Motor systems - function

- locomotor, postural
- eye movements
- breathing
- nutritional
- speech and communication
- defense
- reproduction
- manipulation

Movements

- reflexive - fast, involuntary coordinated patterns of muscle contraction and relaxation elicited by peripheral stimuli
- rhythmic - chewing, swallowing, scratching, walking, breathing
- voluntary movements - initiated to accomplish a specific goal

- conscious processes are not necessary for moment-to-moment control of movement

Sensory information are important in movement control

- to trigger behaviorally meaningful motor acts - withdrawal, coughing or swallowing
- to control of an ongoing motor pattern – breathing, locomotion
- to influence the level of activity of one muscle or a group of close synergists – reflexes
- to detect and counteract any disturbance of body posture – skin, vestibular system, vision, proprioreceptors
- when object is held by the fingers – skin receptors

Motor commands

- are derived from sensory inputs (sensorimotor transformations)

Motor learning

Motor unit

- the elementary unit of motor control
- one motor neuron innervates from a few to several thousand muscle fibers

Reflexes

- are automatic, stereotyped movements in response to stimulation of periphery receptors

- but reflexes are flexible - under normal conditions they can be adapted to a task

Proprioreception

- precise information about:
- the length of the muscle and force exerted
- joint position and angel

- e.g. muscle spindle, Golgi tendon organ

The stretch and tendon reflexes

- control the length of the muscle and its prevention from generating excessive tension
- stabilization of posture
- provide a mechanism for compensating for small changes in load and intrinsic irregularities in the muscle contraction

- cutaneous reflexes produce complex movements that serve protective and postural functions

- central motor commands and cognitive processes can alter synaptic transmission in spinal reflex pathway
- e.g. the strength of the monosynaptic reflex declines as we progress from standing to walking to running

Damage to the CNS produce characteristic alterations in reflex responses and muscle tone

- areflexia or hyporeflexia: often indicate a disorder of one or more of the components of the peripheral reflex pathway (also from lesion of the CNS)
- hyperreflexia: indicates the lesion of the CNS

- paresis
- plegia

Central pattern generators

- are neuronal networks capable of generating a rhythmic pattern of motor activity without phasic sensory input (walking, swimming, respiration, ..)
- the basic pattern produced by a CPG is usually modified by sensory information from peripheral receptors and signals from other regions of the CNS

Locomotion

Phases of the step cycle: swing and stance

Locomotion

- important sensory information: proprioception, tactile receptors in feet, visual

- central pattern generators in spinal cord

- mesencephalic locomotor region - initiation and speed
- postural stability during locomotion - corresponding structures
- goal directed locomotion - cerebellum, basal ganglia, sensorimotor areas (motor cortex, posterior parietal cortex)

Posture

- to maintain a **steady stance (body orientation)** in the presence of gravity - tonic activation of antigravity muscles (neck, back and leg extensors)
- to maintain **equilibrium (balance)** during different conditions, e.g. motor planning, anticipatory postural adjustments

- balance control is also influenced by emotional state

- automatic postural response is a synergistic activation of a group of muscles with the goal of maintaining equilibrium, it is not a simple reflex !

Automatic postural responses counteract unexpected disturbances

Stance determines postural response

Postural control

- important afferent information: somatosensory, vestibular and visual

- spinal cord, reticular formation
- cerebellum (vestibulo- and spinocerebellum), basal ganglia

- suplementary motor area, sensorimotor cortex

Voluntary movements differ from reflexes

- are initiated by an internal decision to act
- involve choices between alternatives
- are organized to achieve some goal in the near or distant future
- context-dependent associations with sensory inputs
- the effectiveness improves with experience and learning

Control of motor behaviour

- involves a sequence of neuronal operations that select, plan and execute a movement
- **parietal, premotor, prefrontal and primary motor regions** of the cerebral cortex

- the **primary motor cortex** plays an important role in the generation of motor commands
- corticospinal pathway: from primary motor cortex, premotor cortices and parietal cortex

Direct and indirect pathways

- fine and precise finger movements – direct corticospinal tract to the lateral alpha motoneurons
- postural adjustment – indirect pathways to the medial alpha motoneurons (through interneurons bilaterally)

Grasping

- intention – motivational subcortical areas
- identification and localization of the object in space – posterior parietal cortex
- planning – premotor cortex and SMA
- choosing the proper motor program from cerebellum and basal ganglia
- movement execution – primary motor cortex and premotor cortex (area 6)

Cerebellar functions

- control of balance and muscle tone
- movement error correction, movements coordination
- motor learning
- motor planning and movement execution
- cognitive functions:
  - timing of serial events
  - judging the elapsed time in cognitive tasks
  - comparing speed of moving objects
  - word-association task

Cerebellum - motor learning

Cerebellar dysfunction

1) hypotonia (pendular reflexes)

2) ataxia of stance (astasia) and gait (abasia)

3) ataxia = abnormal execution of multi-jointed voluntary movements

dysmetria, dysdiadochokinesis

4) intention tremor

Basal ganglia

Major functional roles of the basal ganglia

- selection of appropriate voluntary movement, and the simultaneous suppression of unwanted movement
- action selection, execution of automatic movements
- control of motivated behaviour, mood → adaptive shaping of behaviour and action selection
- motor (skills) and non-motor (habits) learning

Bazal ganglia disorders

- hypokinetic syndrom - akinesis, bradykinesis, rigidity, tremor (resting)
- hyperkinetic syndrom - hypotonia, dyskinesis (e.g. chorea, ballism)

The control of gaze

- conjugate X disconjugate
- six extraocular muscles

form three complementary

pairs, that are controlled by

three cranial nerves

Saccadic eye movements

To redirect the fovea on visual target in the environment

- shift the fovea rapidly to a visual target
- driven e.g. by the existence of object of interest in the visual field

Smooth pursuit movements

To keep the fovea on visual target in the environment.

- keep the image of a moving target on the fovea
- driven by slow moving object

Vestibulo-ocular reflex

To stabilize the eye during head movement.

- i.e. to hold images still on the retina during brief head movements
- driven by signals from the vestibular system

Optokinetic reflex

To stabilize the gaze

- i.e. to hold images during sustained head rotation or translation
- driven by visual stimuli

Vergence eye movements

To keep the fovea on visual target in the environment.

- move the eyes in opposite directions while redirecting gaze from near to far point → the image is positioned on the same place on both foveae
- driven by retinal disparity

Fixation system

- hold the eyes still during intent gaze
- this requires suppression of eye movement

Eye movements control

- **motivational systems -** choose significant objects in the environment as target for eye movements
- cortex: posterior parietal (area 7) - attention

  frontal eye field (area 8) – motor commands

  → superior colliculus

  → brain stem - reticular formation - motor programming: eye position and velocity