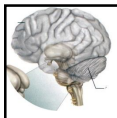

The Roles of The Nervous System In Fatigue

Historical Perspective

Noakes T.D. How did AV Hill understand the VO_2max and the "plateau phenomenon"? Still no clarity? Br J Sports Med 2008;42:574-580.

- Hill may have been one of the first exercise physiologists to theorize a central processing "governor".

- The irony of Noakes' model is that it is named from the work of Hill, who most exercise physiologists argue provided evidence of muscle and cardio-pulmonary derived causes of fatigue during exercise!

"… it would clearly be useless for the heart to make an excessive effort if by so doing it merely produced a far lower degree of saturation of arterial blood; and we suggest that, in the body (either in the heart muscle itself or in the nervous system), there I some mechanisms which causes a slowing of the circulation as soon as a serious degree of unsaturation occurs, and vice versa. This mechanism would tend to act as a 'governor' maintaining a high degree of saruration of the blood."

Hill AV et al. Muscular exercise, lactic acid and the supply and utilization of oxygen: parts VII-VIII. Proc Royal Soc Brit 1924;97:155-176.

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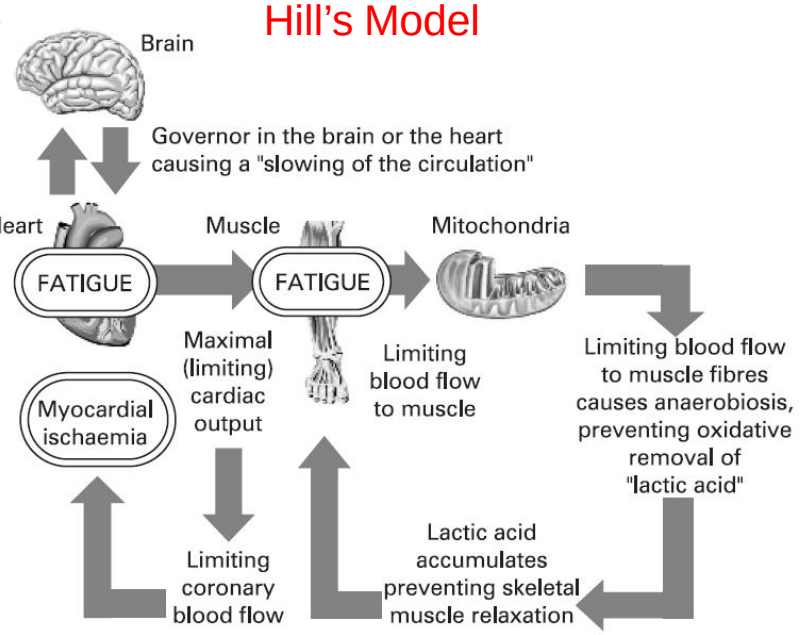
Hill's Model



Noakes T.D. How did AV Hill understand the VO_2max and the "plateau phenomenon"? Still no clarity? Br J Sports Med 2008;42:574-580.

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Classic Exercise Physiology View of Exercise-Induced Fatigue

Experimenter controlled increase in work rate produces linear physiological changes in metabolism/ energy supply, cardiovascular system and body temperature

Fatigue results from a failure to maintain homeostasis either in the active muscles (peripheral fatigue) or in the central nervous system (central fatigue)

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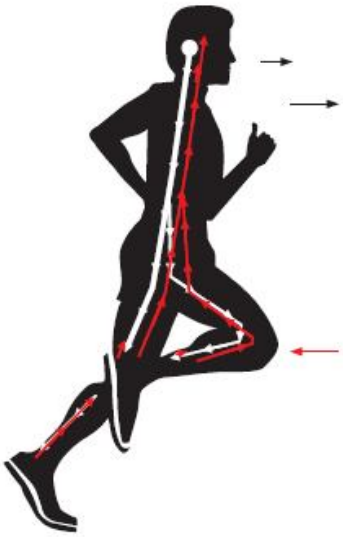
Noakes' Central Governor Model



Physiological and Psychological inputs before exercise:

- Physiological state
- Expected distance/ duration
- Previous experience/ motivation/external competition

Continuous feedback from various body systems is integrated to regulate the exercise intensity by continously modifying the number of motor units recruited in the exercising limbs

Feedback during exercise:

- Fuel reserves
- Rate of heat accumulation
- Hydration state
- Self-belief

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Organization of the Nervous System

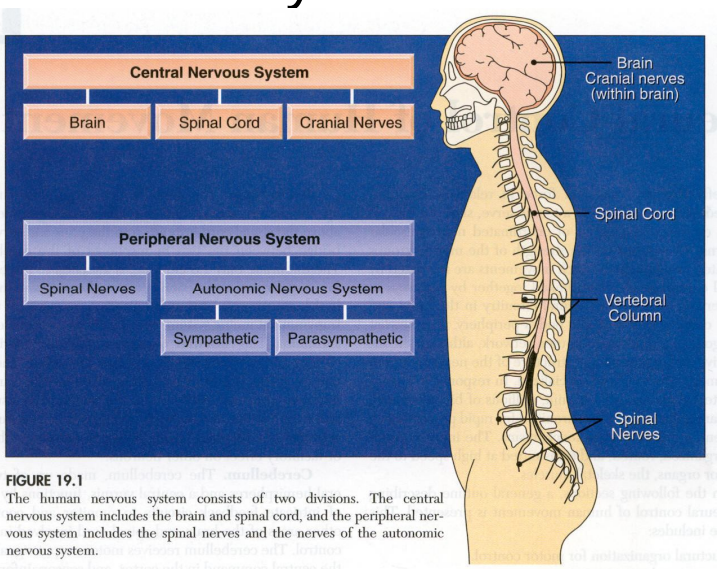

FIGURE 19.1
The human nervous system consists of two divisions. The central nervous system includes the brain and spinal cord, and the peripheral nervous system includes the spinal nerves and the nerves of the autonomic nervous system.

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Major structural divisions of the nervous system

Central nervous system (CNS)	Brain	Gray matter
		White matter
	Spinal cord	Gray matter
		White matter
Peripheral nervous system (PNS)	Nerves	Cranial nerves (12 pairs)
		Spinal nerves (31 pairs)
	Ganglia	

Functional classes of peripheral nerve fibers

Somatic	Sensory
	Motor
Autonomic	Sensory
	Motor

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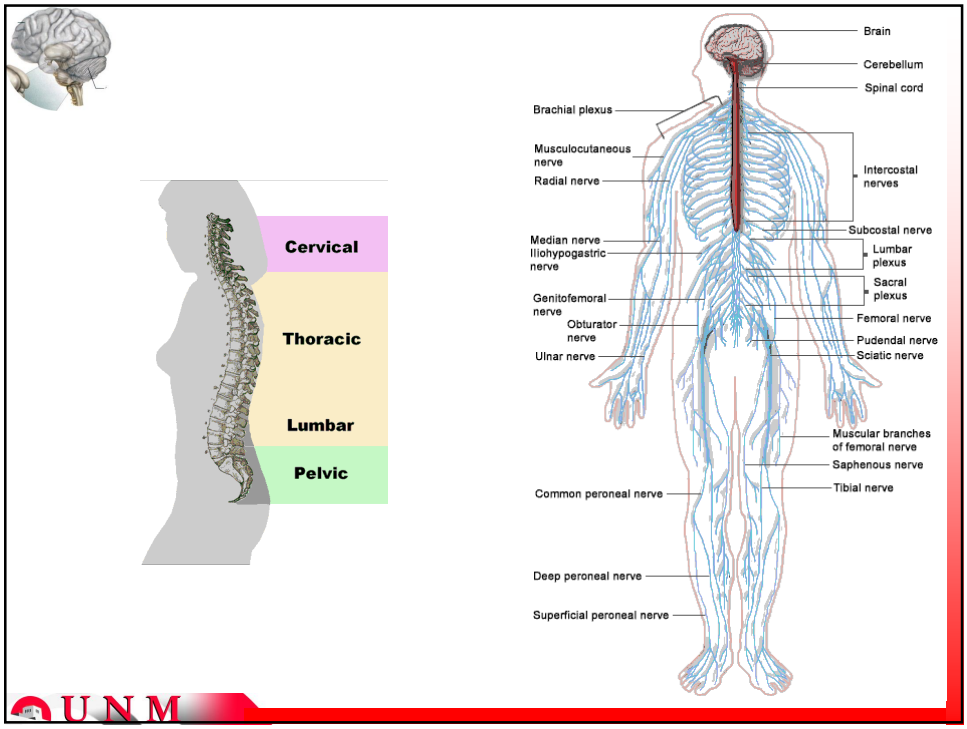
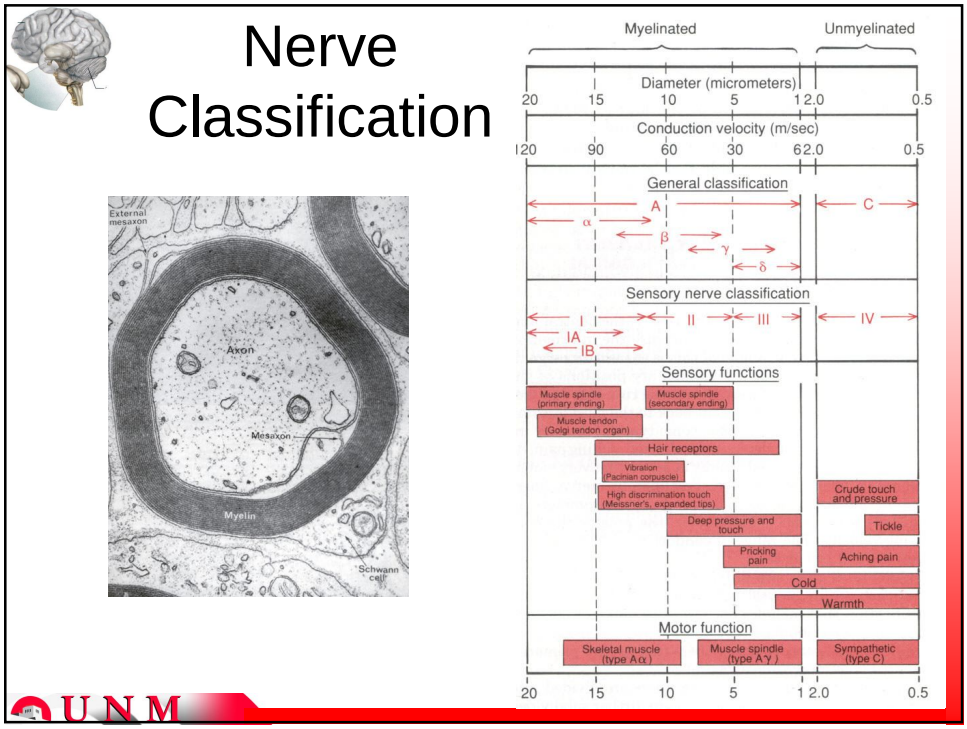
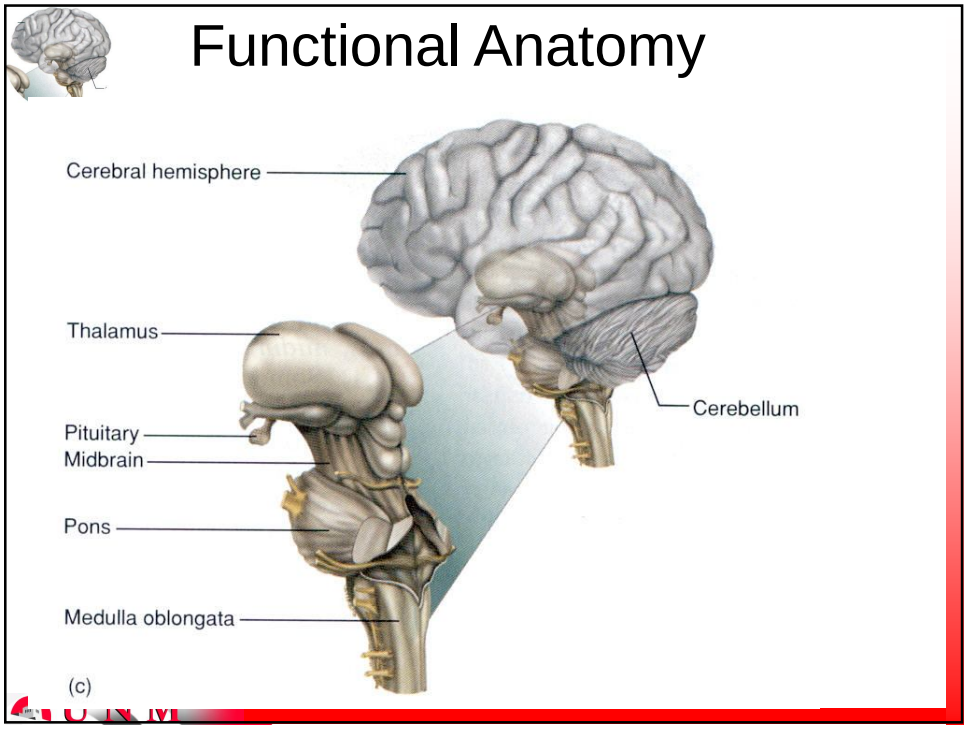
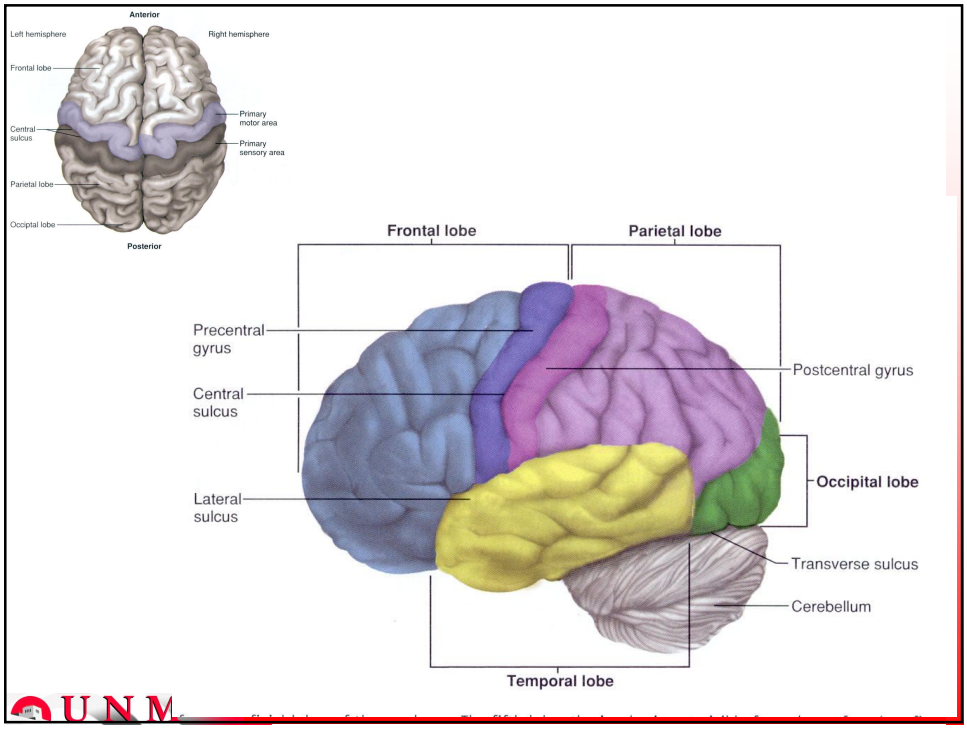
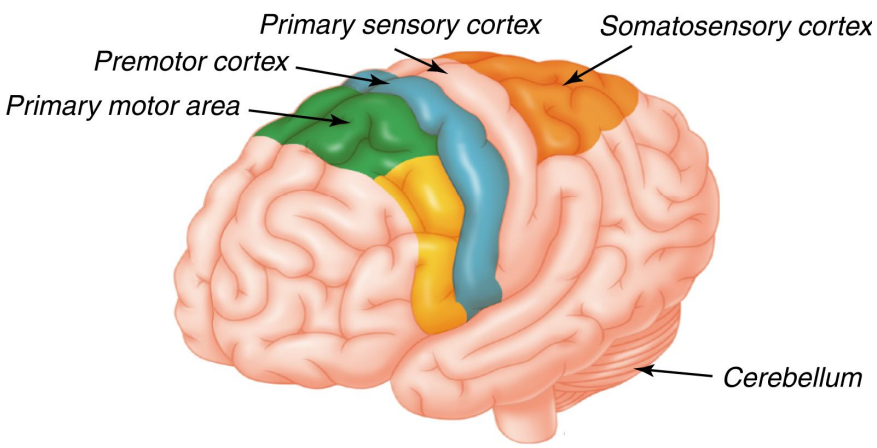

Cervical
Thoracic
Lumbar
Pelvic
Brain
Cerebellum
Spinal cord
Brachial plexus
Musculocutaneous nerve
Radial nerve
Intercostal nerves
Subcostal nerve
Median nerve
Iliohypogastric nerve
Lumbar plexus
Sacral plexus
Genitofemoral nerve
Obturator nerve
Femoral nerve
Ulnar nerve
Pudendal nerve
Sciatic nerve
Muscular branches of femoral nerve
Saphenous nerve
Common peroneal nerve
Tibial nerve
Deep peroneal nerve
Superficial peroneal nerve


Nerve Classification
Myelinated
Unmyelinated
Diameter (micrometers)
20 15 10 5 1 2.0 0.5
Conduction velocity (m/sec)
120 90 60 30 6 2.0 0.5
General classification
A
C
α
β
γ
δ
Sensory nerve classification
I
II
III
IV
IA
IB
Sensory functions
Muscle spindle (primary ending)
Muscle spindle (secondary ending)
Muscle tendon (Golgi tendon organ)
Hair receptors
Vibration (Pacinian corpuscle)
High discrimination touch (Meissner's, expanded tips)
Crude touch and pressure
Deep pressure and touch
Tickle
Pricking pain
Aching pain
Cold
Warmth
Motor function
Skeletal muscle (type Aα)
Muscle spindle (type Aγ)
Sympathetic (type C)
External mesaxon
Axon
Mesaxon
Myelin
Schwann cell


Functional Anatomy
Cerebral hemisphere
Thalamus
Pituitary
Midbrain
Pons
Medulla oblongata
Cerebellum
(c)


Anterior
Left hemisphere
Right hemisphere
Frontal lobe
Primary motor area
Central sulcus
Primary sensory area
Parietal lobe
Occipital lobe
Posterior
Frontal lobe
Parietal lobe
Precentral gyrus
Central sulcus
Lateral sulcus
Postcentral gyrus
Occipital lobe
Transverse sulcus
Cerebellum
Temporal lobe

Motor and Sensory Regions of the Brain



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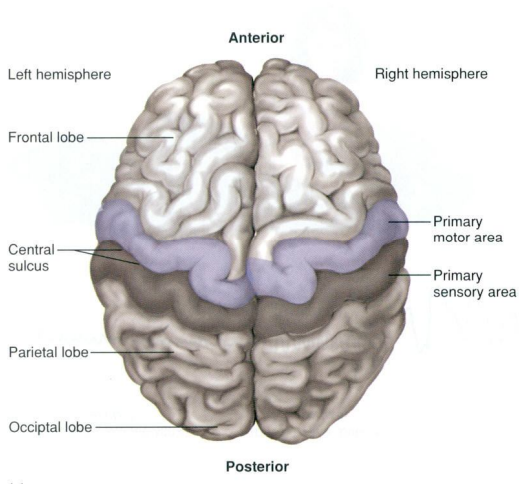
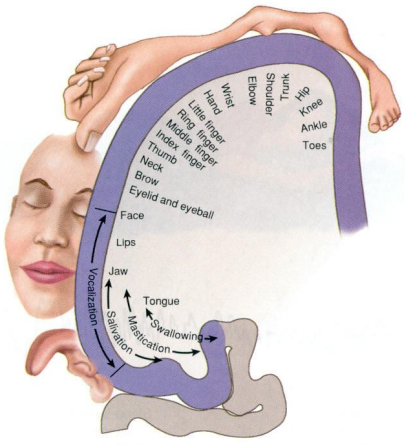
Motor Pathways





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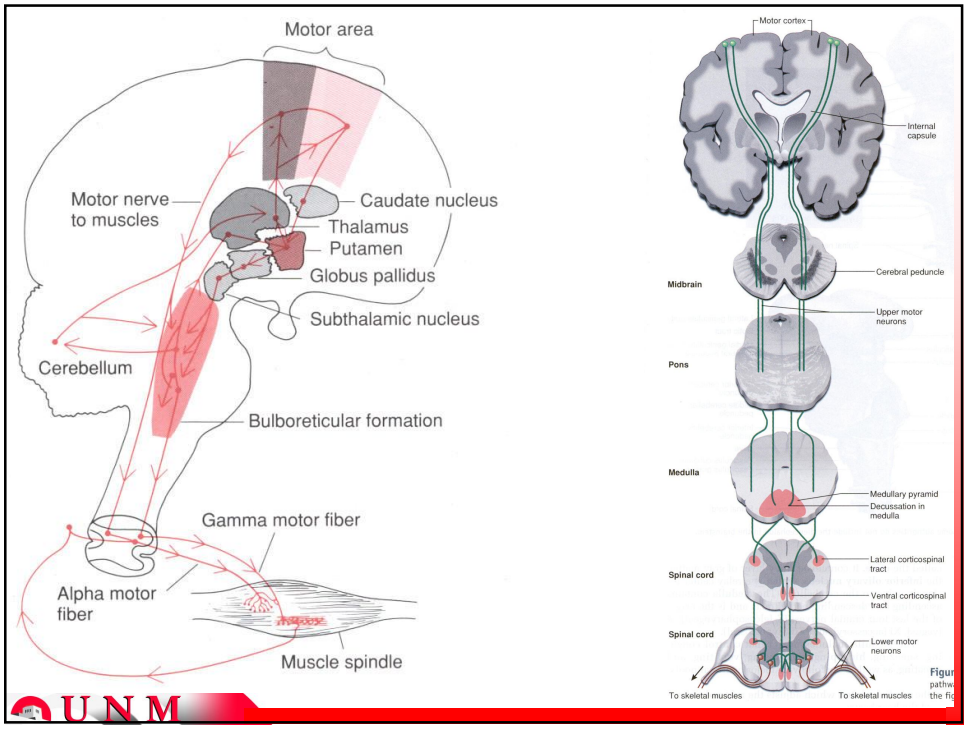

Motor area
Motor nerve to muscles
Caudate nucleus
Thalamus
Putamen
Globus pallidus
Subthalamic nucleus
Cerebellum
Bulboreticular formation
Gamma motor fiber
Alpha motor fiber
Muscle spindle
Motor cortex
Internal capsule
Midbrain
Cerebral peduncle
Upper motor neurons
Pons
Medulla
Medullary pyramid
Decussation in medulla
Spinal cord
Lateral corticospinal tract
Ventral corticospinal tract
Spinal cord
Lower motor neurons
To skeletal muscles
To skeletal muscles
UNM

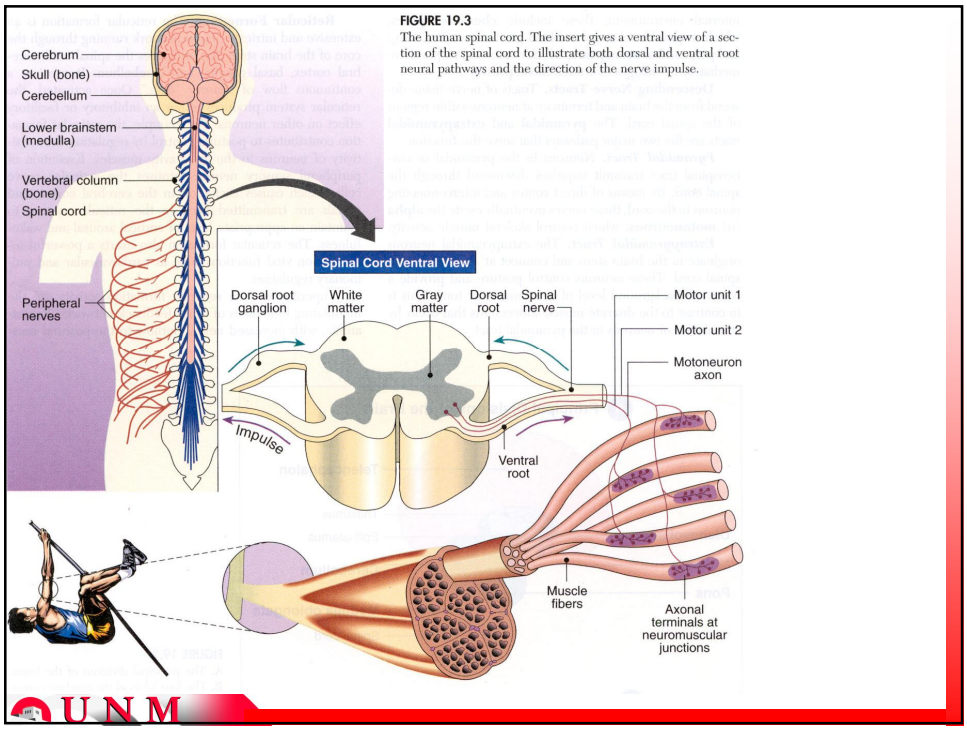
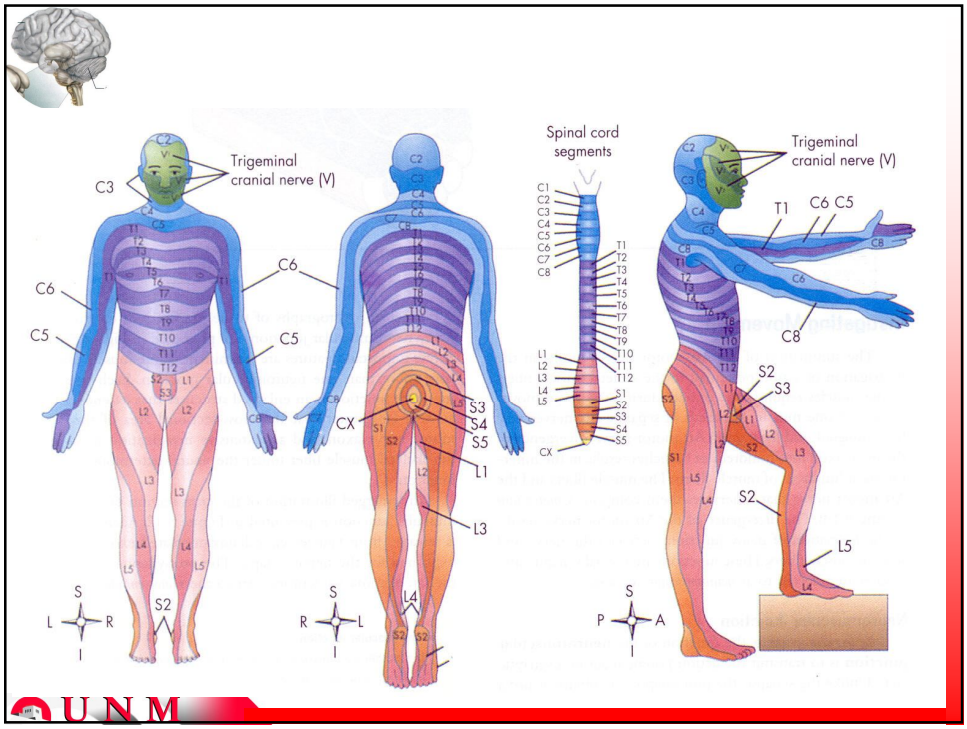


FIGURE 19.3
The human spinal cord. The insert gives a ventral view of a section of the spinal cord to illustrate both dorsal and ventral root neural pathways and the direction of the nerve impulse.
Cerebrum
Skull (bone)
Cerebellum
Lower brainstem (medulla)
Vertebral column (bone)
Spinal cord
Peripheral nerves
Spinal Cord Ventral View
Dorsal root ganglion
White matter
Gray matter
Dorsal root
Spinal nerve
Motor unit 1
Motor unit 2
Motoneuron axon
Impulse
Ventral root
Muscle fibers
Axonal terminals at neuromuscular junctions
UNM



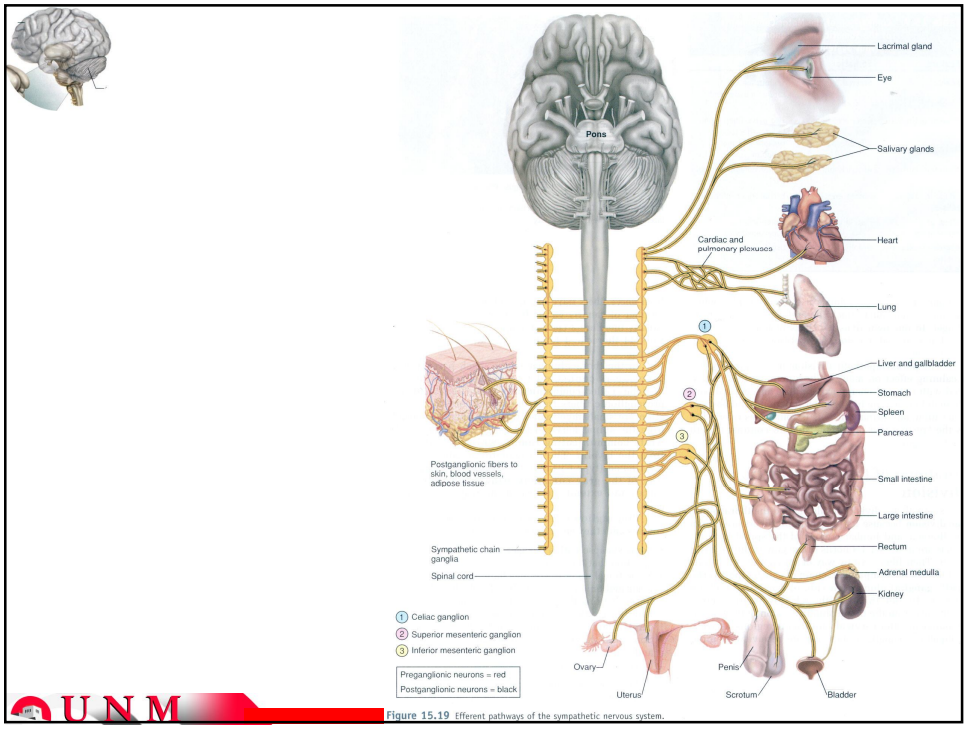
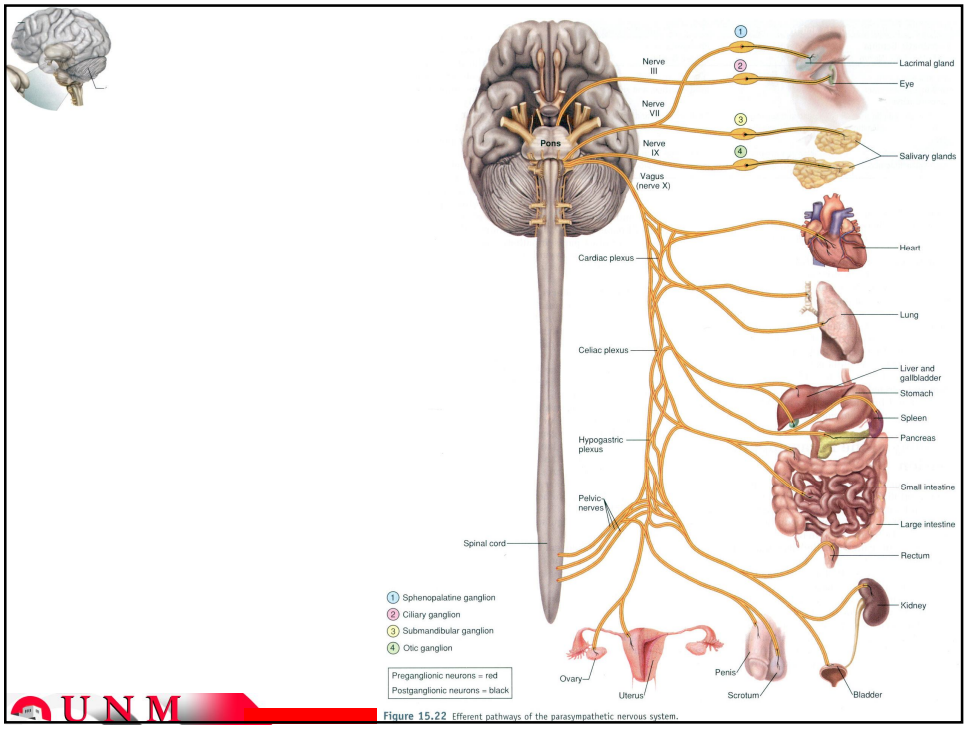
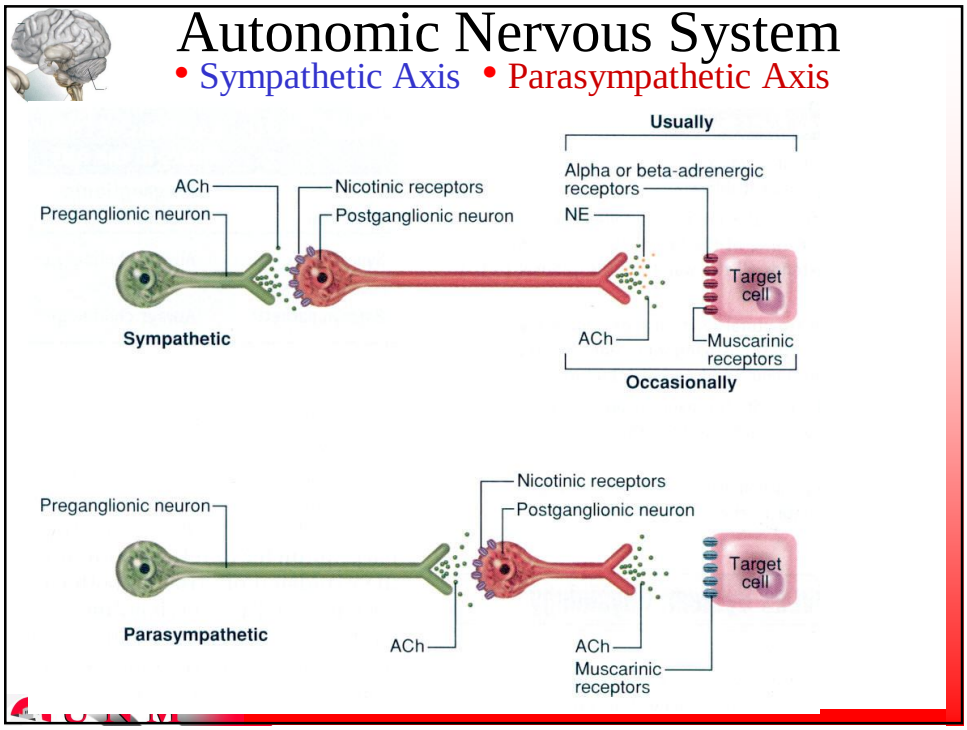
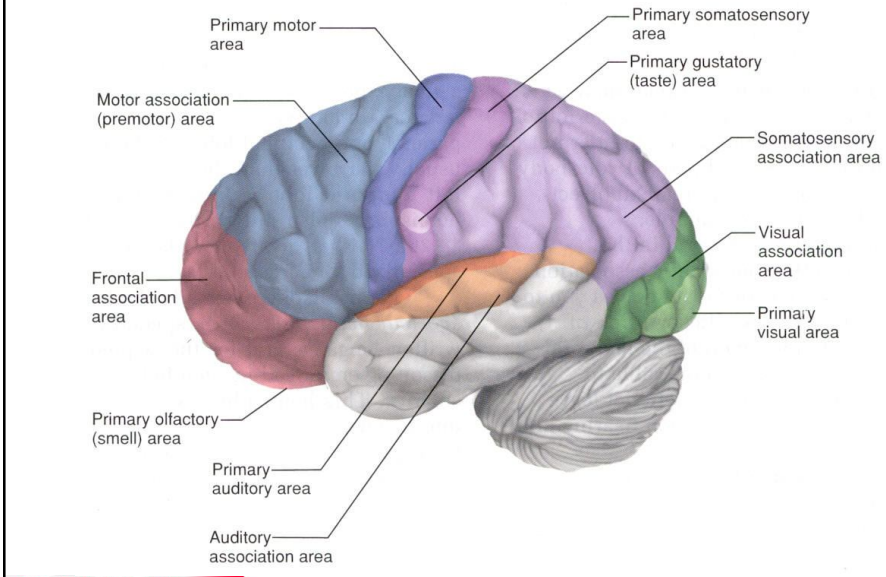


Figure 15.19 Efferent pathways of the sympathetic nervous system.


Nerve III
Nerve VII
Nerve IX
Vagus (nerve X)
Pons
Lacrimal gland
Eye
Salivary glands
Heart
Cardiac plexus
Lung
Celiac plexus
Liver and gallbladder
Stomach
Spleen
Pancreas
Hypogastric plexus
Small intestine
Pelvic nerves
Large intestine
Spinal cord
Rectum
Kidney
1 Sphenopalatine ganglion
2 Ciliary ganglion
3 Submandibular ganglion
4 Otic ganglion
Preganglionic neurons = red
Postganglionic neurons = black
Ovary
Uterus
Penis
Scrotum
Bladder
UNM
Figure 15.22 Efferent pathways of the parasympathetic nervous system.


Autonomic Nervous System
• Sympathetic Axis • Parasympathetic Axis
Usually
ACh
Nicotinic receptors
Preganglionic neuron
Postganglionic neuron
Alpha or beta-adrenergic receptors
NE
Target cell
Sympathetic
ACh
Muscarinic receptors
Occasionally
Nicotinic receptors
Preganglionic neuron
Postganglionic neuron
Target cell
Parasympathetic
ACh
ACh
Muscarinic receptors

Sensory Functions



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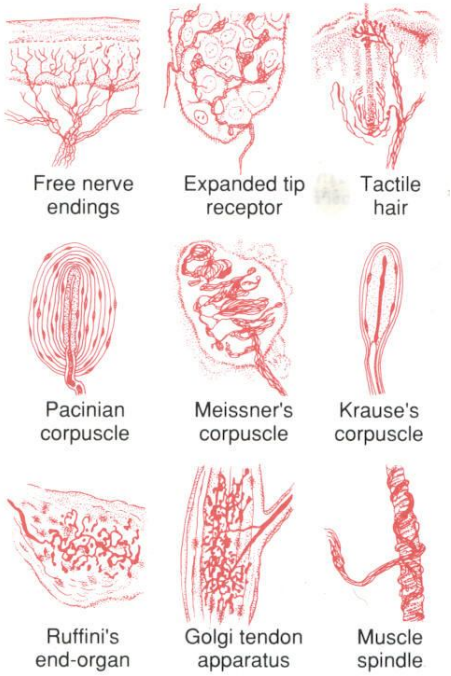

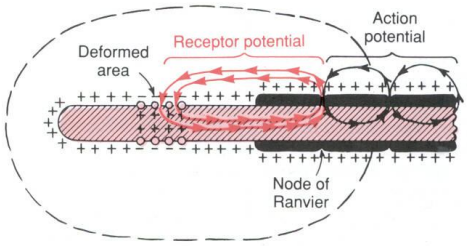

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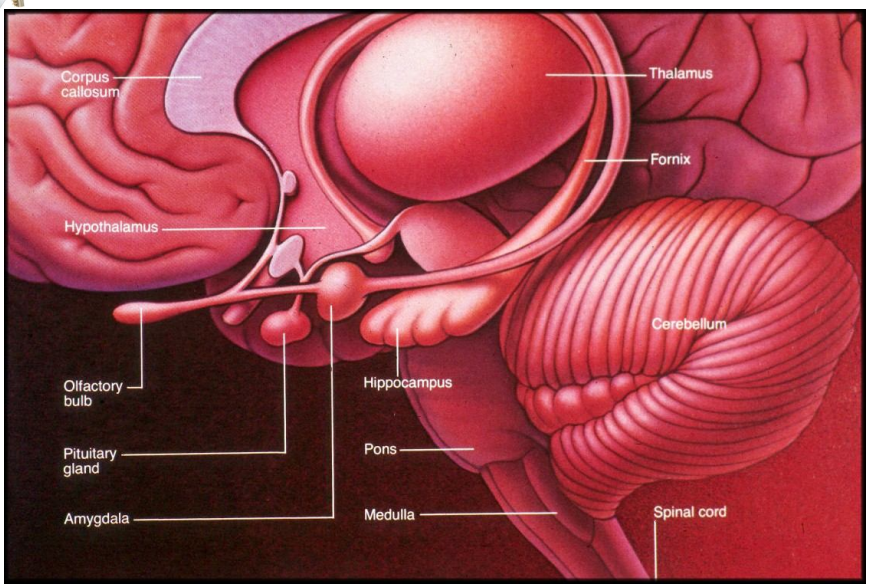
Heat Sensitivity



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- Muscle energy store depletion?
- Muscle metabolite accumulation?
- Acidosis?
- Membrane potential dysfunction?
- Intracellular Ca^{++} issues?
- Motor unit recruitment?
- CNS over-ride (heat, brain fatigue)?

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