NATIONAL REVIEW COURSE

Nervous System

I. Function
   A. The function of the nervous system, along with the endocrine system, is to communicate.
   B. The nervous system is organized to detect changes in internal and external environments, evaluate the information, and initiate an appropriate response.
   C. The nervous system is made up of the brain, the spinal cord, and the nerves.
   D. Animation: “Nervous System Formation.”*

II. Organization of the Nervous System
   A. Central nervous system (CNS)
      1. Structural and functional center of entire nervous system.
      2. Consists of the brain and the spinal cord.
      3. Integrates sensory information, evaluates it, and initiates an outgoing response.
   B. Peripheral nervous system (PNS)
      1. Nerves that lie in “outer regions” of nervous system.
      2. Cranial nerves – originate from brain and brain stem.
      3. Spinal nerves – originate from spinal cord.
   C. Afferent and efferent divisions
      1. Afferent (sensory) division – consists of all incoming sensory pathways.
      2. Efferent (motor) division – consists of all outgoing motor pathways.
   D. Somatic nervous system (SNS)
      1. Somatic motor division – carries information to the somatic effectors (skeletal muscles).
      2. Somatic sensory division – carries feedback information to somatic integration centers in the CNS.
   E. Autonomic nervous system (ANS)
      1. Autonomic motor division – carries information to the autonomic or visceral effectors (smooth and cardiac muscles and glands).
         a. Sympathetic division – prepares the body to deal with immediate threats to the internal environment; produces “fight-or-flight” response.
         b. Parasympathetic division – coordinates the body’s normal resting activities; sometimes called the “rest-and-digest” division.
      2. Autonomic sensory division—carries feedback information to autonomic integrating centers in the CNS.

* http://www.alegent.com/adam/animationplayer/animation_player.html
III. Nerve Cells

A. Neurons – nerve cells responsible for conducting the action potential (nerve impulse).
   1. Cell body – the main mass of the nerve cell; contains the nucleus.
   2. Dendrites – sensory receptors extending from the cell body; bring the action potential into the cell body.
   3. Axon – a long extension of the cell body; responsible for conducting the action potential away from the cell body.
   4. Axon terminal – the far end of the axon; contains synaptic vesicles.
   5. Synaptic vesicles – tiny sacs that contain the neurotransmitters produced by the neuron.

B. Afferent (sensory) neurons – conduct impulses to spinal cord or brain.

C. Efferent (motor) neurons – conduct impulses away from spinal cord or brain toward muscles or glandular tissue.

D. Interneurons – connect PNS neurons to CNS neurons.

E. Neuroglia – supportive cells for the neurons in the central and peripheral nervous systems.

F. Central nervous system glia:
   1. Astrocytes
      a. Star-shaped, largest, and most numerous type of glia.
      b. Cell extensions connect to both neurons and capillaries.
      c. Astrocytes transfer nutrients from the blood to the neurons by forming the blood-brain barrier.
   2. Microglia
      a. Small, usually stationary, cells.
      b. In inflamed brain tissue, they enlarge, move about, and carry on phagocytosis.
   3. Ependymal cells
      a. Resemble epithelial cells and form thin sheets that line fluid-filled cavities in the CNS.
      b. Some produce fluid; others aid in circulation of fluid.
   4. Oligodendrocytes
      a. Hold nerve fibers together and produce the myelin sheath in the CNS.

G. Peripheral nervous system glia:
   1. Schwann cells (neruilemmocytes)
      a. Support nerve fibers and form myelin sheaths.
      b. Gaps in the myelin sheath are called Nodes of Ranvier.

IV. Nerves and Tracts

A. Nerves – bundles of peripheral nerve fibers held together by several layers of connective tissue.
   1. Endoneurium – delicate layer of fibrous connective tissue surrounding each nerve fiber.
   2. Perineurium – connective tissue holding together fascicles (bundles of fibers).
3. Epineurium – fibrous coat surrounding numerous fascicles and blood vessels to form a complete nerve.

B. Tracts—within the CNS, bundles of nerve fibers are called tracts rather than nerves.

C. White matter
   1. PNS – myelinated nerves.
   2. CNS – myelinated tracts.

D. Gray matter
   1. Made up of cell bodies and unmyelinated fibers.

E. Sensory nerves – nerves with predominantly sensory neurons.

F. Motor nerves – nerves with predominantly motor neurons.

G. Mixed nerves – nerves that contain sensory and motor neurons.

V. **Nerve Impulse Transmission**

A. Synapse – the space between a dendrite and a connecting axon terminal.

B. Neurotransmitter – hormones or chemical messengers contained and released by the synaptic vesicles; they stimulate or inhibit action potentials.
   1. Epinephrine (adrenaline) – a sympathetic hormone released into the blood to prepare the body for “fight or flight.”
   2. Acetylcholine – a parasympathetic hormone released at the neuromuscular junction to initiate muscle contraction.

C. Mechanism of synaptic transmission:
   1. Action potential reaches a synaptic knob, causing calcium ions to diffuse into the knob rapidly.
   2. Increased calcium concentration triggers the release of neurotransmitter via exocytosis.
   3. Neurotransmitter molecules diffuse across the synaptic cleft and bind to receptor molecules.
   4. Produces either an excitatory or inhibitory response.
   5. The neurotransmitter’s action is quickly terminated by either neurotransmitter molecules being transported back into the synaptic knob (reuptake) and/or metabolized into inactive compounds by enzymes and/or diffused and taken up by nearby glia.

VI. **Central Nervous System**

A. Bony protection:
   1. Cranial bones encase the brain, and vertebrae encase the spinal cord.

B. Meninges – three layers of connective tissue protection:
   1. Dura mater – thickest, most external layer.
   2. Arachnoid mater – middle layer characterized by delicate, web-like fibers extending to the innermost layer.
   3. Pia mater – thin, vascular innermost layer inseparable from the surface of the brain and cord.

* http://www.alegent.com/adam/animationplayer/animation_player.html
C. Spaces between and around the meninges
   1. Epidural space – located between the dura mater and the bone; contains a supporting cushion of fat and other connective tissues.
   2. Subdural space – located between the dura mater and arachnoid mater; contains lubricating serous fluid.
   3. Subarachnoid space – located between the arachnoid and pia mater; contains a significant amount of cerebrospinal fluid.

D. Cerebrospinal fluid (CSF) – clear liquid formed by filtration of blood by choroid plexuses (collections ependymal cells) in the ventricles of the brain; supports or buoys the brain and cushions the central nervous system.

VII. The Brain
   A. Animation: “Brain Components”*
   B. Cerebrum – the superior portion of the brain; comprises about 80% of total brain mass; divided into right and left hemispheres by the longitudinal fissure; subdivided into lobes.
      1. Frontal lobe – responsible for personality, judgment, planning, and speech; contains the motor cortex which initiates movement of skeletal muscles.
      2. Parietal lobe – responsible for determining distance, size, and shape; contains the sensory cortex which detects general sensory impulses from the skin.
      3. Temporal lobe – contains the auditory and olfactory areas; stores memories of auditory and visual experiences.
      4. Occipital lobe – contains the visual area for interpreting impulses from the retina of the eye.
      5. Insular lobe – lies deep to the other four lobes; integrates cerebral activities.
   C. Cerebellum – the second largest structure of the brain; contains more neurons than the rest of the nervous system combined; located posterior and inferior to the cerebrum; also divided into hemispheres.
      1. Functions:
         a. Coordination of voluntary movements.
         b. Maintenance of balance.
         c. Maintenance of muscle tone.
   D. Diencephalon
      1. Located between the cerebrum and the midbrain; consists of two main divisions, thalamus and hypothalamus.
      2. Thalamus – sorts out incoming sensory impulses and directs them to the proper areas of the cerebral cortex; also helps to filter out unimportant stimuli.
      3. Hypothalamus – controls the pituitary gland by linking the nervous system to the endocrine system; regulates water and electrolyte balance, hunger, body temperature, sleep, sexual response, and raw emotions (e.g. anger, fear, pleasure)

* http://www.alegent.com/adam/animationplayer/animation_player.html
E. Brainstem – interconnects many nervous pathways and helps regulate many visceral functions.
1. Midbrain – uppermost section.
2. Pons – middle portion.
3. Medulla oblongata – lowermost portion; continuous with the spinal cord distal to the foramen magnum; contains the cardiac and respiratory control centers.

VIII. Spinal Cord
A. Lies within the spinal cavity and extends from the foramen magnum to the lower border of the first lumbar vertebra.
B. Oval cylinder that tapers slightly from above downward.
C. Two bulges, one in the cervical region and one in the lumbar region.
D. Anterior median fissure and posterior median sulcus are two deep grooves; anterior fissure is deeper and wider.
E. Cauda equina – bundle of nerve roots extending from the conus medullaris (inferior end of spinal cord).
F. Functions of the spinal cord:
1. Provides conduction routes to and from the brain.
   a. Ascending tracts – carry sensory (afferent) information to the brain.
   b. Descending tracts – carry motor (efferent) information from the brain.
2. Reflex center for all spinal reflexes.
3. Animation: “Reflex Response.”

IX. Peripheral Nervous System
A. Carries sensory information from outlying structures to the CNS via afferent pathways.
B. Carries motor information to outlying structures from the CNS via efferent pathways.
C. Consists of cranial nerves and spinal nerves.
D. Animation: “Feeling Pain.”

X. Cranial Nerves
A. Twelve pairs of cranial nerves connect to the brain, mostly the brainstem.
B. Identified by name (determined by either distribution or function) and/or number (order in which they emerge, anterior to posterior).
2. Sensory cranial nerve – axons of sensory neurons only.
C. Olfactory nerve (I) – sensory information for smell (olfaction).
D. Optic nerve (II) – sensory information for vision.
E. Oculomotor nerve (III) – motor impulses to muscles that move the eye.
F. Trochlear nerve (IV) – motor impulses to muscles that move the eye.
G. Trigeminal nerve (V) – sensory information from the forehead, maxillary region, and mandibular region; motor impulses to muscles of mastication.
H. Abducens nerve (VI) – motor impulses to muscles that move the eye.

* http://www.alegent.com/adam/animationplayer/animation_player.html
I. Facial nerve (VII) – sensory information for taste (gustation); motor impulses to muscles of facial expression.

J. Vestibulocochlear nerve (VIII)
   1. Vestibular portion – sensory information for equilibrium.
   2. Cochlear portion – sensory information for hearing (audition).

K. Glossopharyngeal nerve (IX) – sensory information for taste; motor impulses to muscles of the tongue and pharynx.

L. Vagus nerve (X) – motor impulses to viscera (organs).

M. Accessory nerve (XI) – motor impulses to sternocleidomastoid and trapezius.

N. Hypoglossal nerve (XII) – motor impulses to muscles of the tongue.

XI. Spinal Nerves
A. Thirty-one pairs of spinal nerves are connected to the spinal cord.
B. No special names; are numbered by level of vertebral column at which they emerge from the spinal cavity.
   1. Eight cervical nerve pairs (C1 through C8)
   2. Twelve thoracic nerve pairs (T1 through T12)
   3. Five lumbar nerve pairs (L1 through L5)
   4. Five sacral nerve pairs (S1 through S5)
   5. One coccygeal nerve pair
C. Nerve roots
   1. Dorsal nerve root – carries sensory information into the spinal cord; afferent pathway.
   2. Ventral nerve root – carries motor information out of the spinal cord; efferent pathway.
   3. Spinal nerve – a single mixed nerve on each side of the spinal cord where the dorsal and ventral nerve roots join together.
D. Dermatomes and myotomes
   1. Dermatome – region of skin surface area supplied by afferent (sensory) fibers of a given spinal nerve.
   2. Myotome – skeletal muscle(s) supplied by efferent (motor) fibers of a given spinal nerve.
E. Nerve plexus – a network of interconnecting nerves.
   1. Cervical plexus – arises from nerve roots C1 through C4 and a portion of C5; provides sensory innervation for the skin around the head, neck, and shoulders as well as motor innervation for muscles in the same region.
      a. Phrenic nerve (C3-C5) – innervates the diaphragm.
   2. Brachial plexus – arises from nerve roots C5 through T1; provides sensory and motor innervation for the upper extremities.
   3. Lumbosacral plexus – arises from nerve roots L1 through S4; provides sensory and motor innervation for the lower extremities.
Diseases of the Nervous System

XII. General Terminology
A. Neuralgia – nerve pain.
B. Neuritis – inflammation of a nerve.
C. Neuropathy – weakness in a distal area of a peripheral nerve as a result of trauma or degeneration.
D. Dementia – overall deficiency in memory storage; time and space orientation, language processing, problem solving and planning, and execution of voluntary movements.
E. Referred pain – pain felt in a region of the body distant from the site of tissue damage or injury.

XIII. Disorders
A. Meningitis – inflammation of the meninges; 50 to 60% of cases are fatal if untreated, and 5 to 6% are fatal with treatment; infectious microorganisms invade the subarachnoid space and, together with cellular debris and fibrin, can block cerebrospinal fluid drainage, causing a rapid increase in intracranial pressure; leads to hearing and vision loss and brain damage; symptoms include fever, malaise, headache, lethargy, seizures, delirium, and coma.
   1. Cause: bacterial or viral infection of the meninges spread from an upper respiratory tract infection, otitis media, or pneumonia.
   2. Indications/Contraindications: do not touch client because he or she is contagious.
B. Seizures – sudden, involuntary, and sometimes violent contractions of a group of skeletal muscles accompanied by loss of consciousness.
   1. Cause: increased electrical activity of the brain from injury, fever, or tumor.
   2. Indications/Contraindications: massage is contraindicated during a seizure; deep tissue or painful massage is contraindicated for those who are prone to seizures; avoid perfumes or colognes (may trigger an episode); obtain approval of client’s doctor before performing bodywork if in doubt.
C. Stroke (cerebrovascular accident [CVA]) – brain damage resulting from ischemia to an area of the brain; the third leading cause of death in the US after heart disease and cancer.
   1. Cause: blood vessel rupture or occlusion.
   2. Indications/Contraindications: obtain advice and approval of client’s doctor before performing bodywork; generally, massage should be gentle and rhythmic; avoid pressure on any artery.
   3. Animation: “Stroke.”
D. Amyotrophic lateral sclerosis (Lou Gehrig Disease [ALS]) – a disease characterized by loss of motor neurons in the spinal cord and lower cranial nerves; results in skeletal muscle weakness and eventual death; signs and symptoms include progressive muscle weakness usually beginning with the muscles of the mouth, throat, and extremities and ending with

* [http://www.alegent.com/adam/animationplayer/animation_player.html](http://www.alegent.com/adam/animationplayer/animation_player.html)
impairment of respiratory muscles; often affects those from 50 to 75 years of age; leads to death within 2 to 6 years after diagnosis; no treatment currently available; incidence is about 2 in 100,000.
2. Indications/Contraindications: massage may soothe muscle spasm and improve motor function and psychological well-being; consult with client’s doctor; involve a family member or friend in treatment.

E. Multiple sclerosis – a progressive disease involving demyelination of the neurons in the central nervous system (areas of demyelination are called plaques); faulty nerve conduction causes muscle weakness and uncoordinated muscle activity; affects people between 20 and 40 years of age; symptoms become worse and then resolve for some time, only to become worse again.
2. Indications/Contraindications: use caution because of impaired neurologic sensitivity; massage can reduce muscle spasm and associated anxiety.

F. Thoracic outlet syndrome – compression of the brachial plexus or subclavian artery as it passes through the anterior and middle scalene muscles and under the clavicle and pectoralis minor muscle on its way into the axillary region.
1. Causes: tight scalene muscles; presence of an additional (cervical) rib.
2. Indications/Contraindications: use caution when working near the brachial plexus in the neck or axilla region; massage of cervical muscles, shoulder girdle, and pectoralis minor muscle could relieve compression and stress on the brachial plexus, but avoid prolonged, deep pressure in these areas, particularly if symptoms worsen.

G. Carpal tunnel syndrome (CTS) – most common neuropathy involving the median nerve in the wrist; symptoms include pain, paresthesia (tingling or partial feeling), anesthesia (numbness), or diminished sensation in the hand; common in people who work a lot with their hands; leads to atrophy of the thumb muscles.
1. Causes: compression on median nerve from tenosynovitis (inflammation of the synovial sheath around the tendons); inflammation of the flexor retinaculum.
2. Indications/Contraindications: massage of the cervical muscles, pectoralis minor muscle, and muscles of the upper and lower arms are all indicated to relax the muscles involved and to improve circulation and nerve function.

H. Epilepsy – a condition characterized by long-term disturbances in the brain that lead to seizures; diagnosis depends on a history of at least two unexplained seizures.
1. Cause: increased electrical activity of the brain from unknown cause.
2. Indications/Contraindications: same as for seizures.

I. Parkinson disease – a slow, degenerative disorder that affects the motor neurons in the substantia nigra in the midbrain; flow of motor programs greatly impaired; symptoms include tremors (leading to body rigidity), bradykinesia (slow movement), tiredness, weakness, poor balance, masklike expression of the face, slow speech, shuffling gait, and difficulty with fine motor movements.
1. Cause: loss of cells in the substantia nigra that produce dopamine (a neurotransmitter), resulting in decreased dopamine production.
2. Indications/Contraindications: consult with client’s doctor; massage may reduce muscle spasms and associated stress and anxiety.
3. Animation: “Parkinson’s Disease.”

J. Alzheimer's disease – a progressive disease characterized by dementia and loss of memory (mainly short-term memory); the patient loses more long-term memory and suffers from personality fragmentation as the disease progresses.
1. Cause: genetic defect of chromosome 21 resulting in decreased production of acetylcholine in the brain.
2. Indications/Contraindications: massage can soothe muscular spasm, improve motor function, and improve psychological well-being; consult with client’s doctor; strongly consider having a family member or friend accompany the client during massage sessions.
3. Animation: “Alzheimer’s Disease.”

K. Sciatica – neuritis of the sciatic nerve.
1. Causes: trauma; tight surrounding muscles; bacterial infection.
2. Indications/Contraindications: massage of the lumbar region and posterior thigh is usually very effective in reducing muscle spasm that may be compressing the nerve; if you see no improvement after several treatments, refer to a doctor.

L. Bell’s palsy – neuritis of the facial nerve (CN VII), causing paralysis of one side of the face; can be temporary.
1. Causes: bacterial or viral infection; trauma to the nerve.
2. Indications/Contraindications: massage can reduce anxiety related to this condition and reduce swelling of the nerve; use caution around the ear region.

M. Trigeminal neuralgia (tic douloureux) – degeneration or compression of the trigeminal nerve (CN V) with associated neuralgia or pain along the nerve distribution.
1. Causes: trauma; compression of nerve.

* http://www.alegent.com/adam/animationplayer/animation_player.html
2. **Indications/Contraindications:** avoid the entire facial region because massage could aggravate the condition; massage of nerve root area may reduce spasms and associated pain.

N. **Cerebral palsy** – collection of permanent, nonprogressive motor disabilities; lesions affect certain motor areas and sometimes other areas of the brain, resulting in impairment of motor movement or mental impairment.
   1. Causes: derived from perinatal brain injury (e.g. trauma, infections, toxemia).
   2. **Indications/Contraindications:** consult with client’s doctor; massage may improve motor control and reduce related anxiety; avoid any deep tissue work.

O. **Headache** – pain felt in the head or upper neck.
   1. **Tension headache** – most common form of headache; compression of blood vessels and nerves occurs because of sustained contraction of the muscles of the neck and scalp.
      a. Causes: stress; overuse; sustained, awkward positioning of the neck.
      b. **Indications/Contraindications:** massage to posterior head, neck, and shoulders is very effective in relaxing tense muscles.
   2. **Migraine** – vasoconstriction followed by vasodilation of cerebral blood vessels; characterized by intense throbbing pain, flashing lights, blind spots, double vision, nausea, light sensitivity, and hallucinations.
      a. Causes: stress; caffeine; oral contraceptives; cigarette smoke; various foods and smells.
      b. **Indications/Contraindications:** massage of the neck and shoulders may be very beneficial; use caution during an acute episode; consult with client’s doctor if in doubt.

**Sample Questions**

The cranial nerve responsible for carrying sensory impulses from the face is the:
- A. trigeminal nerve.
- B. abducens nerve.
- C. vagus nerve.
- D. facial nerve.

The visual center of the brain is located in the:
- A. occipital lobe.
- B. frontal lobe.
- C. parietal lobe.
- D. temporal lobe.
Where in the brain is body temperature regulated?
   A. Frontal lobe.
   B. Thalamus.
   C. Hypothalamus.
   D. Cerebellum.

What are tiny gaps in the myelin sheath at which the action potential is relayed along the neuron?
   A. Schwann cells.
   B. Merkel disks.
   C. Golgi bodies.
   D. Nodes of Ranvier.

The neuron that carries impulses from skin to the brain are:
   A. sensory.
   B. motor.
   C. cranial.
   D. cervical.

When in “fight or flight” mode, which system is activated?
   A. Sympathetic nervous system.
   B. Central nervous system.
   C. Parasympathetic nervous system.
   D. Peripheral nervous system.

What are the two major divisions of the autonomic nervous system?
   A. CNS and PNS.
   B. Sympathetic and parasympathetic.
   C. Efferent and afferent.
   D. Cranial and peripheral.

When sympathetic activity is in affect in the lungs, what actions will take place?
   A. Bronchodilation and vasodilation.
   B. Bronchoconstriction and vasoconstriction.
   C. Bronchodilation and vasoconstriction.
   D. Bronchoconstriction and vasodilation.

What receives motor innervation from the hypoglossal nerve?
   A. Eyes.
   B. Ears.
   C. Nose.
   D. Tongue.

Migraine headaches are generally:
   A. tension headaches.
   B. vascular headaches.
   C. phantom headaches.
   D. all of the above are correct.
Slow, light, and rhythmic movements are soothing to the nerves because they produce a low level of excitement to the nervous system, whereas vigorous movements:

A. stimulate the parasympathetic nervous system.
B. decrease synaptic transmission.
C. excite nociceptors.
D. stimulate the sympathetic nervous system.

**Hypertonic scalene muscles may lead to:**

A. Carpal tunnel syndrome.
B. Thoracic outlet syndrome.
C. Sciatica.
D. Torticollis.