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, nerve plexuses** & **ganglia**
~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

some terminology:

	CNS	**PNS**
bundles of axons	tract	nerve
cell bodies, dendrites, synapses	nuclei	ganglia

Nerves

each nerve is an organ composed mainly of nervous tissue (neurons and neuroglia) and fibrous connective tissue with rich supply of blood vessels

arranged in pattern similar to that of muscle organs:

endoneurium →around each individual neuron
perineurium →around bundles of neurons (=fascicles)
epineurium →around entire nerve

2 kinds of neurons can be found in nerves:

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

Nerves can be classified according to the kinds of neurons they contain:

a. **sensory nerves** – contain mainly sensory neurons
b. **motor nerves** – contain mainly different kinds of motor neurons
c. **mixed nerves** – contain a combination of both

ganglia

= groups of cell bodies and sometimes
dendrites and synapses associated with nerves of PNS

examples of PNS ganglia:

dorsal root ganglia = cell bodies of **sensory** neurons

autonomic chain ganglia = cell bodies, dendrites & synapses of autonomic **motor** neurons

nerve plexuses

weblike interconnections of fibers from many nerves

eg. spinal nerve plexuses
→ several spinal nerves come together

eg. autonomic plexuses

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, the cranial nerves originate from:

cerebrum	→ I, II
midbrain	→ III, IV
pons	→ V, VI, VII,VIII (pons/medulla border)
medulla	→ IX, X, XI, XII

functional classification of cranial nerves:

a. **sensory** cranial nerves
I. **Olfactory** [sense of smell]
II. **Optic** [sense of sight]
VIII. **Vestibulocochlear** [senses of hearing and balance]
has a few motor fibers

-injury causes deafness

b. motor cranial nerves
(all also have a few motor fibers)
III. **Oculomotor**
IV. **Trochlear** } [eye movements]
VI. **Abducens**
-injury to VI causes eye to turn inward

c. **mixed** cranial nerves
–contain a large number of both sensory and motor neurons
IX. **Glossopharyngeal** [sense of taste, swallowing]
XII. **Hypoglossal** [tongue]
V. **Trigeminal** [cutaneous senses of head and face, chewing muscles]
VII. **Facial** [sense of taste, facial expression]
X. **Vagus** [sensory and motor to larynx, heart, lungs, digestive system]
XI. **Accessory** [shoulder and head]

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** (C3-C5) → diaphragm

Brachial Plexus

formed from fibers in C5 to C8, & T1

innervates shoulders and upper limbs

emerging nerves include:

- **axillary** (C5,C6) → to deltoid
- **radial** (C5-C8,T1) → triceps and forearm extensors
- **median** (C5-C8,T1) → flexor muscles of forearm and hand
- **ulnar** (C8,T1) → 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 (L2-L4) → 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 (L4,L5, S1-S3) → 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 = "self governed"

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

Somatic	Autonomic
voluntary effectors: striated muscles	**involuntary effectors: smooth & cardiac muscles, glands**
somatic reflexes	**visceral reflexes**
single motor neuron from spinal cord to target organ	**usually 2 neurons with synapse (ganglion) between from spinal cord to target organ**
NT always stimulatory	**NT stimulatory or inhibitory**
ACh released at synapse	**ACh and NE released at synapses**
No firing at rest	**Baseline firing – speeds up when stimulated**
effector at rest is flaccid	**effector at rest has intrinsic tone**
motor neurons cut = paralysis	**motor neurons cut exaggerated response (denervation hypersensitivy)**

ANS is divided into 2 branches:
- **sympathetic**
- **parasympathetic**

Structure of ANS Branches

Sympathetic

formed by neurons from **spinal nerves T1 to L2**

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

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

Functions of ANS Branches

Sympathetic

adapts body for intense physical activities:
increases alertness, blood pressure, air flow, blood sugar concentrations, blood flow to heart and skeletal muscles

acts as an **emergency system**
emergency or stress that threatens homeostasis
"fight or flight"
maximum energy expenditure

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"

tends to have a calming effect on body:
reduced energy expenditure and
normal body maintenance

organs are individually activated
no mass activation

→ 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

the body doesn't alternate between only sympathetic or parasympathetic activity

normally, both systems are active
both always exhibit at least a baseline level of "**autonomic tone**"

eg. parasympathetic always maintains smooth muscle tone in intestine and keeps heart rate down to 70 bpm (vs intrinsic 100 bpm)

eg. sympathetic always maintains smooth muscle tone around most blood vessels to maintain blood pressure

most visceral organs receive dual innervation of both branches of ANS

in organs with dual innervation can be
antagonistic
cooperative

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

Autonomic Control Centers

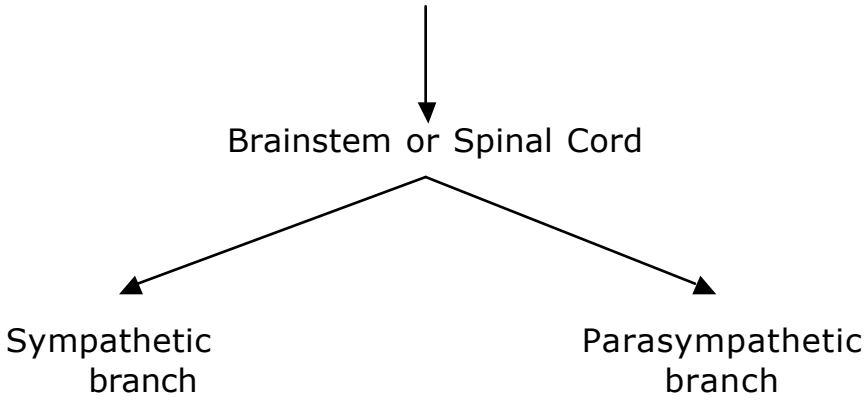
many autonomic reflexes have been discussed earlier when discussing Brain

but regulation of ANS is far from being completely automatic as implied earlier
→ there is a hierarchy of control of autonomic effectors

Autonomic Centers in Cerebral Cortex
(frontal lobe)

Autonomic Centers in Limbic System

Autonomic Centers in Hypothalamus



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