**Autonomic Nervous System**

2 major subdivisions of the motor neurons of the PNS

- **somatic** - innervate skeletal (voluntary) muscles
- **autonomic** – innervate smooth and cardiac (involuntary) muscles & glands

Autonomic nervous system consists of motor fibers that innervate the visceral organs; organs that function automatically

ANS tends to regulate visceral effectors in ways that tend to maintain or restore homeostasis

### Differences Between Somatic and Autonomic Motor Neurons

<table>
<thead>
<tr>
<th>Somatic</th>
<th>Autonomic</th>
</tr>
</thead>
<tbody>
<tr>
<td>voluntary effectors:</td>
<td>involuntary effectors:</td>
</tr>
<tr>
<td>striated muscles</td>
<td>smooth &amp; cardiac muscles, glands</td>
</tr>
<tr>
<td>single motor neuron</td>
<td>usually 2 neurons with synapse (ganglion)</td>
</tr>
<tr>
<td>from spinal cord</td>
<td>between from spinal cord to target organ</td>
</tr>
<tr>
<td>to target organ</td>
<td></td>
</tr>
<tr>
<td>NT always stimulatory</td>
<td>NT stimulatory or inhibitory</td>
</tr>
<tr>
<td>ACh released at synapse</td>
<td>ACh and NE released at synapses</td>
</tr>
<tr>
<td>No firing at rest</td>
<td>Baseline firing – speeds up when stimulated</td>
</tr>
<tr>
<td>effector at rest is flaccid</td>
<td>effector at rest has intrinsic tone</td>
</tr>
</tbody>
</table>
ANS is divided into 2 branches:

**sympathetic**

**parasympathetic**

**Structure of ANS Branches**

**Sympathetic**

formed by neurons from **spinal nerves T1 to L1**

sympathetic neurons branch from spinal nerves as they exit intervertebral foramina and form interconnected ganglia (= **chain ganglia**) in ventral body cavity on each side of vertebral column

- **ACh** is secreted from preganglionic fibers (inside chain ganglia) = **cholinergic fibers**

- **NE** is secreted from most post ganglionic fibers (at organ innervated) = **adrenergic fibers**

**Parasympathetic**

formed by neurons in cranial nerves:

- III (oculomotor)
- VII (facial)
- IX (glossopharyngeal)
- X (vagus)

and fibers in some sacral (S2-S4) spinal nerves

no chain ganglia, fibers not interconnected

ganglia are usually near organs they innervate

- **ACh** usually released from both preganglionic fiber (in ganglion) and at target organ; ie. all **cholinergic fibers**

**Functions of ANS Branches**

**Sympathetic**

acts as an **emergency system**

emergency or stress that threatens homeostasis

“**fight or flight**”
maximum energy expenditure

changes promote **intense physical activity**
> heart beat
> blood vessels to skeletal muscles dilate
> bronchi dilate
> blood sugar levels
> metabolic rate

acts as a unit = mass activation

more diffuse, body-wide response

effects are longer lasting

**Parasympathetic**

most active in non-stressful, non-emergency situations
> “resting and digesting”

organs are individually activated; no mass activation

ACh is quickly produced and quickly destroyed
> short lived, localized effects

promotes normal daily activities:
> GI tract works to process food
  > glandular secretions
  > peristalsis
> blood pressure, heart rate, respiratory rates
  maintained at low levels

**Interactions between two branches of ANS**

in organs with dual innervation can be

  antagonistic
  cooperative

some organs lack dual innervation and there is **no interaction**

1. **Antagonistic Interactions**
   In some organs with dual innervation the branches work antagonistically

   the net effect is due to the ratio of stimuli being received from both branches:
eg. heart
> sym stimulation  
  → faster
> parasym stimulation  
  → slower

eg. digestive tract
> sym stimulation  
  → inhibits
> parasym stimulation  
  → promotes

eg. respiratory system
> sym stimulation  
  → dilation (inhibition) of air passages
> parasym stimulation  
  → constriction

eg. iris muscles
> sym stimulation  
  → radial mm constrict
  → pupil dilate
> parasym stimulation  
  → circular mm constrict
  → pupil constricts

2. Cooperative Interactions

  each branch promotes a different but related response
  need both to complete function

eg. urination
  sym  → urge, muscle tone
  parasym  → contraction of bladder muscles

eg. intercourse
  parasym  → vasodilation and erection of penis and clitoris
  (difficulty when upset or nervous → sym is more active)
  sym  → males: ejaculation
       females: reflex peristalsis

3. No Interaction

  some visceral organs lack dual innervation
  receive only sympathetic innervation

eg. adrenal medulla
  sym  → release of NE to promote and prolong bodywide sympathetic effects

eg. arrector pili
  sym  → goose bumps when cold or scared orig to “fluff” fur
eg. sweat glands
   \textit{sym} \rightarrow \text{sweat to cool down when active}
   \rightarrow \text{sweat when stressed or nervous}

eg. thermoregulatory response
   \textit{sym} \rightarrow \text{reflex dilation of skin vessels}
   \rightarrow \text{activation of sweat glands}

eg. most blood vessels (not penis)
   \textit{sym} \rightarrow \text{raise BP in emergency}

eg. release of renin from kidney
   \textit{sym} \rightarrow \text{renin} \rightarrow \text{>BP}

eg. general increase in metabolic effects
   \textit{sym} \text{stim:}
   \begin{itemize}
     \item \text{>metabolic rate}
     \item \text{> blood glucose}
     \item \text{> fat hydrolysis}
     \item \text{> RAS} \rightarrow \text{mental alertness}
   \end{itemize}
   \text{all aided by stim of hormones from adrenal medulla}
   \rightarrow 25-50\% \text{ of sympathetic response}

\textbf{Autonomic Control Centers}

many autonomic reflexes have been discussed earlier when discussing Brain

but regulation of ANS is far from being completely automatic as implied earlier
\rightarrow \text{there is a hierarchy of control of autonomic effectors}

\begin{itemize}
  \item Autonomic Centers in Cerebral Cortex (frontal lobe)
  \item Autonomic Centers in Limbic System
  \item Autonomic Centers in Hypothalamus
  \item Brainstem or Spinal Cord
\end{itemize}

\begin{itemize}
  \item Sympathetic branch
  \item Parasympathetic branch
\end{itemize}
Brainstem
most direct control over autonomic reflexes
almost all autonomic responses can be elicited by
stimulation of brainstem

Hypothalamus
orchestrates somatic, autonomic and hormonal
activity
coordinates heart activity, BP, body temp, water
balance,

Limbic System
helps regulate emotional states and basic
biological drives (hunger, pleasure, pain, etc)
linked directly to hypothalamus

Cerebellum
nausea and sweating of motion sickness are
abolished when efferent tracts from cerebellum to medulla are cut

Cerebrum
the ANS is not entirely out of our conscious control
→ some people are able to dilate pupils or
produce goose bumps on command
also, we can learn to control some autonomic
functions

eg. Meditation is a voluntary alteration of autonomic responses

a specific set of physiological changes occur
during meditation
→ mainly depressed sympathetic
effectors

opposite “fight or flight” response

eg. decrease in oxygen consumption
reduced blood pressure
generate slower alpha waves
less lactate in blood
increase in electrical resistance of skin

eg. Biofeedback is based on idea that Autonomic responses can be
consciously controlled
in somatic NS we get feedback (or reward/punishment) to learn to control movements
   eg. hit thumb with hammer

in ANS we normally get no conscious feedback

but using monitors, brain waves, flashing lights, etc we can learn to make a specific visceral response

   eg. Harvard exp:
       learned to increase blood pressure, light flashed each time pressure rose
       when successful were rewarded by seeing nude pinup

   eg. migraine headaches
       90/100 subjects learned to reduce their headaches through brainwave training

biofeedback is difficult and frustrating to learn but has been successful in treating migraines
   lowering BP and heart rate
   managing stress
Autonomic Imbalances

disorders generally reflect exaggerated or deficiencies in controlling smooth muscle activities

1. Raynaud’s Disease
   sever vasoconstriction

2. Hypertension
   high BP
   renal disease
   stress
   atherosclerosis

3. Mass Reflex
   in some quadriplegics
   massive activation of sympathetic system
   no higher brain control of reflex responses