

# Introduction to Neuropsychology

## *Motor Behaviour*

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# Example Exam Questions

1. How have neuropsychological investigations informed our current understanding about the neural mechanisms behind motor behaviour?
2. What differences exist between the behavioural deficits resulting from damage to the *cerebellum* and damage to the *basal ganglia*?
3. How have investigations into motor disorders informed us about the layout of motor representations in the brain?

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# Language *Lecture Outline*

1. **Cerebral Cortex**
  - Primary motor (M1)
  - Sensory-motor
  - Supplementary motor area (SMA)
2. **Basal Ganglia**
3. **Cerebellum**

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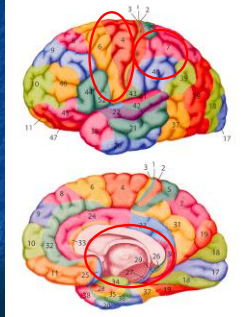
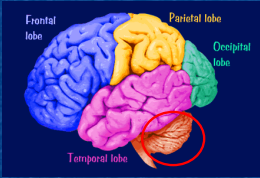
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## Basic Anatomy




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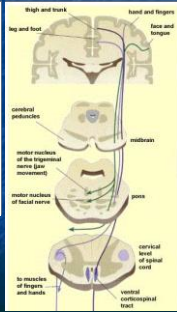
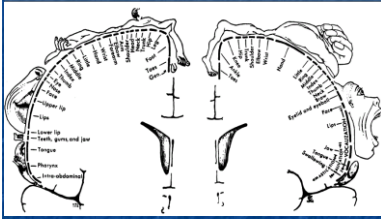
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## The Motor System Cerebral Cortex



(Penfield & Rasmussen, 1950; see Schott, 1993)

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## Cerebral Cortex Apraxia

- "...a disorder of skilled movement not caused by weakness, akinesia, deafferentation, abnormal tone or posture, movement disorders such as tremor or chorea, intellectual deterioration, poor comprehension, or uncooperativeness" (Heilman and Rothi, 1993)
- A higher-order motor disorder not due to elementary sensory and/or motor deficits (i.e. not a problem in moving the muscles themselves)
- Assessed (in order of severity) as impairment of:
  - Movement on command of examiner
  - Imitation of movement performed by examiner
  - Appropriate movement in response to a seen object
  - Correct handling of an object
- Detected in ~50% left and <10% right hemisphere patients

(Petreska et al., 2007; Zadifoff & Lang, 2005; Wheaton & Hallett, 2007)

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## Cerebral Cortex Apraxia

- Defined by errors and the manner in which they're elicited:
  - Temporal errors
    - Impaired timing and poor sequencing of movements requiring multiple positioning
    - Overall, movement is recognizable
  - Spatial errors
    - Abnormal amplitude, configuration orientation and body-part-as-object substitution
  - Content errors
    - Perseveration
  - "Other" errors
    - Lack of response
    - Entirely unrecognizable response

(Petreska et al., 2007; Zaidoff & Lang, 2005; Wheaton & Hallett, 2007)

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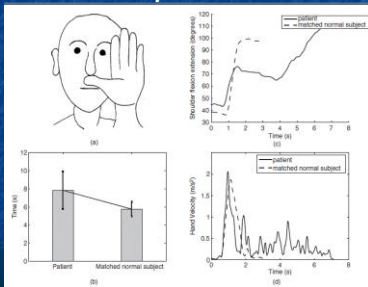
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## Cerebral Cortex Apraxia



(Petreska et al., 2007)

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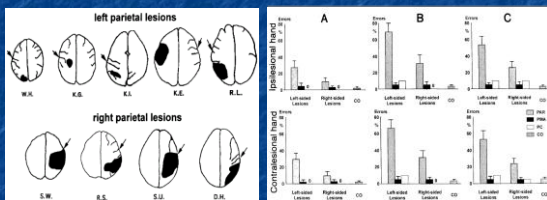
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## Cerebral Cortex Apraxia



A = Symbolic gestures; B = Actions towards body; C = Imagined tool use in extra-personal space

(Halsband et al., 2001)

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## Apraxia Models

- Liepmann (1909)
  - Disconnection between the "motor engram" (space-time plan) in *left parietal cortex* and the "central region" (*pre- and post-central gyri, and middle and superior frontal gyri*)
- Roy & Square (1985)
  - "Conceptual system" provides knowledge about (1) the functions of tools and objects; (2) actions independent of tools and objects; (3) the organization of single actions into sequences
  - "Production system" incorporates a sensorimotor representation of the action and mechanisms for movement control
- Heilman and Rothi (1993)
  - Spatio-temporal representations of actions in *inferior parietal lobule* cannot be sent to motor cortices

(Petreska et al., 2007)

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## Cerebral Cortex Ideomotor Apraxia

- "...a disorder of the *production* component of the praxis system, i.e., sensorimotor action programs that are concerned with the generation and control of motor activity... It is characterized by errors in the timing, sequencing and spatial organization of gestural movements..."
- Errors include:
  - Temporal
    - Increased or decreased rate of production of a pantomime,
    - Addition, deletion, or transposition of movement parts
  - Spatial
    - When asked to pantomime teeth brushing, the fist is tight with no space for the imagined toothbrush
- Improves on imitation and with use of actual tool, and transitive worse than intransitive
- Impairment greater in clinical setting than everyday life

(Wheaton & Hallett, 2007 [but see Sunderland & Shinner, 2007])

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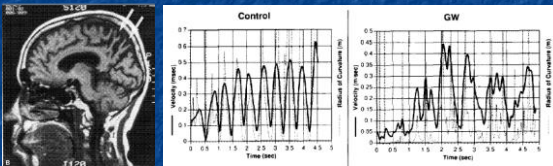
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## Ideomotor Apraxia Patient G.W.



- Identify tools from verbal functional descriptions (10/10)
- Tool function identification (10/10)
- Tool selection (10/10)
- Verbally describe actions required for tool use (15/15)
- Verbal description of serial actions (flawless)

(Rapcsak et al., 1995)

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## Cerebral Cortex Ideational Apraxia

- "...a disruption of the **conceptual** component of the praxis system, i.e., action semantics memory... Patients with ideational apraxia are not impaired in the action execution per se, but demonstrate inappropriate use of objects and may fail in gesture discrimination and matching tasks."
- Errors include:
  - Content
    - Impaired performance of single tool use - cannot associate tools/objects with the corresponding action
      - Unable to choose a hammer to drive a nail or correctly
  - Impaired performance of action sequences requiring the use of various objects
  - Impaired performance of multiple-step tasks
    - Preparing a letter to mail (perseveration)

(Petreska et al., 2007)

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## Ideational Apraxia Example Patient

- Lesion to "left parietal lobe"
- No signs of low-level motor disturbance
- "When asked to pantomime certain motions with either her right or left arm (i.e. "Show me how you would use a key"), [she] would look down at her hand and say, "I can't do it"... When asked if she understood the question, [she] would verbally demonstrate comprehension, i.e. "Keys are used for opening locks"."
- "When the correct movement was shown... she was always able to select the correct movement... [and] She was able to imitate in a flawless manner."
- "[She showed] no difficulty with multiple object sequencing (i.e. taking a cigarette out of a pack, putting it in her mouth, lighting it, and then smoking)."

(Heilman, 1973)

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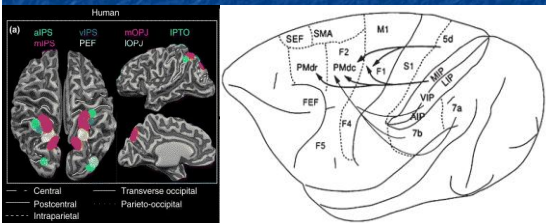
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## Cerebral Cortex Apraxia



(Culham & Valyear, 2006; Iacoboni, 2006; Petreska et al., 2007)

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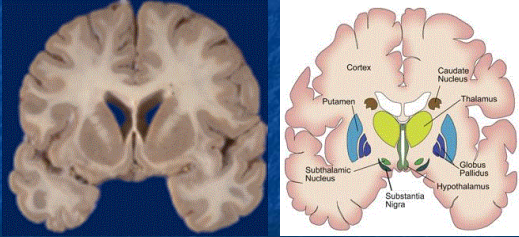
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## The Motor System Basal Ganglia



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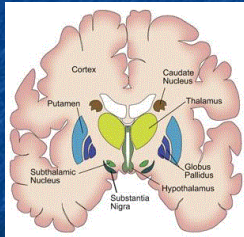
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## The Motor System Basal Ganglia

- **Input**
  - **Striatum**
    1. Caudate
    2. Putamen
- **Output**
  - 3a. Globus Pallidus (internal)
  4. Substantia Nigra  
  5. Subthalamic nuclei
  - 3b. Globus Pallidus (external)



(DeLong, 1990)

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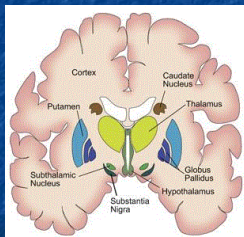
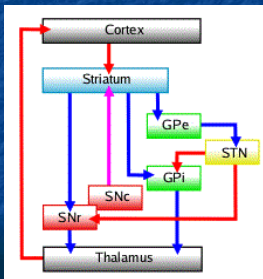
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## The Motor System Basal Ganglia



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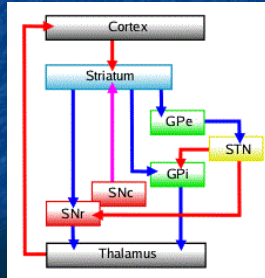
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## The Motor System Basal Ganglia

- Increased conduction through indirect pathway
  - **Increased** pallido-thalamic inhibition
    - Hypokinesia (PD)
- Increased conduction through direct pathway
  - **Decreased** pallido-thalamic inhibition
    - Hyperkinesia (HD)



(DeLong, 1990)

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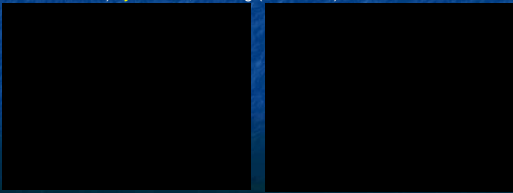
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## Basal Ganglia Parkinson's Disease

- **Hypokinetic**
  - Impaired movement initiation (*akinesia*); reduced velocity and amplitude of voluntary movement (*bradykinesia* [1]);
  - Muscular rigidity (*dystonia* [2]); resting *tremor*; (L-DOPA induced) *dyskinesia*; freezing (*festination*)




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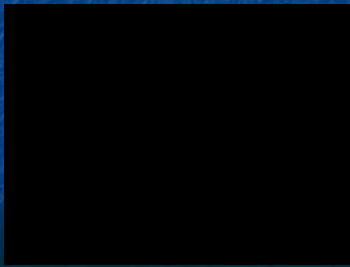
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## Basal Ganglia Parkinson's Disease

- Treatment with L-DOPA ("ON" vs. "OFF" phase)




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## Basal Ganglia *Huntington's Disease*

- Hyperkinetic
  - Involuntary movements (*dyskinesias*)



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## Basal Ganglia *Huntington's Disease*

- *Dystonia* and treatment by *pallidotomy*



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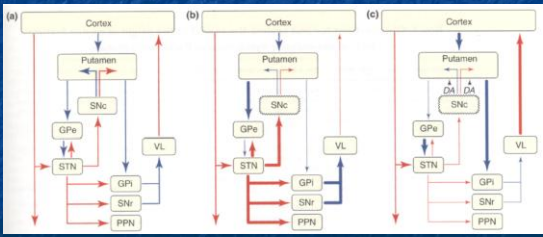
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## Basal Ganglia *Movement Disorders*



(Obeso et al., 2000)

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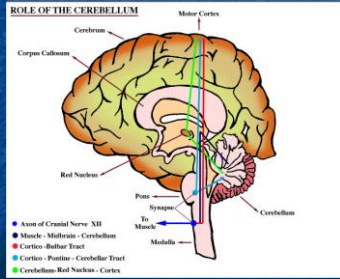
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## The Motor System Cerebellum



(Fredericks, 1996)

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## The Motor System Cerebellum

- Contains more cells than the rest of CNS
- Ipsilateral control of motor behavior (cross twice)
- Inputs arrive from vestibular (inner ear), somatosensory, visual, and auditory systems
- Outputs to deep cerebellar nuclei, which in turn send output to:
  - Medial: Descending extrapyramidal nuclei (brainstem)
  - Lateral: Ascending projections to frontal and motor cortices via thalamus

(Fredericks, 1996)

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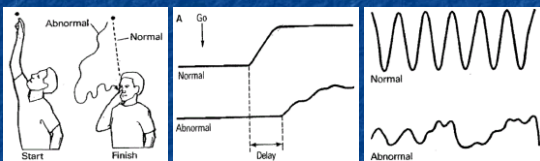
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## Cerebellar Ataxia Movement Disorders



- Consequential behavioural impairments
  - *Hypotonia* (antagonist); *dysdiadochokinesia*; *dysmetria* (*hypometria* vs. *hypermetria*); *cerebellar gait* (postural instability)

(Fredericks, 1996)

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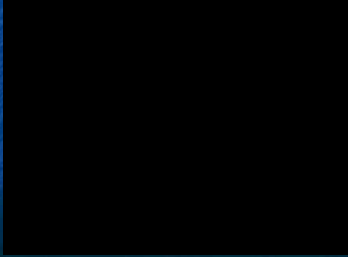
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## The Motor System Cerebellum

- *Cerebellar gait* (Impairment of posture and fluidity in walking)



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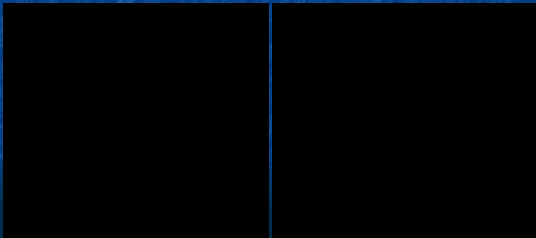
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## The Motor System Cerebellum

- *Dysidiadochokinesia* (Impairment of rapid movements )



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