The Autonomic Nervous System

Overview
• Primary function - homeostasis
  – including both sensory and motor
• Control over smooth & cardiac muscle and glands
• Little conscious control - input from hypothalamus, medulla and indirectly from
  limbic and cerebrum (reaction to situations seen or heard)
• Divided into sympathetic and parasympathetic
  – Many regions with dual innervation (opposing)

Sensory Input
• General visceral sensory neurons
• Receptors include interoceptors - chemoreceptors and mechanoreceptors
• Usually not consciously perceived
  – Exceptions - visceral nausea or pain, bladder fullness, angina

Motor Output
• General visceral motor neurons
• Excitatory or inhibitory of smooth or cardiac muscle or gland
  – e.g. pupil size, accommodation, vessel diameter, heart rate and force of
    contraction, peristalsis, secretion
• Series of two motor neurons
  – 1) CNS to autonomic ganglion - preganglionic neuron (myelinated and cell body in CNS)
  – 2) Autonomic ganglion to effector - postganglionic neuron (unmyelinated
    and cell body in ganglion)
  – Neurotransmitter may be either ACh or norepinephrine
  – Autonomic ganglion contain synapses (possible integration)

Autonomic NS Innervation (graphic)
Preganglionic Neurons
• Sympathetic - cell bodies in lateral gray horns of T1-12 and L1-2
  (thoracolumbar division)
• Parasympathetic - cells bodies in nuclei of 4 cranial nerves (oculomotor, facial,
  glossopharyngeal and vagus) and lateral gray horns of S2-4 (craniosacral
  division)
  – Vagus is 80% parasympathetic outflow

Autonomic Motor Pathways (graphic)

Autonomic Ganglia
• Sympathetic trunk ganglia (paravertebral ganglia) - chain of ganglia on either
  side of spinal cord
  – White rami communicates
  – Total 22, 3 cervical, 11 or 12 thoracic, 4 or 5 lumbar, 4 or 5 sacral
– Typically innervate organs above diaphragm
– Vertical collaterals - sympathetic chains (trunk)

• Sympathetic prevertebral ganglia (collateral ganglia) - anterior to spinal cord near specific arteries (celiac, superior and inferior mesenteric)
  – Typically innervate organs below diaphragm

• Some sympathetic preganglion fibers don’t synapse in ganglion
  – Some form splanchnic nerves
  – Some provide neuro-secretory function supplying adrenal medulla (primarily norepinephrine & epinephrine)

• Parasympathetic terminal ganglia (intramural ganglia) - located in or near effector organ
  – Those near are from cranial portion and include ciliary, pterygopalatine, submandibular, and otic ganglia

• Autonomic plexuses - localized aggregations of both sympathetic and parasympathetic motor neurons, some sympathetic ganglia, and some autonomic sensory neurons, frequently associated with major arteries

**Sympathetic Ganglia** (graphic)

**Sympathetic Ganglion** (graphic)

**Autonomic Motor Pathways** (graphic)

**Postganglionic Neurons**

• Sympathetic - divergence pre to postganglionic neurons (1:20) to various effectors

• Parasympathetic - divergence pre to postganglionic neurons (1:4) of single effector

**Autonomic Innervation**

• Most structures receive dual inervation
  – Hypothalamus maintains balance between them

• Those with sympathetic only - sweat glands, arrector pili muscles, adipose cells, kidneys and most blood vessels

• Those with parasympathetic only - lacrimal glands

**Autonomic Neurotransmitters**

• Cholinergic (Ach) - may be excitatory or inhibitory (unlike skeletal muscles)
  – All autonomic preganglionic neurons
  – All parasympathetic postganglionic neurons
  – Some sympathetic postganglionic neurons (most sweat glands and some blood vessels in skeletal muscle)

• Adrenergic (norepi or epi) - may be excitatory or inhibitory
  – Most sympathetic postganglionic neurons - norepinephrine
  – Adrenergic response more prolonged than ACh
    • Greater divergence at sympathetic ganglia
    • Slower removal of norepi from synaptic cleft - dependent on re-uptake by presynaptic membrane or a slower enzymatic inactivation
• Neuro-secretory release of norepi and epi from adrenal medulla (liver ultimately, enzymatically breaks them down)

**Autonomic Synapses (graphic)**

**Membrane Receptors**

- **Cholinergic receptors**
  - Nicotinic (nicotine mimics activity) - both sympathetic and parasympathetic postganglionic neurons
    - Always excitatory
  - Muscarinic - (mushroom poison mimics activity) muscles and glands (effectors) innervated by parasympathetic postganglionic neurons and most sweat glands and some blood vessels innervated by sympathetic postganglionic neurons
    - Usually excitatory
    - Sometimes inhibitory - e.g. smooth muscle sphincters of gastrointestinal tract

- **Andrénergic receptors** - found on membranes of sympathetic effectors
  - Alpha receptors with subtypes - stimulated more by norepi or epi
  - Beta receptors with subtypes - stimulated more by epi
  - Alpha and Beta -1 are excitatory, -2 are inhibitory
  - Agonist - mimics neurotransmitter or hormone release (promotes effect), antagonist - blocks receptors (minimizes effect) e.g. beta blockers ↓ BP

**Parasympathetic Action**

- Energy conservation/restorative activities
- Increased SLUDD (salivation, lacrimation, urination, digestion defecation) and decreased heart rate, airway passage, pupil size
- Predominant control during normal activity
- Paradoxical fear (causing urination or defecation)

**Sympathetic Action**

- “E” response: exercise, emergency, excitement, embarrassment
- Predominant control during during physical or emotional stress
- Pupils dilate, HR, force of contraction and BP increase, vasoconstriction of non-essential vessels, rate and depth of breathing increases, blood glucose level increases (liver glycogen), digestive activity declines

**Autonomic Reflexes**

- Similar to somatic reflexes with little or no recognition by cerebrum
- Include HR, BP, respiration, digestion, defecation and urination
- Reflex centers include cardiovascular, respiratory, swallowing and vomiting centers in medulla and temperature control center in hypothalamus.

**Autonomic Pathways**

- Hypothalamus is primary ANS control center with inputs from emotions, visceral function, olfaction, taste, temperature, osmolarity and blood component levels
• Posterior and lateral portions - sympathetic
• Anterior and medial portions - parasympathetic
• Cerebral control at two levels - emotional response to outside stimulus, biofeedback control