INTRODUCTION TO SOMATIC MOTOR SYSTEMS

A. Functions

1. Posture: maintain appropriate body position against external forces
2. Movement: change of body position to accomplish desired act
3. Coordination: control pattern and sequence of muscle contraction for smooth, effective action

B. Initiation of Function

1. Involuntary: motor act, initiated by specific internal or external stimulus, generally stereotyped, need not involve conscious volition
2. Voluntary: sometimes initiated without any obvious stimulus, often complex and varied, requires conscious volition

   Note: voluntary and involuntary are not separate systems, since they involve shared effector organs and pathways, and interact with each other

C. Effector Structures

1. skeletal muscle: regular (*extrafusal*, ordinary) skeletal muscle fibers

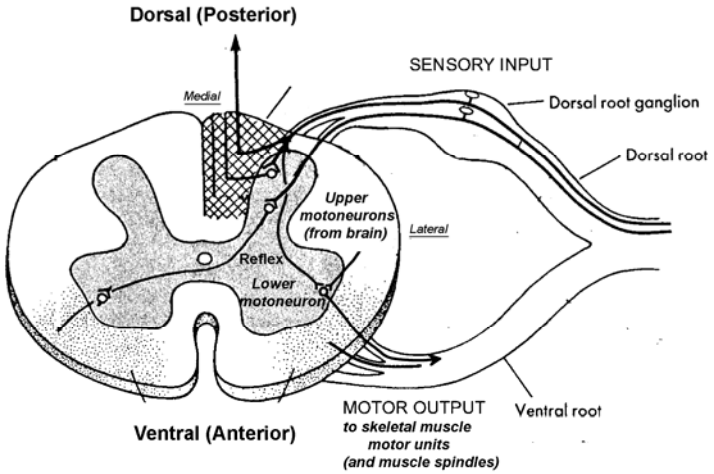
2. neurons innervating skeletal muscle fibers: alpha (large) motoneurons in the spinal cord and cranial motor nerve nuclei (*motor unit*, final common pathway, lower motor neuron, always excitatory)

   a. spinal cord: alpha motoneurons in ventral horn, innervating muscles of movement and posture

   b. cranial nerves: motor nuclei in the bulb/brainstem (medulla, pons, midbrain) controlling

      1) eye movement
      2) mastication (chewing)
      3) muscles of facial expression
      4) muscles of the soft palate and larynx
      5) muscles supporting the head
      6) tongue muscles

      Note: the brainstem is sometimes called the "bulb"



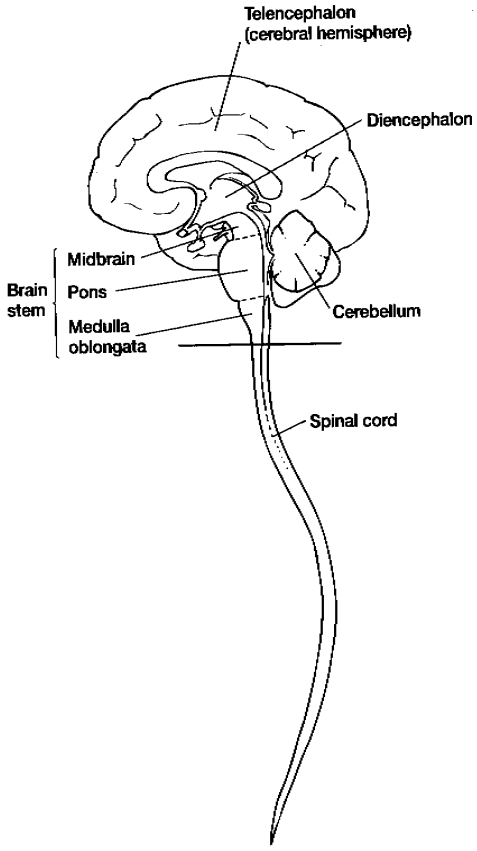
INTRODUCTION (continued)

D. Influences on Motoneurons (= motor neurons)

1. reflexes: simple, stereotyped, involuntary movements (e.g. flexion reflex, myotatic reflex)
2. brain stem nuclei (tone)
3. brain stem pattern generators: more complex movements involving several muscles, often voluntarily initiated (e.g. chewing, swallowing, walking, vomiting)
4. motor cortex (primary motor cortex, M1; essential for voluntary activity)
5. premotor cortex (input to motor cortex)
6. supplementary motor cortex (input to motor cortex)
7. cerebellum (feedback to motor cortex; coordination, balance, posture/tone)
8. basal ganglia (elaboration of movement & suppression of unwanted movements)

E. Terms and Definitions

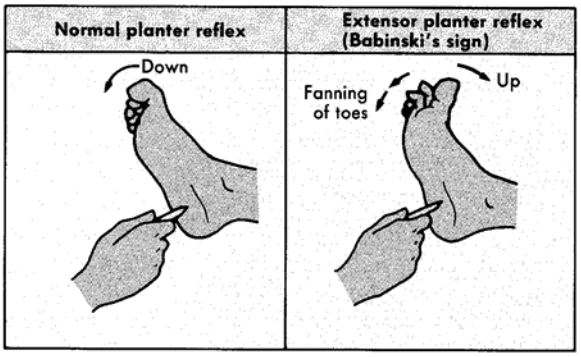
tone	muscle tension in the absence of voluntary activity
hypertonia / hypotonia	increased / reduced muscle tone compared to normal
dystonia	tonically rigid posture
hyper- / hyporeflexia	increased (brisk) / reduced reflex response
clonus	oscillatory contraction and relaxation of muscle (reflex)
spasticity	hypertonia, hyperreflexia, clonus
tremor	involuntary, small, rapid motions
passive tremor	tremor associated with rest
intention tremor	tremor accompanying voluntary motion
rigidity	hypertonia resisting passive movement
asthenia	weakness, loss of strength
paresis	partial loss of voluntary control
paralysis	complete loss of voluntary control
flaccid	paralysis and hypotonia
spastic	paralysis and spasticity
-plegia	paralysis (suffix)
paraplegia	paralysis of the lower half of the body
quadriplegia	paralysis from the neck down
hemiplegia	paralysis of one side of the body
ataxia	awkward, uncoordinated movement



INTRODUCTION

E. Terms and Definitions (continued)

decomposition of movement	sequential performance of normally synchronous actions
dysmetria	overshoot of movement (“past pointing”)
hyperkinetic movements	involuntary but voluntary-like movements
lower motoneuron	neuron innervating skeletal muscle (alpha motoneuron) lesion results in flaccid paralysis, muscle atrophy
upper motoneuron	neuron innervating lower motoneuron, either directly or through interneurons lesion results in spastic paralysis, Babinski sign
synergist muscles	muscles effecting the same action at a joint
antagonist muscles	muscles performing opposing actions at a joint (e.g. flexors and extensors)



VOLUNTARY MOTOR SYSTEM

A. General Organization

1. Primary motor cortex issues commands to motor neurons either directly to alpha motoneurons (corticospinal or corticobulbar tracts) or indirectly by way of intermediate brain stem nuclei

2. Premotor cortex activates the primary motor cortex to activate groups of movements to generate coordinated actions

3. Supplementary is responsible for planning and preparation for movement

4. Cerebellum and Basal Ganglia are responsible for monitoring and coordination of movements by modifying the output from the motor cortex (but do not innervate alpha motoneurons directly

VOLUNTARY MOTOR SYSTEM (continued)

B. Primary Motor Cortex (M1)

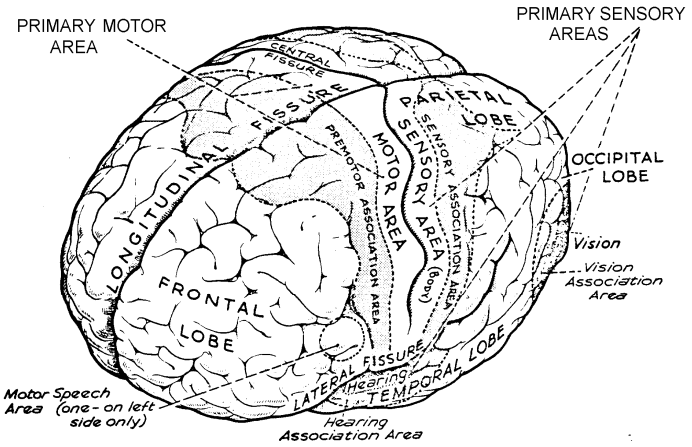
1. Located in precentral gyrus area of the frontal lobe

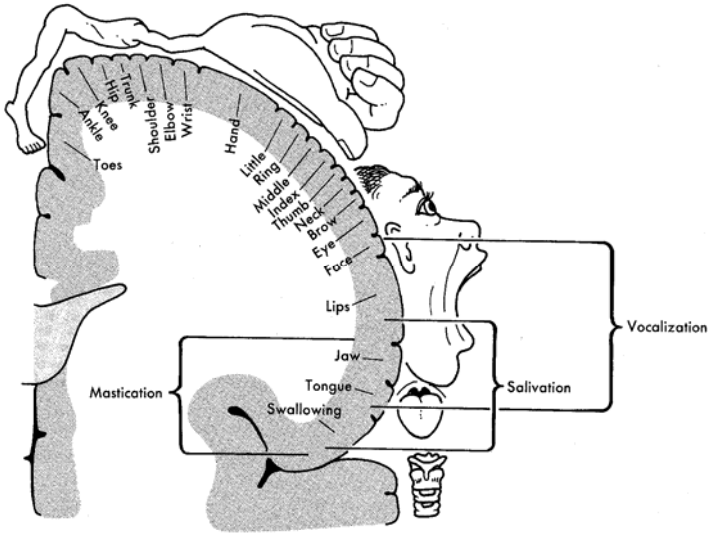
2. Somatatopically organized

Note: primary motor cortex “map” is similar to primary sensory cortex “map” on the postcentral sulcus parietal cortex, except that cortical area on the motor cortex depends on precision and complexity of motor activity instead of density of sensory innervation as on primary sensory cortex

a. electrical stimulation produces fine, discrete movements

b. representation mainly contralateral as the descending pathways from the primary motor cortex cross (decussate) as the fibers transition from the brain to the spinal cord; exception: several cranial nerves have both ipsilateral and contralateral control





VOLUNTARY MOTOR SYSTEM (continued)

B. Primary Motor Cortex (continued)

3. Role

a. Voluntary Movement: essential

Note: effect of primary motor cortex lesions or interruptions of corticospinal tract in man (*stroke*): immediate loss or reduction of voluntary function in contralateral muscles corresponding to the region of injury, and often spastic paralysis; frequently there is some recovery of function with time

4. Motor cortex neurons give rise to two descending tracts for skeletal muscle control

a. corticospinal tract

1) originates in the primary motor cortex and terminates on alpha motoneurons in the of the spinal cord or on spinal interneurons that project to them

2) control muscles in the distal part of the limbs and truck

3) components

a) corticospinal tract (*pyramidal tract*, axons passing directly from the cortex to the spinal cord)

Note: most (80-90%) of corticospinal tract fibers decussate (cross) at the junction of the medulla and spinal cord; most of the rest decussate in the spinal cord; thus, contralateral control

Note: some cortical axons in the pyramidal tract synapse directly on alpha motoneurons, rather then interneurons, supporting precise and direct control of motor activities involving these muscles

4) role

a) control fine, discrete, precise movements, particularly those involving the hands and face
b) suppress Babinski sign (after full development by 1 year of age)

5) pathophysiology: interruption of the pyramidal tract (common, because these fibers pass through the internal capsule, one of the more frequent sites of vascular “accidents”), results in typical response of upper motoneuron lesion:
a) paralysis or paresis
b) spasticity (usually)
c) release of Babinski’s sign

b. corticobulbar tract

1) originates in the primary motor cortex and terminates on alpha motoneurons of the nuclei of the cranial nerves with somatic motor components or on interneurons that project to them

2) control skeletal muscles of the eyes, face, oral cavity, and those supporting the head

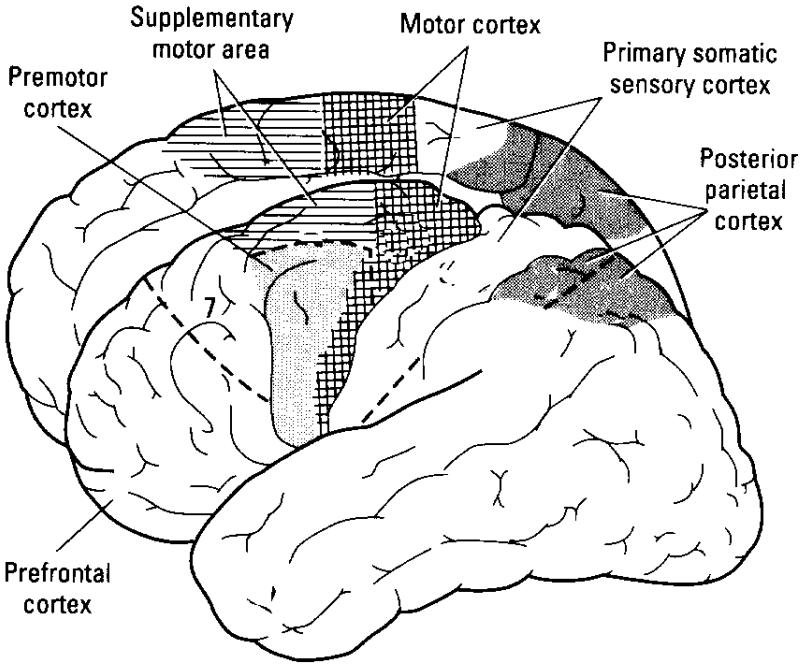
VOLUNTARY MOTOR SYSTEM (continued)

C. Premotor Cortex

1. Projects to primary motor cortex and brain stem (particularly descending reticular formation)

2. Associated with assembling movements into coordinated actions. Lesions impair ability to develop appropriate sequences of muscle contractions

3. Participates in movements that involve several joints and/or are bilateral (i.e., complex sequential movements)



D. Supplementary Motor Area (SMA)

1. Projects to primary motor cortex and brain stem

2. Plans complex movements; becomes active when thinking about movement before movement actually begins

BASAL GANGLIA

Note: Basal Ganglia and Cerebellum do not innervate alpha motoneurons either directly or indirectly through interneurons; instead, they sample the output of the motor cortex and then modify the motor cortex program

A. Structures: certain nuclei

1. at the base of the cerebrum underlying the cerebral cortex
2. in the diencephalon, below the thalamus
3. in the midbrain

BASAL GANGLIA

B. Input and Output

1. Afferent (input): Motor cortex (also other structures)
2. Efferent (output): Thalamus => motor cortex

C. Function

1. Planning and programming of movement

2. Elaborating associated movements (e.g. swinging arms when walking; changing facial expression to match emotion)

3. Moderating and coordinating movement (suppressing unwanted movements)

D. Pathophysiology

1. Classification of abnormalities
2.
   a. hyperkinetic movement: excessive and abnormal movement
      1) chorea: rapid, involuntary movements
      2) atheosis: continuous slow writhing movements
      3) ballismus: involuntary, violent flailing movements

   b. hypokinetic movement:
      1) akinesia: difficulty in initiating movement
      2) bradykinesia: slowness of movement

3. Huntington's disease

   a. characteristics
      1) onset age 30-50
      2) hyperkinetic chorea
      3) eventually dementia

   b. cause: inherited (autosomal dominant)

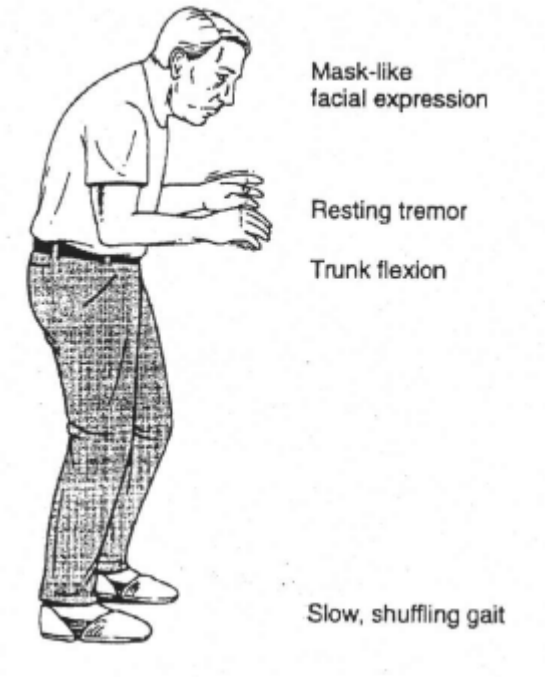
   c. treatment: none; invariably fatal

4. Parkinson's disease

   a. characteristics
      1) akinesia
      2) bradykinesia
      3) loss of associated movements ("reptilian stare")
      4) passive tremor
      5) reflex rigidity

   b. cause
      1) degeneration of dopaminergic neurons in the basal ganglia
      2) side effect of certain tranquilizers
      3) dopamine receptor blockers

   c. treatment



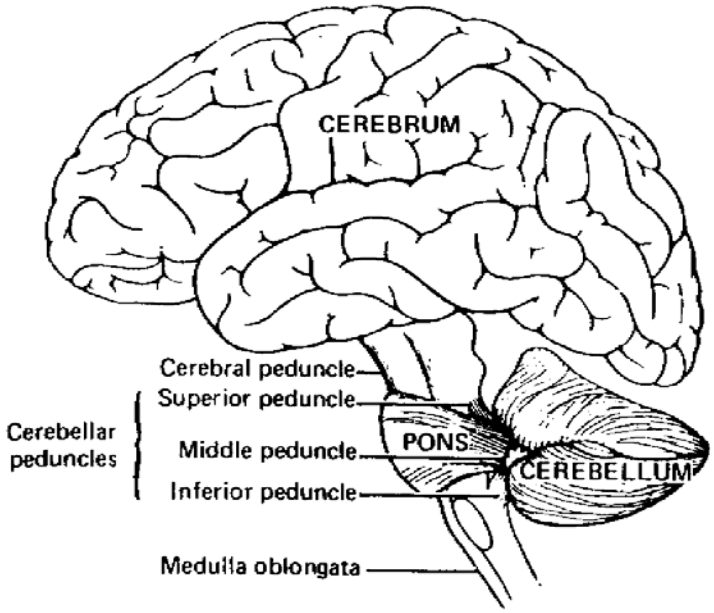
Parkinson's Disease

1) L-dopa

CEREBELLUM

A. Structure

1. Located on top of the pons
2. Communicates with the remainder of the CNS by way of the cerebellar peduncles



B. Input and Output

1. Afferent (input)
   a. motor cortex
   b. proprioceptors, especially from skeletal muscle
   c. vestibular organs (balance)

2. Efferent (output)
   a. motor cortex by way of the thalamus

C. Function

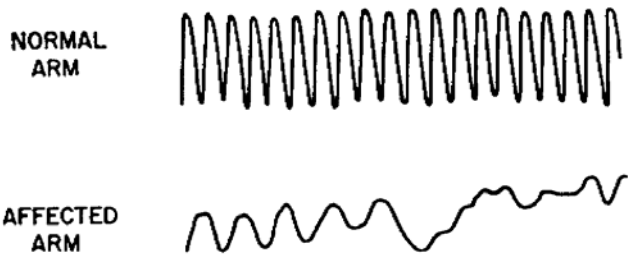
1. Equilibrium and balance
2. Postural muscle tone
3. Comparison of actual movement (proprioceptors) with desired movement (motor cortex) and adjustment of movement timing, direction, and force
4. Motor learning (manual dexterity acquisition)

CEREBELLUM (continued)

D. Pathophysiology

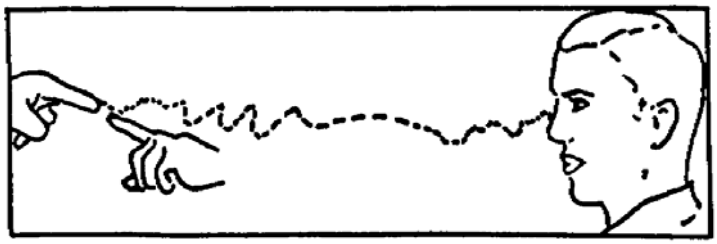
1. Deficits apparent only upon movement
2. Ataxia
3. Intention tremor
4. Bradykinesia (inability to perform rapid movements)

   Example: alternating pronation and supination of hand

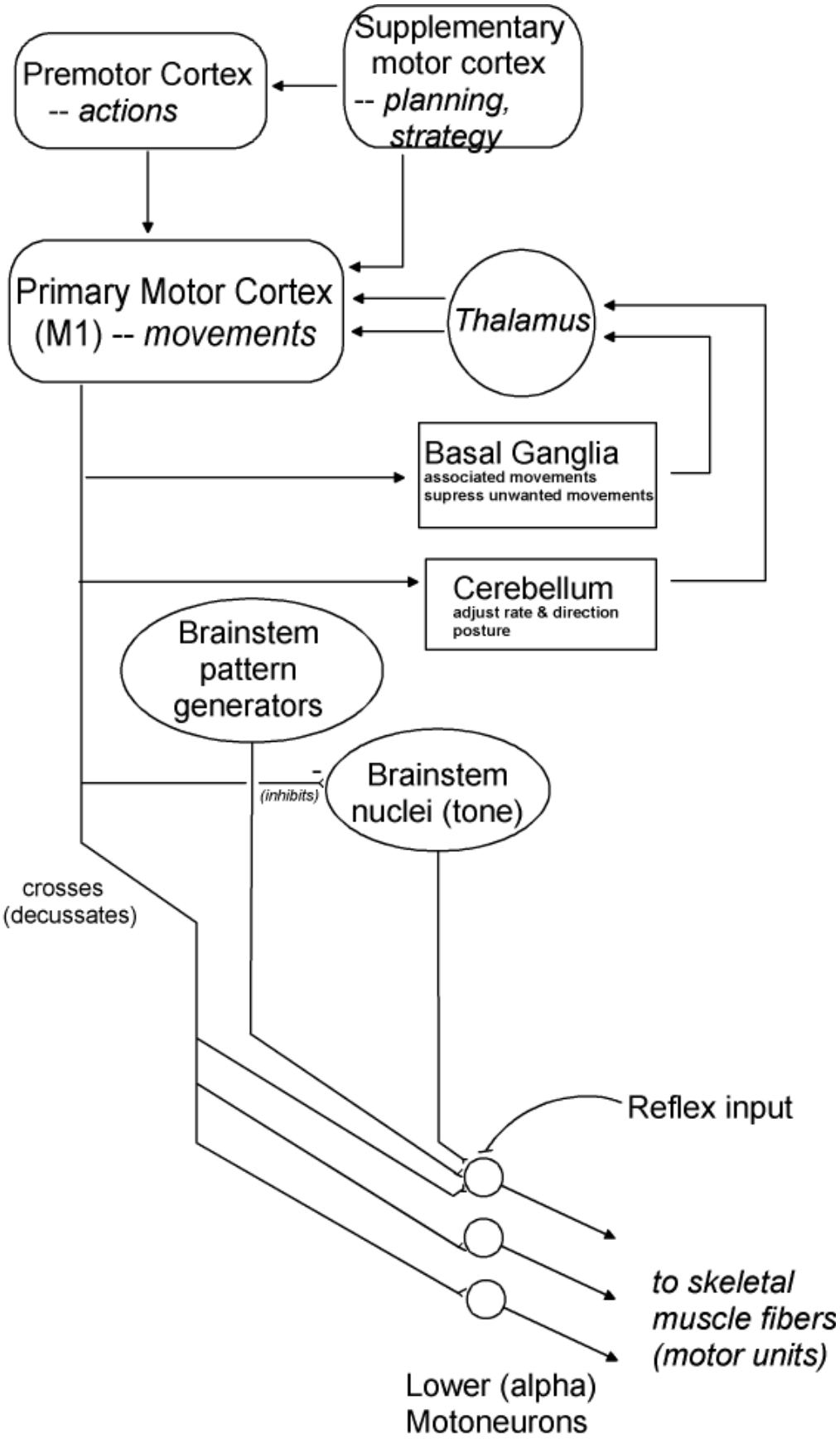


5. Dyskinesia (past pointing)

   Example: nose-finger tracking



6. Decomposition of movement


Supplementary motor cortex -- planning, strategy
Premotor Cortex -- actions
Primary Motor Cortex (M1) -- movements
Thalamus
Basal Ganglia
associated movements
supress unwanted movements
Cerebellum
adjust rate & direction
posture
Brainstem pattern generators
(inhibits)
Brainstem nuclei (tone)
crosses (decussates)
Reflex input
to skeletal muscle fibers (motor units)
Lower (alpha) Motoneurons