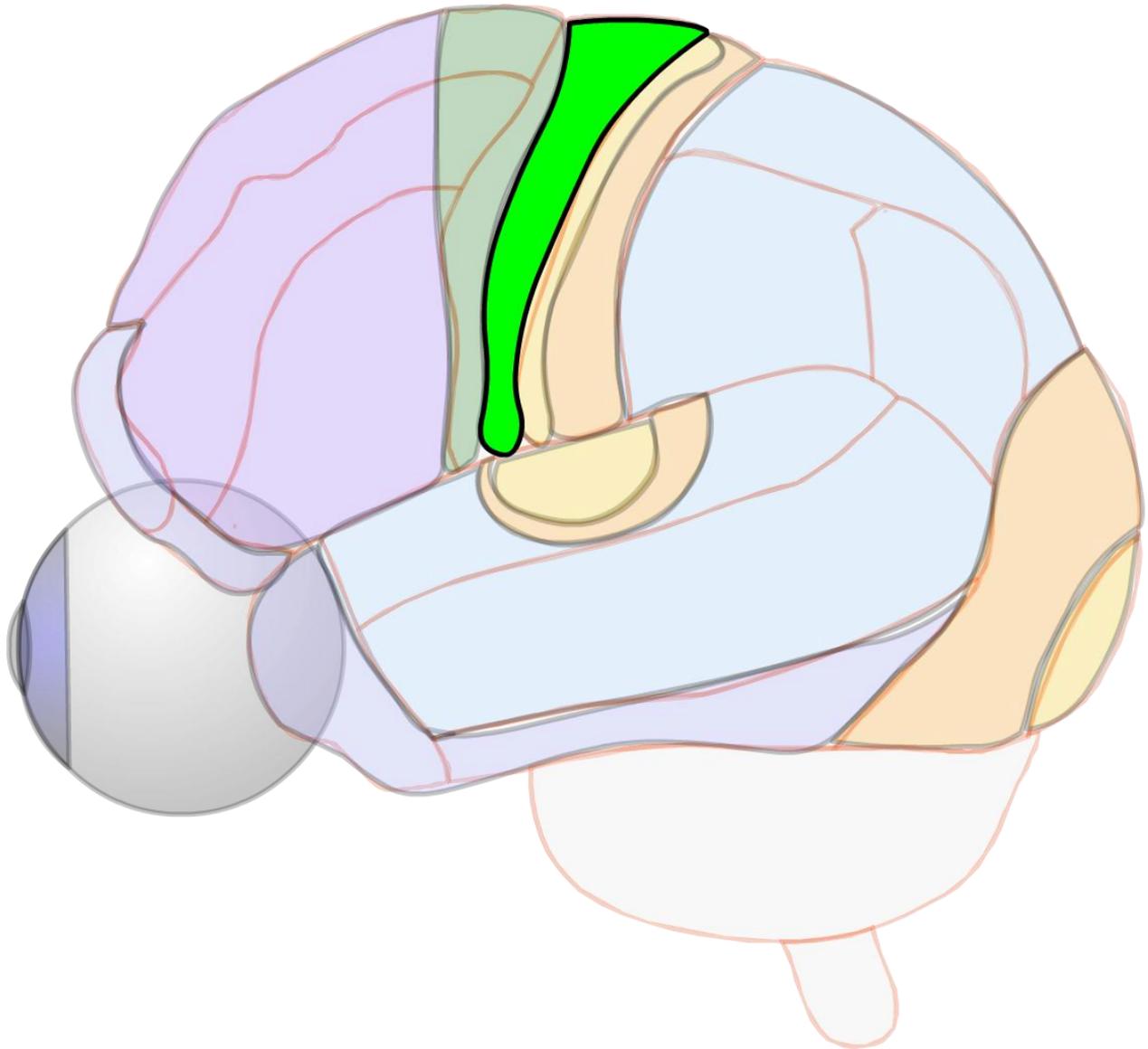


# Motor Cortex



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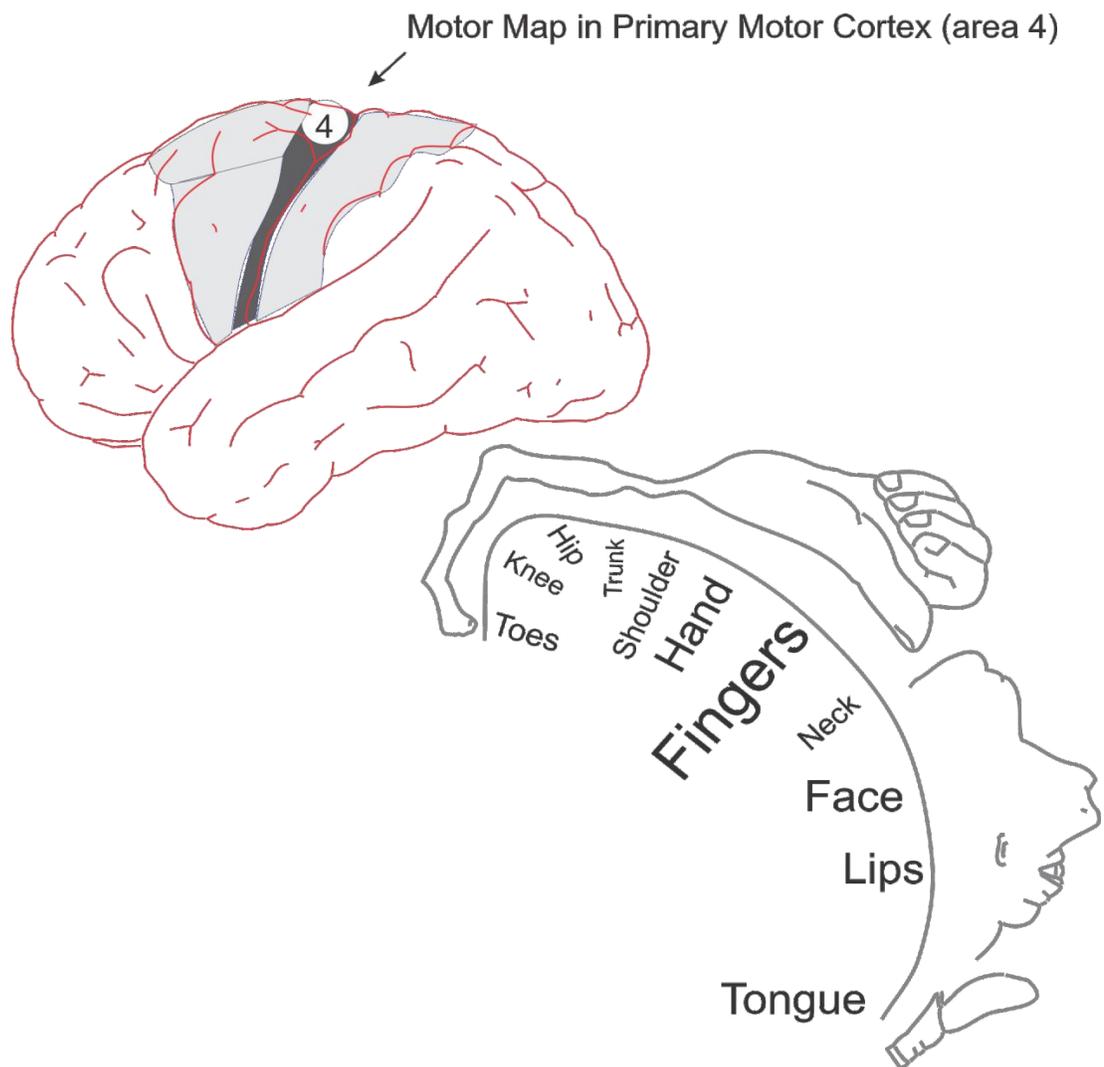
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## Characteristics

The primary motor cortex, which is located in area 4, along the precentral sulcus, mirrors the somatosensory map located in the postcentral sulcus. Leg muscle contraction is represented medially and face muscle is represented laterally. The map is also distorted like the somatosensory map, with a large representation of the hand and face. These large representations permit fine control of individual muscles of the hand and face.

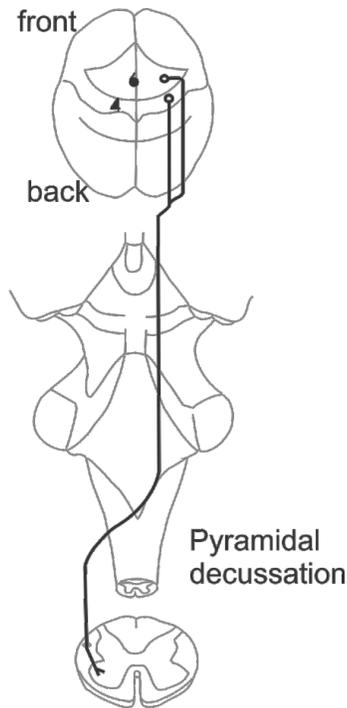
There is some evidence that the areas expand with use. In professional right-handed violinists, the representation of the finger digits are more expanded on the left side.

An epileptic seizure follows this topology. If the seizure starts with finger flexion, it spreads to cause wrist contraction, then elbow contraction, etc.



## Corticospinal tract

### Lateral Corticospinal



#### 1) *Lateral corticospinal tract*

This is the larger with 70-90% of the fibers.

It originates from the premotor cortex (6) and the primary motor cortex (4).

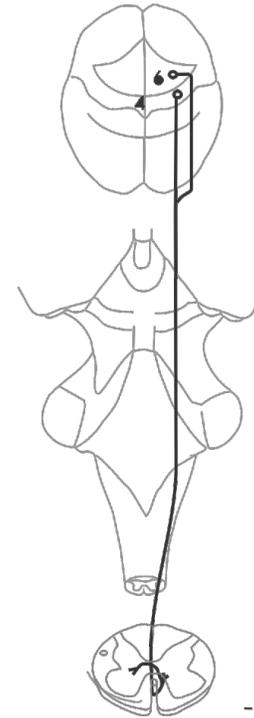
It crosses at the pyramidal decussation. It projects to the lateral motoneurons. Some fibers make monosynaptic connections on motoneurons of distal muscles.

This enables fine independent finger movements.

It is not fully developed at birth.

It is most highly developed in primates.

### Anterior Corticospinal



#### 2) *Anterior (ventral) corticospinal tract*

This remains uncrossed until the spinal cord.

Here bilateral & polysynaptic connections are made on medial motoneurons of proximal/axial muscles.

These muscles are used primarily for posture.

## The homunculus on the cortex is a map.

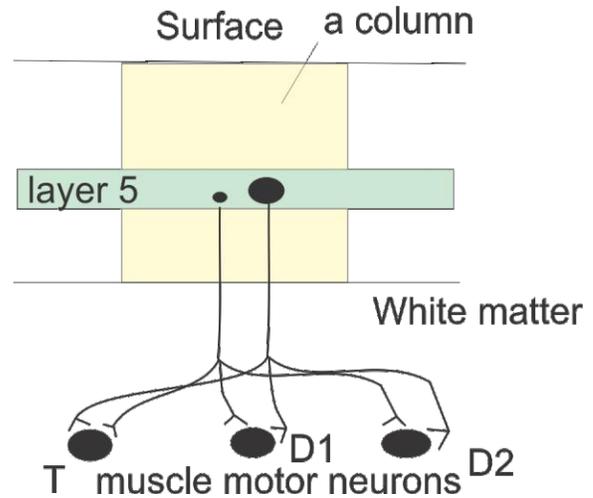
What does the map represent? There are two theories.

*The old theory:* it is a map of the body's muscles.

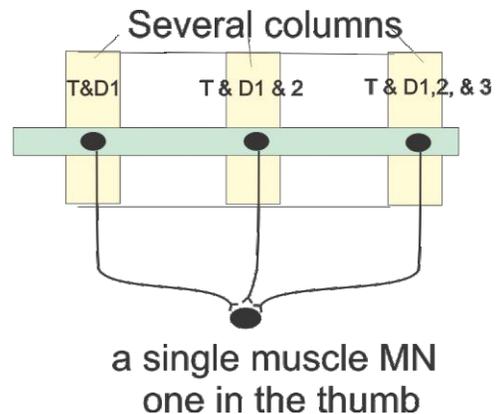
*The new theory:* it is a map of the body's movements.

## Columnar organization

Cells in the same column influence common synergistic muscles. Synergistic muscles are those that act together - cooperate in a movement. An example of synergistic muscles is those muscles that you contract to hold a bottle.



A single muscle can be activated by a colony of columns. This is because a single muscle may be a synergist in a variety of different movements. For example to pick up a bottle, the thumb may be used with digit 1 or with digits 1 and 2 or with digits 1, 2, and 3.



## Two functions of area 4 corticospinal neurons

### *Function 1: activity initiates movements.*

This is based on input from area 6 where planning related activity precedes movements by up to 800msec.

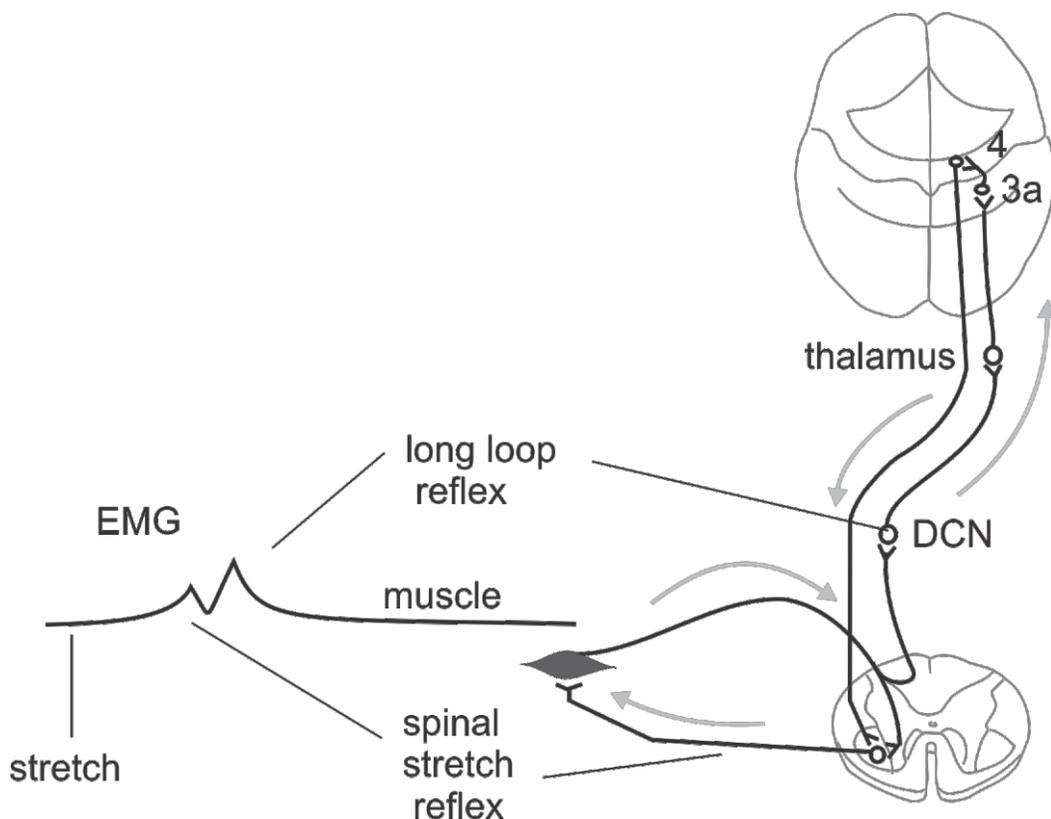
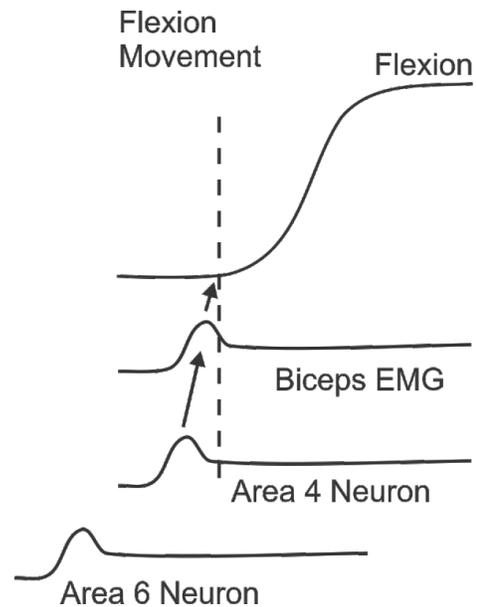
Both alpha and gamma motor units in muscles are activated.

The firing rate determines the magnitude muscle force and its rate of change.

### *Function 2: neurons contribute to the stretch reflex.*

The muscle stretch activates two responses:  
i) the spinal monosynaptic stretch reflex and ii) the cortical long loop response.

Long loop responses are under voluntary control. The responses are set, or context dependent, and are controlled by the cerebellum. This is what adds learnt motor skills to our responses. A good example of a learnt motor skill is catching a ball. The catch is pre-set to the expected characteristics of the ball. The long loop response becomes larger if it is best to resist the stretch, and smaller if best to give way.



## Upper motor neuron lesions

This is a lesion of neurons in the cortex or their axons (e.g. in the spinal cord).

*If the lesion is small:* The only long lasting effect may be the loss of refined movement; e.g. unable to make independent finger movements.

*If the lesion is extensive:*

Initially one observes flaccid paralysis (& loss of muscle tone). Later, one observes spasticity because of increased motor neuron sensitivity to remaining inputs (e.g. from the spinal reflexes and brain stem nuclei).

Symptoms include:

- 1) hypertonia and spasms
- 2) hyper-reflexia (joint feels stiff if displaced quickly because of hyperactive stretch reflex) and clonus (i.e. tremor)

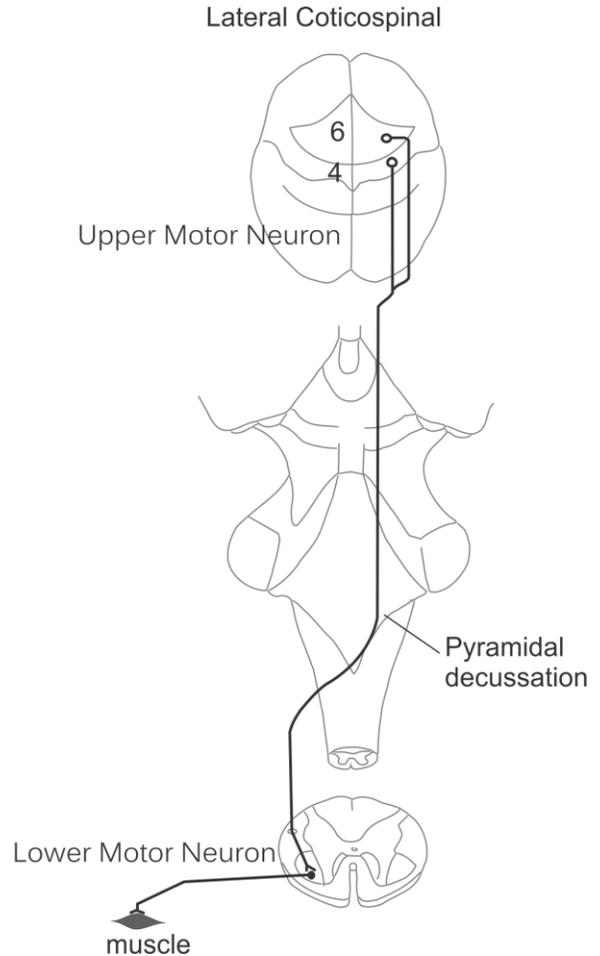
- 3) Babinski sign (extension of big toe which is also observed in infants before the growth of the corticospinal tract is complete)

- 4) no fasciculations

- 5) no muscle atrophy

**Spasticity** is an excessive contraction initiated by stretch. The strength of the contraction is dependent on how fast the stretch is.

**Rigidity** is a constant elevated muscle tone that occurs in diseases of the Basal Ganglia. The strength of the contraction is independent of how fast the stretch is.



## Lower motor neuron lesions

This is a lesion of motoneurons or their axons (e.g. poliomyelitis)

Symptoms include weakness or paralysis of isolated muscles which are flaccid.

Other symptoms are:

- 1) hypotonia

- 2) hypo-reflexia

- 3) no Babinski sign

- 4) After motor neuron irritation, fasciculations are visible which are spontaneous firings of motoneurons.

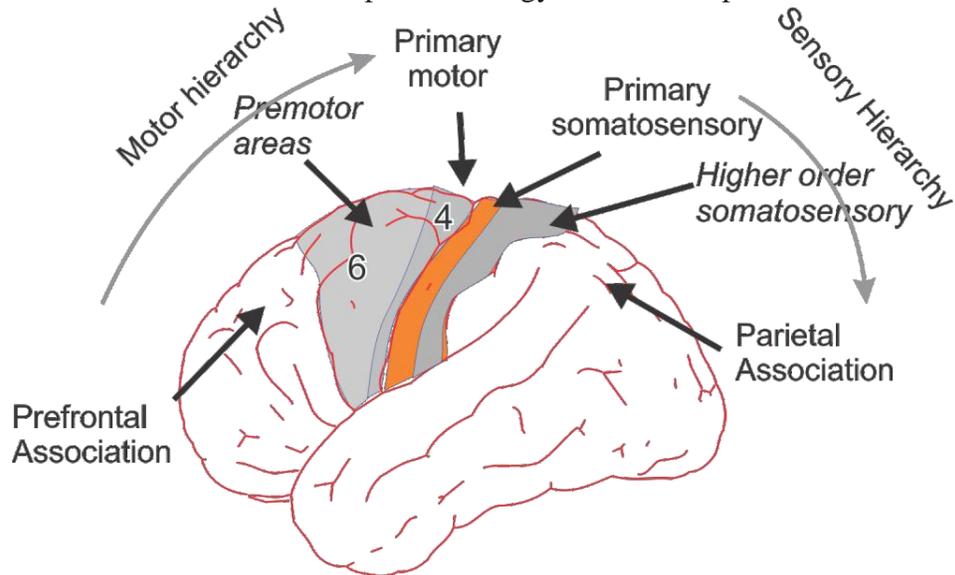
After motor neuron death, fibrillations can be recorded which are spontaneous contractions of muscle fibers.

- 5) atrophy (loss of mass).

## A puzzle

Recall that the signals from the muscle spindles and the receptors for the sense of touch form a map of the body in the somatosensory cortex located in the postcentral gyrus. The control of the body's muscles originates from the primary motor area located in the adjacent precentral gyrus. One might therefore think that the bulk of the connections from the postcentral gyrus would be in a forward direction to the precentral gyrus. But this is not the case.

Rather, the bulk of the fibers from the post central gyrus head in a posterior direction. Why is this?

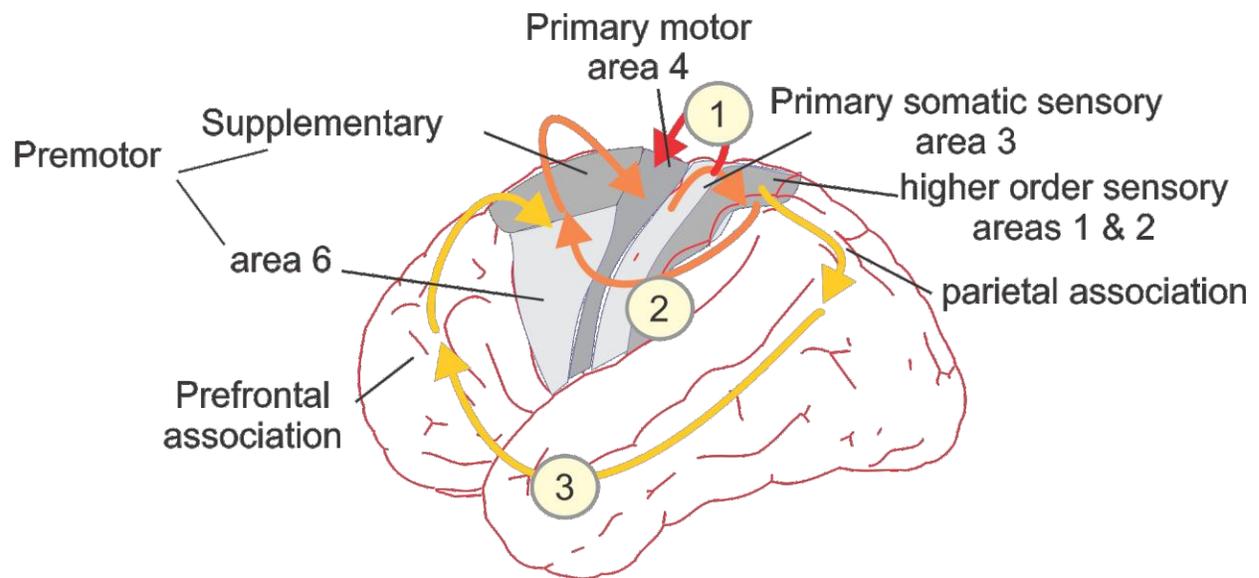


## The answer

*Sensory hierarchy:* Primary sensory areas send information to higher order areas and then to association areas.

*Motor hierarchy:* Primary motor areas receive information from premotor areas which in turn receive info from the prefrontal association areas

An example of 3 cortical pathways that contribute to picking up a cup



**Loop 1:** This cortical “long loop” response is used for simple acts, like quickly regulating the pressure on the cup.

The primary somatosensory cortex senses finger position from muscle afferents and pressure from touch receptors.

The primary motor cortex signals the contraction of individual synergistic muscles.

**Loop 2:** This longer loop is used in more complex acts like selecting a muscle synergy (which fingers to contract together to lift the cup).

Higher order areas contribute to the recognition of shape and texture by touch. The premotor area selects the synergy appropriate for that shape and texture.

**Loop 3:** This longest loop is used for still more complex acts like reaching for the cup. When reaching for a phone, the parietal association areas integrate touch and vision while focusing attention on the phone.

Prefrontal association area helps one decide whether the appropriate action is to reach for the ringing phone.

## Function of the intra-parietal sulcus (IPS)

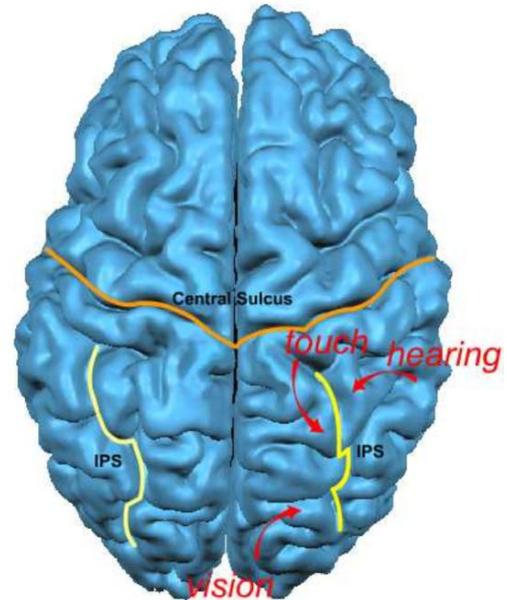
Recall that visual information separates into two streams: a **ventral** stream through which one perceives objects and a **dorsal** stream that projects along the IPS and directs actions.

The IPS, located in the parietal association areas, **integrates** the senses to code, and to **attend** to the location of targets for action.

Locations can be **seen, felt, or heard**. These locations undergo coordinate transformations in the IPS with the help of the cerebellum.

When one looks at an object, its location is coded with respect to the retina. To reach for the object the current location of the arm and eye must be coded. The transformation of these locations into appropriate coordinates is the function of the parietal cortex.

Patients with lesions here have various ataxias; difficulty in accurately directing gaze (i.e. making saccades), grasps, reaches, and feeding.



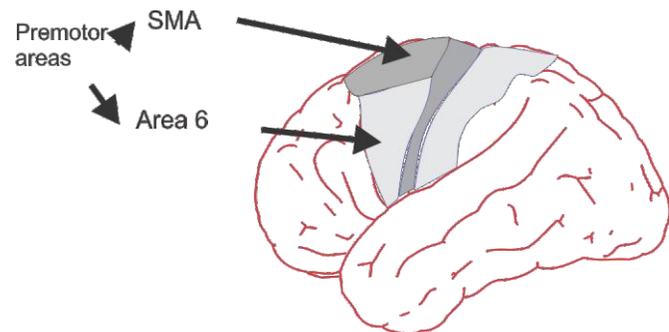
## Function of the premotor area

The premotor area is subdivided into:

- 1) supplementary motor area (SMA)
- 2) Area 6.

Area 6, together with the basal ganglia, is involved in the selection of movements to external cues.

The SMA is involved in the selection of movement sequences from internal cues (i.e. memory).



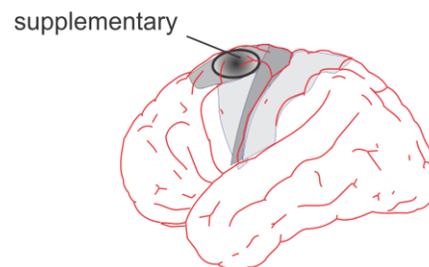
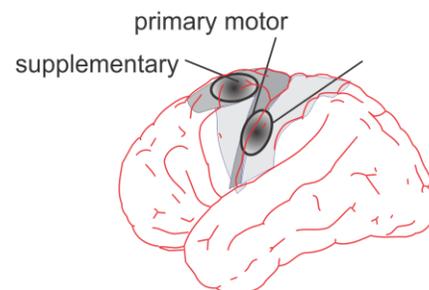
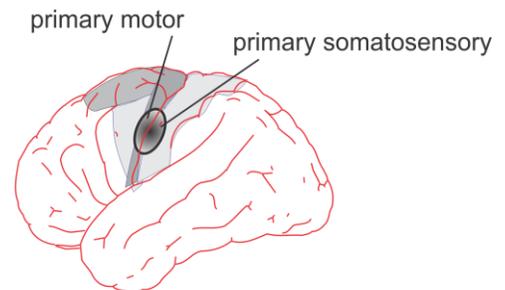
## Function of supplementary motor cortex (SMA)

Neural activity is measured with PET by using radioactive tagging or with functional MRI, which images blood flow, and also offers much higher resolution.

a) When the subject makes a simple finger movement, activity is seen in the finger area of the primary motor cortex and the primary somatosensory cortex.

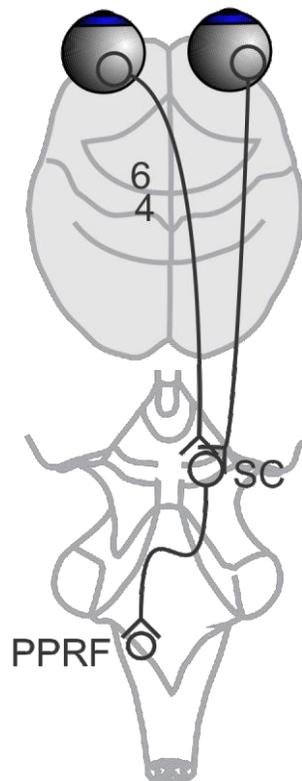
b) When the subject makes a complex finger movement sequence, such as opposing thumb with each finger in turn, activity is seen in the finger area of the primary motor cortex, the primary somatic sensory cortex, and the supplementary motor area.

c) When the subject imagines the same complex finger movement sequence, activity is seen only in the supplementary motor area.

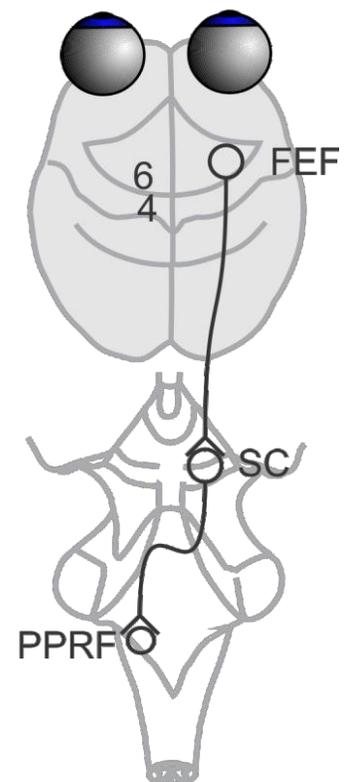


Supplementary activity is seen when making a sequence with either hand (as opposed to primary motor activity which is always contra-lateral). This bilateral activity is useful in movements that require both hands (e.g. tying one's shoe laces).

## The function of the frontal eye fields



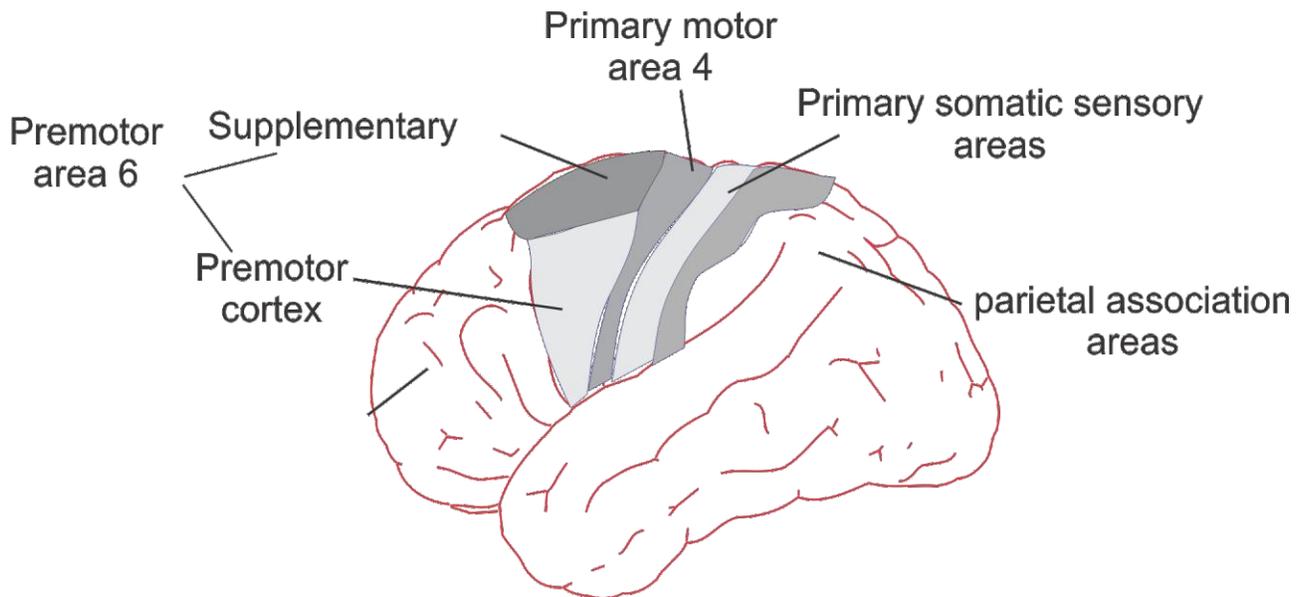
Recall that the superior colliculus (SC) generates rapid reflexive saccades to a flashing/novel visual target; the visual grasp reflex.



The frontal eye fields (FEF) generate voluntary saccades to a remembered target or one selected by attention (via the Intra Parietal Sulcus (IPS)). Patients with frontal eye field lesions cannot voluntarily break fixation.

Both the right SC and right FEF are  
1) activated by targets on the left and  
2) project to the left paramedian pontine reticular formation (PPRF),  
The left PPRF generates a saccade to the left.

## Summary of cortical lesions affecting motor function



**Primary motor cortex (area 4):** Patient's fingers lack precise coordination. Patient cannot precisely contract just one digit or a particular group of digits.

**Premotor cortex (lateral area 6):** Patient cannot initiate the movement the patient wishes to make. Patient exhibits motor apraxia (defect in motor performance without paralysis) because the selection of a particular movement is impaired.

**Supplementary motor area (medial area 6):** Patient cannot tie shoe laces (impaired selection of a particular movement sequence).

**Parietal association:** Patient has no sock on one foot because of sensory neglect. Patient has ataxia (inaccurate movements)

**Somatosensory cortex:** Patient must look to sense where the hand is. Loss of proprioception results in a reluctance to use affected limb.

## Practice problems

1. The supplementary motor area is activated when a subject
  - a) flexes his finger.
  - b) performs a complex finger movement sequence or when he only thinks about the sequence.
  - c) only thinks about a complex finger movement sequence but not when the subject actually makes the movement sequence.
  - d) makes a complex finger movement sequence but not when he only thinks about the movement sequence.
  - e) touches an object with his fingers.
  
2. A large lesion of the motor cortex produces
  - a) muscle fiber twitches (fasciculations).
  - b) hypertonia in antigravity muscles.
  - c) muscle atrophy.
  - d) a negative Babinski sign.
  - e) normal reflex responses to muscle stretch.

Answers

1. b)
2. b)

See also: <http://www.tutis.ca/NeuroMD/L5Motor/MotorProb.swf>