Another Efferent (outgoing) System

The spinal cord also sends out autonomic commands and is involved in autonomic reflexes.
Autonomic Nervous System (ANS)

- Nerves supplying organs, glands and blood vessels
- Function automatically, unconsciously
- Help maintain the internal milieu of body, meeting its moment to moment needs
- AKA “visceral nervous system”
Sympathetic Division - arouses body in response to stress/increased demands

- Increase HR & BP
- Increase respiration
- Dilate blood vessels to heart
- Increase blood flow to muscles
- Release adrenaline

- Release stored energy (glycogen)
- Dilate pupils
- Sweat to cool body
- Decrease blood to skin
- GI tract slows down; mouth dry
Parasympathetic Division - serves non-emergency, body maintenance functions, conserving & replenishing body reserves

• Decreases HR & BP
• Slows breathing
• Lubricates mouth, eyes
• Stimulates digestion and storing energy

• Constricts pupil
• Responsible for elimination
Sending an autonomic message requires a 2 neuron sequence
Sympathetic Nerves

- leave CNS at thoracic or lumbar levels (“thoracolumbar system”)
- preganglionic neurons are SHORT, traveling to just outside the spinal column to a long “chain” or “trunk” of sympathetic ganglia.
- postganglionic neurons are long, traveling rest of the way to body organs, glands, & vessels.
- almost all release NE as their transmitter (except those to sweat glands)
- Sympathetic nerves usually respond in unison.
Parasympathetic Division

• leave CNS from the brain or from sacral cord ("craniosacral").
• preganglionic neurons are LONG and go all the way out to body organs to reach ganglia.
• postganglionic neurons are short, going from those ganglia to nearby organ/gland cells.
• All release ACh.
• Parasympathetic nerves tend to operate individually, as needed.
Parasympathetic Nervous System
or Craniosacral outflow
- Parasympathetic ganglia are near to organs and are not all interconnected.
Example of the Opposite Actions of Sympathetic and Parasympathetic Nerves
Sympathetic

Parasympathetic

(a) Vasoconstriction

(b) Vasodilation
Constant Interaction Between Sympathetic & Parasympathetic to maintain internal balance
<table>
<thead>
<tr>
<th>Division</th>
<th>Preganglionic Fibers</th>
<th>Postganglionic Fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sympathetic</td>
<td>Always cholinergic</td>
<td>Mostly adrenergic; a few cholinergic</td>
</tr>
<tr>
<td>Parasympathetic</td>
<td>Always cholinergic</td>
<td>Always cholinergic</td>
</tr>
</tbody>
</table>
Drug Manipulation of ANS

• Drugs which act like NE or make NE more available will produce sympathetic effects (asthma inhalers, amphetamine, cocaine are some “sympathomimetics”).

• Drugs which block NE receptors will decrease sympathetic function (e.g. beta “blockers” to control blood pressure).
Drug Manipulation

• Drugs which act like ACh can be used to stimulate parasympathetic function.

• Drugs which block ACh receptors will decrease parasympathetic function (e.g. “anticholinergics” like atropine).
ANS Afferents

• Autonomic nerves also carry sensory fibers from organs to CNS
• These play a role in autonomic reflexes as well as in our conscious awareness of some bodily functions
• Localization of autonomic sensations is imprecise (e.g. referred pain phenomena discussed in pain topic)
An Autonomic Dysfunction: Raynaud’s Disease

• Over-reaction of sympathetic nerves to peripheral blood vessels to cold causing intense vasoconstriction, pallor, cyanosis and pain in fingers.
CNS-ANS Interaction

• The hypothalamus, brainstem reflex centers, & even frontal lobe centers help to coordinate & control ANS activity.

• Some autonomic reflexes are spinal reflexes & can function independent of the brain.

• Spinal injuries can damage:
  • descending voluntary control pathways (ANS “UMNs”)
  • damage the “LMNs” of the ANS, causing loss of reflex responses
Autonomic Dysreflexia After SCI
(med. emergency syndrome after upper cord injury)(after spinal shock wears off)

- Cervical or upper thoracic (T6 or above) spinal injury disrupts normal feedback between sympathetic & parasympathetic nerves.
- Bladder/bowel distension/irritation, skin irritation, uterine contractions, pain or air temperature changes can provoke uninhibited autonomic discharges (sym. below injury, parasymp. above) with dangerous hypertension.
- Signs: intense headache, sweating, hypertension
The Hypothalamus

- Small but highly specialized ventral region of diencephalon containing many nuclei
- Many hypothalamic cells are sensitive to special stimuli (hormones, glucose, sodium, temperature)
- Some hypothalamic cells release hormones rather than transmitters
Functions of Hypothalamus

• Involved in basic motivations (hunger, thirst, sex, keeping warm, sleep and biorhythms) & the related behaviors
• CNS center for autonomic controls
• CNS center for endocrine controls
• Part of limbic system - plays a role in emotional experience & expression and memory consolidation
Hypothalamus Controls Pituitary (Hypophysis) in 2 Very Different Ways
Pituitary = 2 Glands in 1

• One part is a physical extension of the hypothalamus (neurohypophysis or Posterior Pituitary)

• One part developed from oral ectoderm (adenohypophysis or Anterior Pituitary)
Oxytocin - Paraventricular

ADH/Vasopressin - Supraoptic

The posterior pituitary is really the axon endings of hypothalamic neurons which release these hormones into the bloodstream instead of releasing neurotransmitter.
Oxytocin (from Paraventricular Hypothalamus)

Labor contractions, milk ejection, orgasmic contractions
Released in response to pleasurable touch; associated with bonding/affiliation/love
Anti-Diuretic Hormone (aka vasopressin)

Allows kidney to produce concentrated urine by reabsorbing water.
Without ADH you will have Diabetes Insipidus (weak, watery urine copiously produced, unable to conserve water so always thirsty)
No relationship to Diabetes Mellitus
When you are dehydrated your blood volume decreases so another effect of this hormone is to constrict blood vessels to maintain BP
Anterior Pituitary

- No hypothalamic neurons extend down to anterior pituitary
- Instead, hypothalamus regulates function of AP by secreting “releasing” and “inhibiting” hormones into the blood supply to the AP
• Chain of command must work for normal sex, thyroid, adrenal hormone secretion

In turn, the AP secretes “Trophic” hormones into blood to turn on distant glands
Hypothalamus & the Internal Milieu

• Via its autonomic, endocrine & limbic connections the hypothalamus triggers motivational, behavioral, and bodily responses that help regulate:
  1) Body water/salt balance & blood pressure/volume
  2) Body temperature
  3) Energy intake & metabolism
  4) Reproductive function & associated sex-linked characteristics
  5) Sleep/waking
  6) Stress responses
Extremes of Hypothalamic Dysfunction

- Overeating (hyperphagia)—anorexia
- Polydipsia --- adipsia
- Precocious or inappropriate sexual function—absent sexual function
- Gigantism, acromegaly, dwarfism
- Altered autonomic, endocrine, temp regulation, biorhythms, sleep waking
- Mood swings, emotion extremes
- Over-secretion or under-secretion of hormones
Best Known Limbic Structures
The limbic system also includes the inner most regions of the cortex (immediately surrounding the brainstem and subcortical structures). This inner most cortex (or “paleocortex”) is evolutionarily more ancient than the neocortex we see on the surface of the brain. Some anatomists even consider this old cortex as a separate “lobe” – the limbic lobe – distinct from the overlying neocortex lobes.
Paleocortex Regions
Limbic Memory Regions

- Essential for the storage of new memories
  - hippocampus
  - mammillary bodies & medial thalamus

- Emotional aspects of memory-
  - Amygdala

- Long-term memories
  - out
cortex

http://www.youtube.com/watch?v=CL-0gpf_6g
Limbic Memory Regions

- Hippocampal damage – problems storing new declarative memories (semantic & episodic)
- Mammillary bodies & medial thalamus damage - memory difficulties of Korsakoff’s syndrome
- Damage to selective areas of cortex – may lose specific long term memories (like the names for things or the color of things)
• Oldest cortex-like structure ("archicortex") – hippocampus, which has 3 layers
• As cortex continued to evolve → more layers
• "Paleocortex" regions transition between 3-5 layers

• Evolutionarily newest cortex ("neocortex") usually has 6 layers
• Most of human cortex is neocortex
• As an evolutionarily old system, the limbic system mostly operates at the unconscious level
• But through its interaction with neocortex, it can generate some conscious experiences (emotions, memories, motivational states)
• For the ancient limbic system, a primary source of input was olfaction
• Limbic areas are sometimes referred to as the “rhinencephalon” (smell brain)
Pathways in the olfactory system
“Olfactory cortex”
In Many Species Olfaction, Pheromones & the Rhinencephalon Are Critically Involved in Basic Behaviors

- Hunt/forage/food intake
- Detecting predators & other threats
- Maternal/parenting behaviors
- Infant attachment
- Sexual selection
- Marking & sensing territory & competitors
- Hormone regulation
- These instinctive behaviors were also associated with primitive emotions (aggression & rage, fear, attraction)
• Limbic system regions involved in emotional experience and expression
• Hypothalamus triggers bodily signs of emotion
• Amygdala particularly critical for recognizing and experiencing fear; also probably involved in aggressive/rage type emotions
• Can trigger emotional response to stimulus before conscious perception
• Provides emotional aspects of memory
Amygdala Within Temporal Lobe
Joseph LeDoux and his associates have demonstrated that the brain is wired to learn to associate fear with a visual image, sound, smell, tactual sensation without mediation by the cerebral cortex (i.e., without thought). A person can experience a fear reaction before they are consciously aware of the stimulus.

Illustration from Rita Carter's Mapping The Mind
fMRI to seeing a fearful face

- Amygdala responds even if presentation is too brief to allow conscious recognition
Amygdala Also Responds to Fearful Body Language

Hadjikhani and de Gelder
Changes in Basic Responses if Damaged: Kluver-Bucy Syndrome

Damage to the Medial Temporal Lobe/Amygdala produces:

- **Emotional Blunting**: a flat affect and may not respond appropriately to stimuli.
- **Hyper-orality/Hyperphagia**: strong tendency for those with Kluver-Bucy to compulsively place inedible objects in their mouths; abnormal eating and weight gain
- **Inappropriate Sexual Behavior**: atypical sex behaviors, mounting inanimate objects, other species
- **Visual Agnosia**: “psychic blindness,” i.e. an inability to visually recognize objects.
SM – A Case of Amygdala Damage & Altered Emotion Function

SM:
A life-long pattern of social and emotional inadequacy. Fear most strongly disrupted.

Urbach-Wiethe Disease Damages amygdala