - a. 19
 - b. 21
 - i. posterior portion (Wernicke's Area)
 - c. 22
 - i. posterior portion (Wernicke's Area)
 - d. 37
 - i. subportion (Wernicke's Area)

B. limbic cortex

1. area 23
2. area 24
3. area 38
4. area 28
5. area 11

C. frontal cortical areas

1. dorsolateral prefrontal cortex
 - a. area 8a
 - b. area 8b

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- c. area 9
- d. area 44 (Broca's Area)
- e. area 45 (Broca's Area)
- f. area 46
- g. area 47
- 2. anterior cingulate cortex
 - a. area 24
 - b. area 32
- 3. orbitofrontal cortex
 - a. area 11
 - b. area 12
 - c. area 13
 - d. area 14
- 4. frontopolar
 - a. area 10

XV. Autonomic Structures

A. parasympathetic system

- 1. central structures
 - a. midbrain
 - i. Edinger-Westphal nucleus (III)
 - b. pons
 - i. lacrimal
 - ii. salivatory nuclei
 - a. superior
 - b. inferior
 - c. medulla
 - i. inferior salivatory nucleus
 - ii. dorsal vagal nucleus
 - iii. nucleus ambiguus
 - d. sacral spinal cord
- 2. peripheral structures
 - a. ciliary ganglion
 - b. pterygopalatine ganglion
 - c. submandibular ganglion
 - d. otic ganglion
 - e. terminal ganglion
 - f. pelvic plexus

B. sympathetic system

- 1. central structures
 - a. spinal cord
 - i. intermediolateral gray matter
- 2. peripheral structures
 - a. superior cervical ganglion
 - b. middle cervical ganglion

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- c. stellate ganglion
- d. sympathetic chain ganglia
- e. adrenal gland
- f. celiac ganglion
- g. aorticorenal ganglion
- h. superior mesenteric ganglion
- i. inferior mesenteric ganglion
- 3. enteric system
 - a. myenteric plexus
 - b. submucous plexus

XVI. Spinal Structures

- A. gray matter
 - 1. dorsal horn
 - a. lamina I (marginal zone)
 - b. lamina II (substantia gelatinosa)
 - c. lamina III (nucleus proprius)
 - d. lamina IV (nucleus proprius)
 - e. lamina V (nucleus proprius)
 - f. lamina VI (nucleus proprius)
 - 2. intermediate zone
 - a. lamina VII
 - i. Clarke's nucleus
 - ii. intermediolateral nucleus
 - 3. ventral horn
 - a. lamina VIII
 - b. lamina IX (motor nuclei)
 - 4. lamina X
- B. white matter (fiber tracts)
 - 1. dorsal columns
 - 2. lateral columns
 - 3. ventral columns
- C. tract of Lissauer
- D. fasciculus proprius