Peripheral Nervous System

Nervous system consists of

**CNS** = brain and spinal cord
- ~90% (90 Bil) of all neurons in body are in CNS

**PNS** = Cranial nerves and spinal nerves
- ~10% (10 Bil) of all neurons in body are in PNS

PNS is our link to the outside world; without it CNS us useless
sensory deprivation → hallucinations

- **sensory** (afferent) neurons
  - ~2-3M; 6-8x’s more sensory than motor fibers
- **motor** (efferent) neurons
  - ~350,000 efferent fibers
- **somatic** motor neurons
- **autonomic** motor neurons

these neurons are bundled into **nerves**

difference between **nerve** and **neuron**:

- **neuron** = individual nerve cell
- **nerve** = bundle of axons outside CNS surrounded by layers of connective tissue

<table>
<thead>
<tr>
<th>CNS</th>
<th>PNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axons</td>
<td>Tracts</td>
</tr>
<tr>
<td>Cell Bodies</td>
<td>Nuclei</td>
</tr>
<tr>
<td></td>
<td>Ganglia</td>
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</tbody>
</table>

Nerves consist of either sensory or motor neurons or a combination of both = **mixed nerves**

mixed nerves often carry both somatic and autonomic motor fibers

ganglia examples:

- **dorsal root ganglia** = cell bodies of **sensory** neurons
- **autonomic chain ganglia** = cell bodies, dendrites & synapses of autonomic **motor** neurons

PNS consists of 43 pairs of nerves branching from the CNS:
- 12 pairs of cranial nerves
- 31 pairs of spinal nerves

**Cranial Nerves**
- 12 pairs of cranial nerves
structurally originate from:
  cerebrum:  I, II
  midbrain: III, IV
  pons:  V, VI, VII, VIII (pons/medulla border)
  medulla:  IX, X, XI, XII

functionally:
  some are **sensory** only:
     I. Olfactory [sense of smell]
     II. Optic [sense of sight]
     VIII. Vestibulocochlear [senses of hearing and balance]
         -injury causes deafness
  some are **motor** only:
     III. Oculomotor
     IV. Trochlear [eye movements]
     VI. Abducens
         -injury to VI causes eye to turn inward
  some are **mixed nerves**:
     V. Trigeminal [cutaneous senses of head and face, chewing muscles]
     VII. Facial [sense of taste, facial expression]
     IX. Glossopharyngeal [sense of taste, swallowing]
     X. Vagus [sensory and motor to larynx, heart, lungs, digestive system]
     XI. Accessory [shoulder and head]
     XII. Hypoglossal [tongue]

severe head injury often damages one or more cranial nerves

**Spinal Nerves**

31 pairs
all are mixed nerves
all but 1st pass through **intervertebral foramina**
they are named and numbered according to the level of the vertebral column from which they arise:
  8 cervical
  12 thoracic
  5 lumbar
  5 sacral
  1 coccygeal

each spinal nerve is attached to spinal cord by two roots:
  **dorsal** (posterior) root → sensory neurons and a **ganglion**
  **ventral** (anterior) root → motor neurons
the two roots joint to form a mixed, spinal nerve

**Dermatomes**

sensory neurons of each spinal nerve innervate the
skin and skeletal muscles in the roughly same order in which they emerge from the spinal cord

detailed mapping of the skin surface reveals a close relationship between the source of nerve fibers and the location (superior to inferior) of the skin segments each innervates

→ **segmental arrangement** of spinal nerves

this is clinically useful since physicians can determine the site of spinal damage by simple pinprick exam

**Spinal Nerve Plexuses**

after the spinal nerves exit the intervertebral foramina they branch and interconnect to form **plexuses**

from these plexuses new nerves emerge that contain a mixture of fibers from various spinal nerves

**Cervical Plexus**
formed from C1 – C4,5
supplies sensory and motor neurons to head, neck and upper shoulders
emerging nerves include:

- **phrenic nerve** → diaphragm

**Brachial Plexus**
formed from fibers in C5 to C8, & T1
innervates shoulders and upper limbs
emerging nerves include:

- **axillary** → to deltoid
- **radial** → triceps and forearm extensors
- **median** → flexor muscles of forearm and hand
- **ulnar** → wrist and hand muscles

this plexus is sometimes stretched or torn at birth leading to paralysis and numbness of baby’s arm
if untreated may produce “withered arm”

prolonged use of crutch may injure this plexus = **crutch palsy**

[most thoracic spinal nerves (2-12) do not form a plexus]

**Lumbar Plexus**
formed from fibers in L1 to L4
innervates abdominal wall, genitals, parts of leg
emerging nerves include:

**femoral nerve** → thigh and leg muscles

**Sacral Plexus**
formed from fibers in L4 & 5, S1 to S4
supplies nerves to buttocks, perineum, leg
emerging nerves include:

**sciatic nerve** → leg muscles; largest nerve in body

**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 and 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</td>
</tr>
<tr>
<td>from spinal cord</td>
<td>(ganglion) between from</td>
</tr>
<tr>
<td>to target organ</td>
<td>spinal cord to target organ</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</td>
</tr>
<tr>
<td></td>
<td>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;
i.e. 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**

some organs lack dual innervation and there is no interaction

in organs with dual innervation can be
  antagonistic
  cooperative

1. **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

eyg. arrector pili
  sym \rightarrow goose bumps when cold or scared
  \text{orig to “fluff” fur}

eyg. sweat glands
  sym \rightarrow sweat to cool down when active
  \rightarrow sweat when stressed or nervous

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

2. 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
  \begin{itemize}
  \item > sym stimulation \rightarrow faster
  \item > parasym stimulation \rightarrow slower
  \end{itemize}

  eg. digestive tract
  \begin{itemize}
  \item > sym stimulation \rightarrow inhibits
  \item > parasym stimulation \rightarrow promotes
  \end{itemize}

3. Cooperative Interactions
  each branch promotes a different but related response
  need both to complete function

  eg. urination
  \begin{itemize}
  \item sym \rightarrow urge, muscle tone
  \item parasym \rightarrow contraction of bladder muscles
  \end{itemize}

  eg. intercourse
  \begin{itemize}
  \item parasym \rightarrow vasodilation and erection of penis and clitoris
  \item \text{(difficulty when upset or nervous \rightarrow sym is more active)}
  \item sym \rightarrow males: ejaculation
  \item females: reflex peristalsis
  \end{itemize}

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 → there is a hierarchy of control of autonomic effectors

**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:
  - 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