ANATOMY & PHYSIOLOGY

The Nervous System

How one organ system is divided, why the divisions are drawn where they are, and what each branch actually does.

CNS / PNS

AFFERENT / EFFERENT

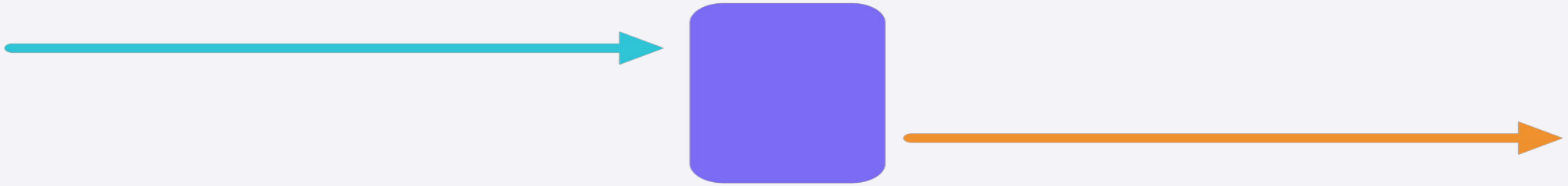
SOMATIC / AUTONOMIC

SYMPATHETIC / PARASYMPATHETIC

NERVOUS SYSTEM

Everything it does, in three steps

Whatever the structure, the nervous system is always doing one of these three things.



SENSORY INPUT

Receptors detect a change — inside the body or outside it — and send that information toward the center. This is the afferent side.

INTEGRATION

The central nervous system processes what arrived, compares it with what it already knows, and decides on a response.

MOTOR OUTPUT

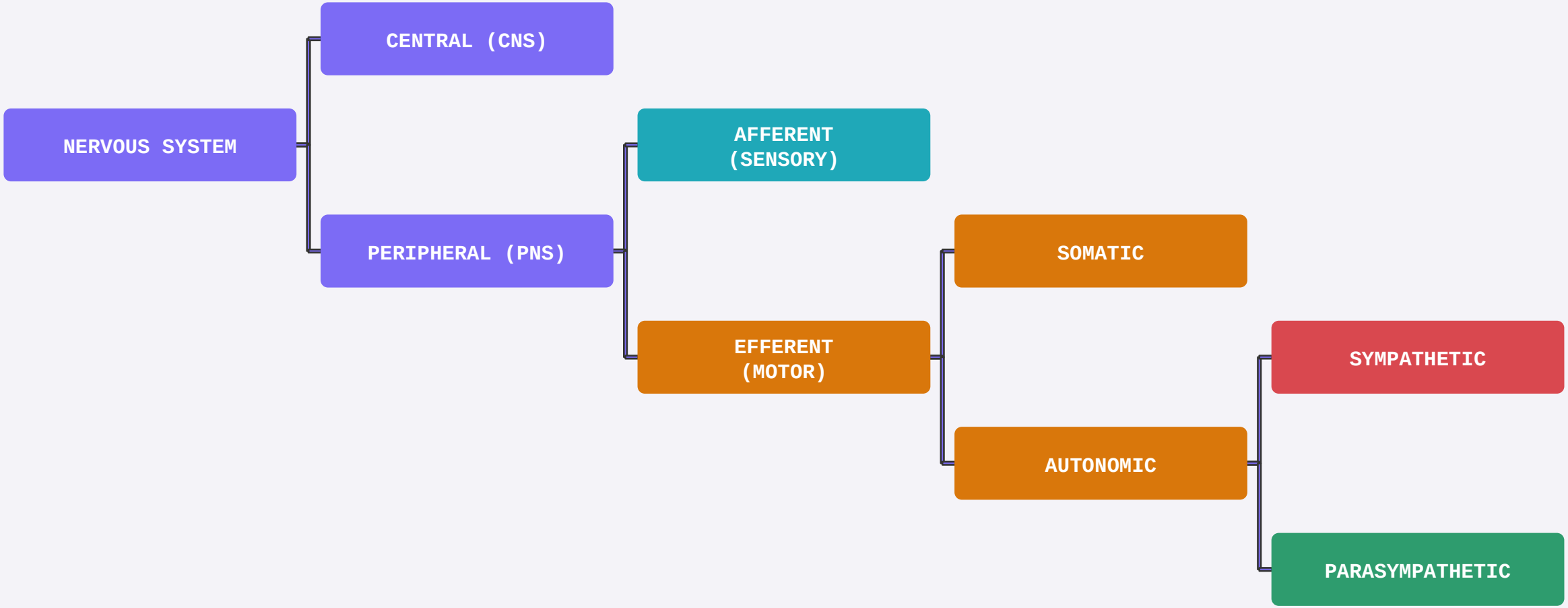
A command travels out to muscles or glands, which carry out the response. This is the efferent side.

Hold onto the words afferent and efferent — A for arriving, E for exiting. They come back at every level of the system.

NERVOUS SYSTEM

The map for the whole session

Five branch points. We will take them one at a time, and this diagram will reappear with the current branch lit.



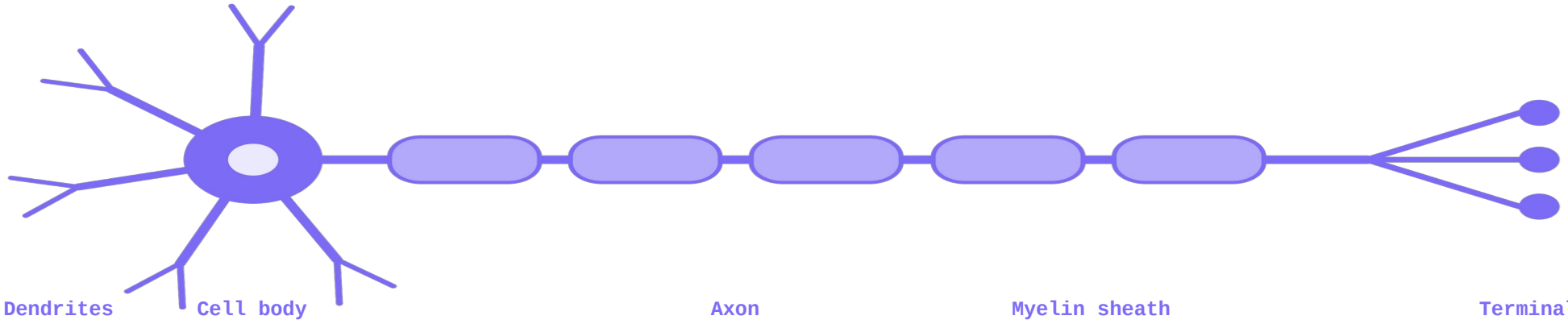
THE CELL

The neuron, and how a signal moves

NERVOUS SYSTEM

The neuron

One cell, three functional regions: a part that listens, a part that decides, and a part that transmits.



Dendrites

Branching extensions that receive signals from other neurons. More branches means more incoming connections.

Cell body

Contains the nucleus. Sums the incoming signals and decides whether to fire.

Axon

A single long process that carries the signal away from the cell body — sometimes over three feet.

Myelin

A fatty insulating sheath laid down in segments. Gaps between segments let the signal jump, greatly increasing speed.

Terminals

The end branches, which release chemical messengers onto the next cell.

NERVOUS SYSTEM

Neurons are not the only cells

Glial cells outnumber neurons and do the supporting work. Neurons themselves come in three functional types.

Three functional types of neuron

- Sensory (afferent) — carry information toward the CNS.
- Motor (efferent) — carry commands away from the CNS.
- Interneurons — sit entirely within the CNS and connect the other two. They make up the great majority of neurons.

Glial cells: the support crew

- Astrocytes — support neurons and help form the blood–brain barrier.
- Oligodendrocytes (CNS) and Schwann cells (PNS) — produce myelin.
- Microglia — the immune cells of the nervous system.
- Ependymal cells — line the ventricles and help make cerebrospinal fluid.

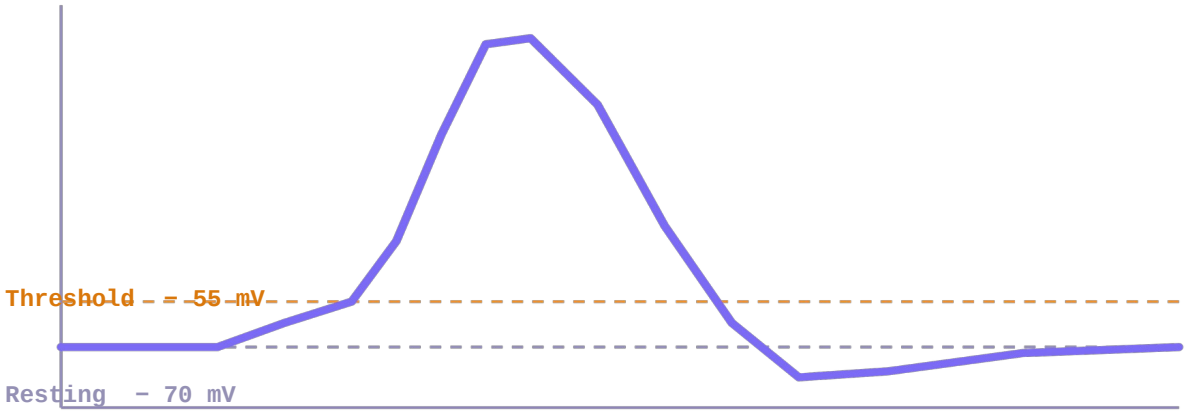
Why neurons are unusual cells

- Excitable — they can generate and conduct electrical signals across their membrane.
- Extremely long-lived — most last a lifetime, and most cannot be replaced if lost.
- Metabolically demanding — they depend on a constant supply of oxygen and glucose, which is why interruptions cause damage so quickly.

NERVOUS SYSTEM

How a signal travels

Electrical along the neuron, chemical between neurons. That two-part answer covers most of the introductory material.



All-or-none is the point students most often miss. A neuron cannot fire harder for a stronger stimulus. Intensity is coded by how often it fires and by how many neurons fire — not by the size of each signal.

01 **AT REST**

The inside of the neuron is negative relative to the outside — about − 70 mV — maintained by pumps and by unequal ion distribution.

02 **THRESHOLD**

A stimulus makes the inside less negative. If it reaches about − 55 mV, the neuron fires. Below that, nothing happens.

03 **ACTION POTENTIAL**

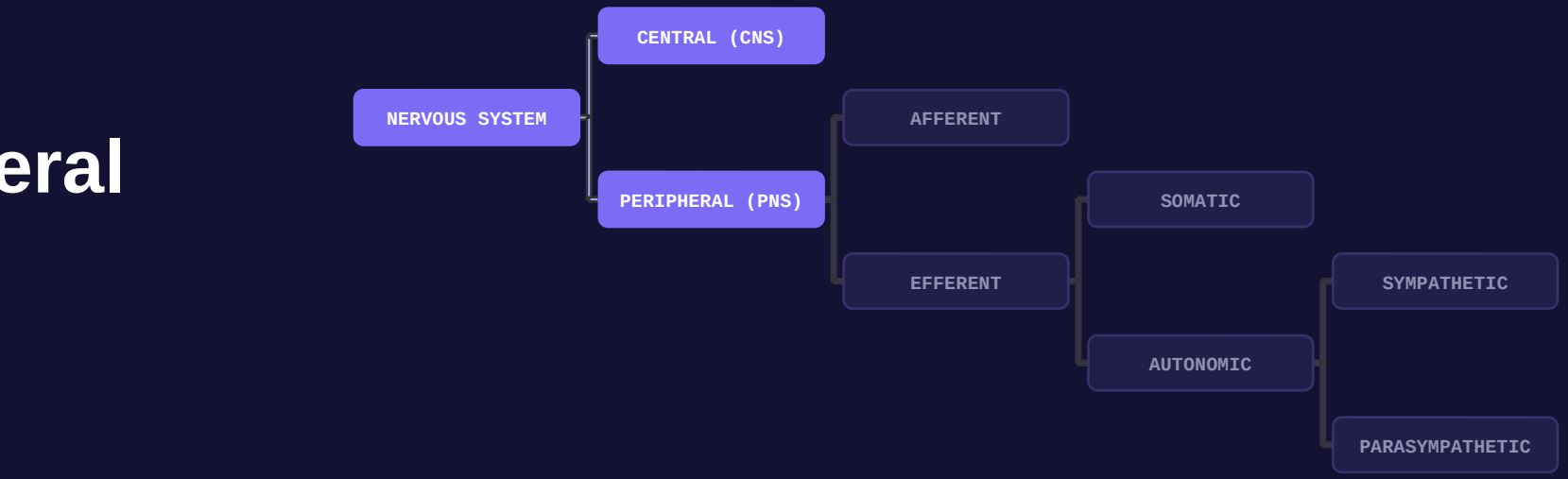
Sodium rushes in and the inside briefly becomes positive, then potassium leaves and the cell recovers. It is all-or-none: every firing is the same size.

04 **THE SYNAPSE**

At the terminal, the electrical signal triggers release of a neurotransmitter into the gap, which binds to the next cell and either excites or inhibits it.

FIRST DIVISION

Central and peripheral



NERVOUS SYSTEM

Central and peripheral

The first cut is purely anatomical: is the tissue inside the skull and spine, or outside it?

CENTRAL NERVOUS SYSTEM

Brain + spinal cord

- The integration and command center — where information is processed and decisions are made.
- Encased in bone: the skull and the vertebral column.
- Wrapped in three membranes (the meninges) and cushioned by cerebrospinal fluid.

PERIPHERAL NERVOUS SYSTEM

Everything else

- All the nerves running between the CNS and the rest of the body — the cabling.
- 12 pairs of cranial nerves, arising from the brain.
- 31 pairs of spinal nerves, arising from the spinal cord.

Why the distinction matters

Peripheral nerves can regenerate after injury; central ones largely cannot. Peripheral tissue is exposed to trauma, while central tissue is protected by bone — but that same bony box means swelling has nowhere to go. Almost every clinical difference between central and peripheral problems traces back to these two facts.

NERVOUS SYSTEM

Inside the CNS: the brain

Four regions worth knowing by name at this stage, and what each is broadly responsible for.

CEREBRUM

The largest part, divided into two hemispheres and four lobes. Conscious thought, voluntary movement, sensation, language, personality and memory.

DIENCEPHALON

Thalamus and hypothalamus. The thalamus relays almost all sensory traffic to the cortex; the hypothalamus runs temperature, hunger, thirst, hormones and the autonomic system.

CEREBELLUM

Sits behind and below. Coordinates movement, balance and posture. It does not initiate movement — it refines it.

BRAINSTEM

Midbrain, pons and medulla. Contains the centers for breathing, heart rate and blood pressure, and is the route for everything travelling between brain and cord.

Grey matter and white matter

Grey matter is cell bodies and unmyelinated fibres — where processing happens. White matter is myelinated axons — the wiring that carries signals between regions. In the brain grey matter is on the outside; in the spinal cord the arrangement is reversed.

NERVOUS SYSTEM

Inside the CNS: the spinal cord

A two-way conduction highway that also makes some decisions entirely on its own.

A conduction pathway

Ascending tracts carry sensory information up to the brain. Descending tracts carry motor commands down. Damage at a given level affects everything below it.

A reflex center

Some responses are processed in the cord itself without waiting for the brain. This is what makes reflexes fast — and what makes them testable.

Protected, but finite

It runs from the brainstem to roughly the first or second lumbar vertebra, then continues as a bundle of nerve roots. Thirty-one pairs of spinal nerves branch off along its length.

Three layers of protection

Bone

The skull and the vertebral column form a rigid outer case.

Meninges

Three membranes — dura mater (tough, outer), arachnoid mater (middle), pia mater (delicate, hugging the tissue).

Cerebrospinal fluid

Circulates between the middle and inner layers and through the ventricles, cushioning the tissue and letting the brain float.

NERVOUS SYSTEM

Inside the PNS: the cabling

Nerves are bundles of axons wrapped in connective tissue, running to and from the CNS.

12 pairs of cranial nerves

Arise directly from the brain and brainstem rather than the spinal cord. They serve mostly the head and neck — smell, vision, eye movement, facial sensation and expression, hearing, balance, taste, swallowing and tongue movement.

One of them, the vagus, is the exception: it travels down into the chest and abdomen.

31 pairs of spinal nerves

Emerge between the vertebrae along the length of the cord: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal.

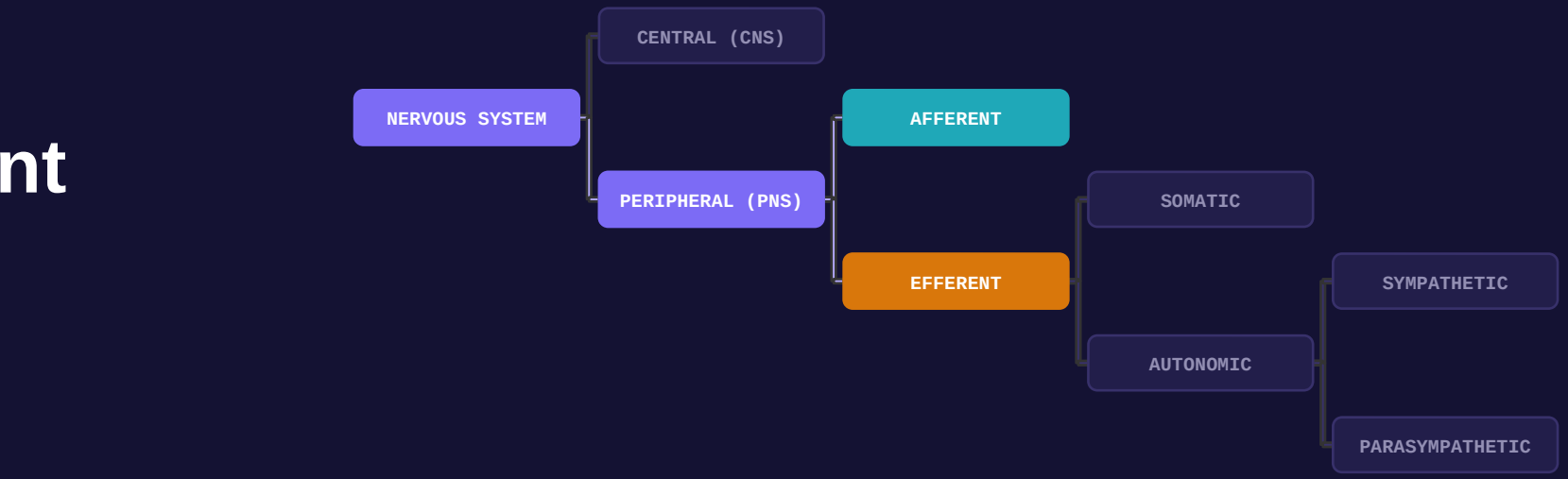
Each carries both sensory and motor fibres, and each supplies a defined strip of skin and a defined group of muscles — which is why a lesion at one level produces a predictable pattern.

A note on names

From here on, every remaining division is a division of the peripheral nervous system — afferent and efferent, somatic and autonomic, sympathetic and parasympathetic. The CNS branch of the tree stops where it is. That is worth saying out loud, because the branching diagram makes it look as though all four divisions apply to the whole system, and they do not.

SECOND DIVISION

Afferent and efferent



NERVOUS SYSTEM

Which way is the traffic going?

The second cut is about direction of travel, and it applies to the peripheral nervous system only.

AFFERENT · SENSORY · ARRIVING

Toward the CNS

- Carries information from receptors into the central nervous system.
- Somatic sensory — from skin, muscles and joints: touch, temperature, pain, position.
- Visceral sensory — from organs: stretch, chemical change, and poorly localized pain.
- Special senses — vision, hearing, balance, taste and smell.

EFFERENT · MOTOR · EXITING

Away from the CNS

- Carries commands from the central nervous system out to effectors.
- An effector is whatever carries out the response — a muscle or a gland.
- This is the branch that divides again, into somatic and autonomic.
- The afferent side does not subdivide further at this level.

Receptor types worth naming: mechanoreceptors (touch, stretch, pressure), thermoreceptors (temperature), nociceptors (tissue damage — pain), chemoreceptors (chemical change, including oxygen and CO_2), photoreceptors (light) and proprioceptors (body position).

NERVOUS SYSTEM

The reflex arc: both sides in one loop

The clearest demonstration that afferent and efferent are two halves of a single pathway.

Detects the stimulus — heat, stretch, pressure.

Carries the signal into the spinal cord.

Processed in the cord, often through a single interneuron.

Carries the command back out.

The muscle contracts. The hand withdraws.

Why it bypasses the brain

The decision is made in the spinal cord, so the response begins before the brain has been informed. That is why you have already pulled your hand away by the time you feel the pain — the withdrawal and the sensation travel on separate timelines.

Fewer synapses means less delay. Speed is the entire point.

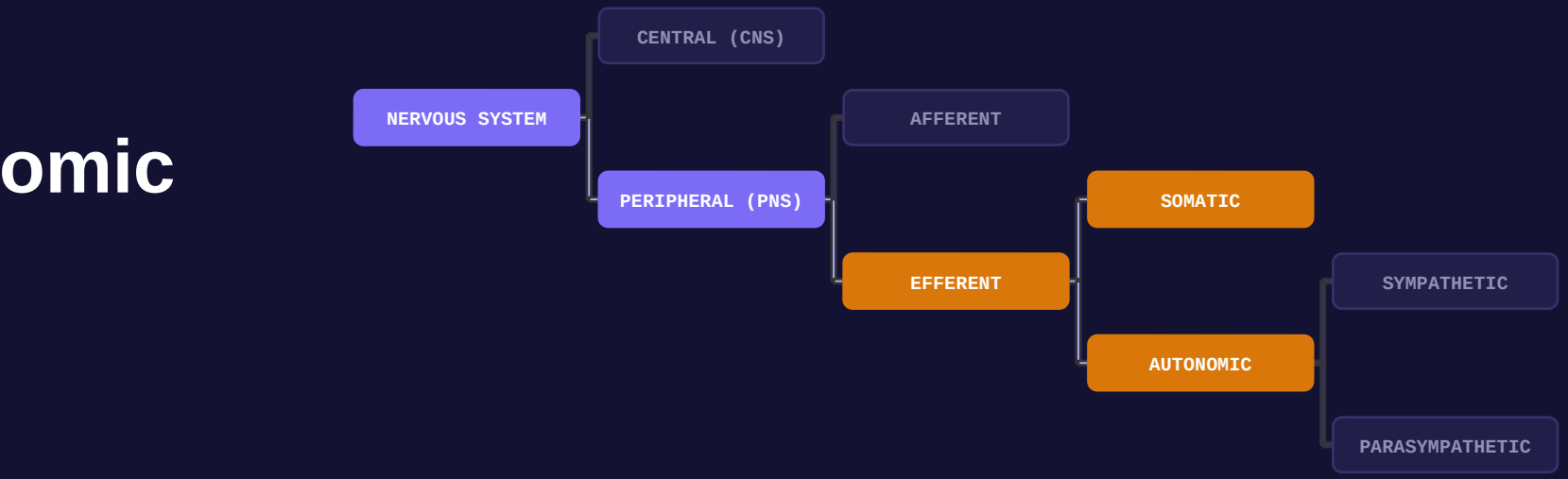
Two kinds worth knowing

Monosynaptic — sensory neuron synapses directly onto the motor neuron, with no interneuron. The knee-jerk (patellar) reflex is the classic example.

Polysynaptic — one or more interneurons sit in between, allowing more complex responses such as withdrawing one limb while bracing the other.

THIRD DIVISION

Somatic and autonomic



NERVOUS SYSTEM

Under conscious control, or not

The efferent branch splits by what it controls and whether you can choose to do it.

SOMATIC

Voluntary · skeletal muscle

- Under conscious control — you decide to move.
- Targets skeletal muscle only.
- One neuron runs the whole way from the CNS to the muscle.
- Always excitatory: it can tell a muscle to contract, never to relax. Relaxation is simply the absence of signal.

AUTONOMIC

Involuntary · organs and glands

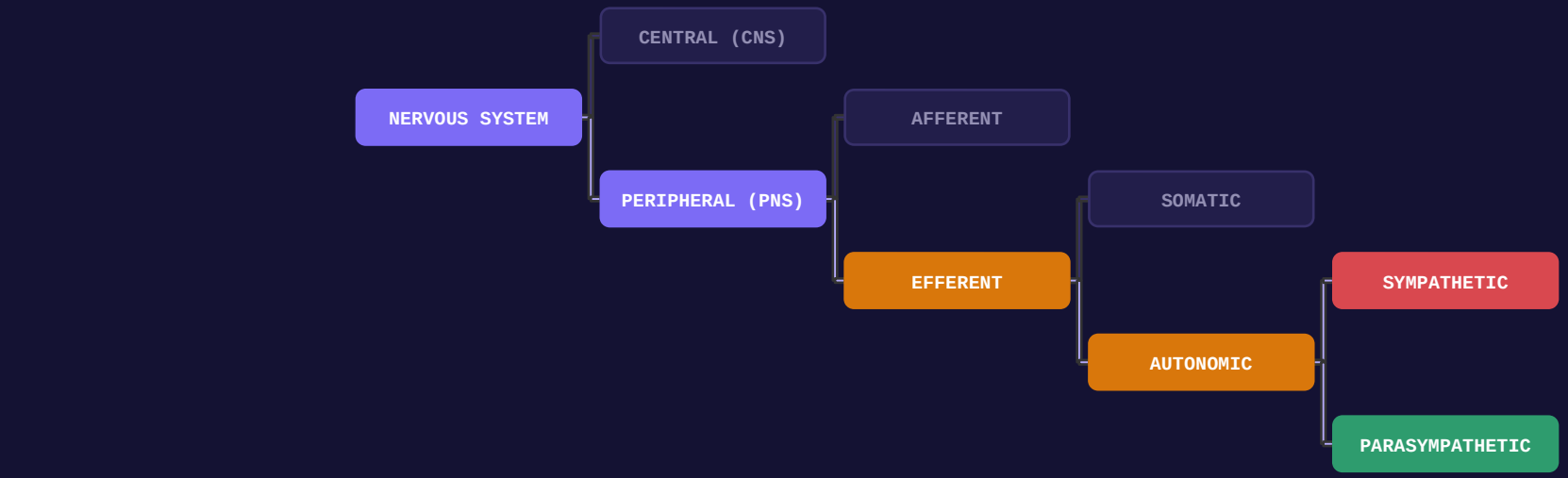
- Runs automatically, below conscious awareness.
- Targets smooth muscle, cardiac muscle and glands.
- Two neurons in series, with a ganglion (a relay point) between them.
- Can excite or inhibit — it can speed the heart or slow it.

The two-neuron chain is the structural signature of the autonomic system

A preganglionic neuron leaves the CNS and synapses in a ganglion; a postganglionic neuron carries on to the target. Where that ganglion sits — near the cord or near the organ — is exactly what separates the two autonomic divisions on the next slides.

FOURTH DIVISION

Sympathetic and parasympathetic



NERVOUS SYSTEM

Two opposing arms of one system

Both are running all the time. What changes is the balance between them.

SYMPATHETIC

Fight or flight

- Prepares the body for exertion, threat or stress.
- Origin: thoracolumbar — spinal cord segments T1 to about L2.
- Short preganglionic neuron, long postganglionic neuron. The ganglia sit in a chain close to the spinal cord.
- That arrangement lets one signal spread widely, so the response is diffuse and whole-body.
- The adrenal medulla acts as a modified ganglion, releasing epinephrine (adrenaline) into the blood to prolong the effect.

PARASYMPATHETIC

Rest and digest

- Conserves energy and runs maintenance — digestion, repair, elimination.
- Origin: craniosacral — four cranial nerves plus sacral segments S2 to S4.
- Long preganglionic neuron, short postganglionic neuron. The ganglia sit on or in the target organ.
- That arrangement gives precise, organ-by-organ control rather than a body-wide surge.
- The vagus nerve alone carries the majority of parasympathetic output to the chest and abdomen.

Remember the origins by their names: sympathetic is thoracolumbar (the middle of the cord), parasympathetic is craniosacral (both ends).

NERVOUS SYSTEM

The same organ, two opposite instructions

Most organs receive both, and the resting state is a balance rather than an off switch.

ORGAN	SYMPATHETIC	PARASYMPATHETIC
Heart	Rate and force increase	Rate slows
Airways	Bronchioles dilate	Bronchioles constrict
Pupils	Dilate	Constrict
Digestion	Motility and secretion slow	Motility and secretion increase
Salivary glands	Thick, scant secretion	Watery, copious secretion
Bladder	Wall relaxes, sphincter contracts — retention	Wall contracts — emptying
Liver	Releases glucose	Stores glucose
Skin vessels	Constrict, shunting blood to muscle	Little direct effect
Sweat glands	Increase secretion	No significant supply

NERVOUS SYSTEM

The chemical messengers

Two transmitters do nearly all of the autonomic work — the pattern of which goes where is simpler than it first looks.

Every preganglionic neuron

In both divisions, the first neuron releases acetylcholine at the ganglion. There is no difference between sympathetic and parasympathetic at this first relay — the divergence happens only at the second neuron.

The postganglionic neuron

Parasympathetic: releases acetylcholine onto the target — a cholinergic system.

Sympathetic: releases norepinephrine onto the target — an adrenergic system. The sweat glands are the notable exception, receiving acetylcholine despite being sympathetic.

Why this matters beyond the exam

A very large share of everyday medicines work by imitating or blocking these two transmitters. Beta blockers occupy norepinephrine's receptors and slow the heart; anticholinergic drugs block acetylcholine and dry secretions, speed the heart and dilate pupils. Learning which transmitter goes where is the foundation for understanding the drugs later — and for recognizing the pattern when someone has taken too much of one.

NERVOUS SYSTEM

Balance, not a switch

Three refinements that separate a working understanding from a memorized list.

AUTONOMIC TONE

Neither division ever turns fully off. Both send a steady background level of signal, and the body adjusts by shifting the balance. Slowing the heart usually means increasing parasympathetic output rather than switching the sympathetic system off.

DUAL INNERVATION

Most organs receive fibres from both divisions, which is what allows fine control in either direction. A few do not: sweat glands, most blood vessels and the adrenal medulla receive sympathetic supply only, and are regulated by varying that one input.

THE ENTERIC SYSTEM

The gut has its own extensive network of neurons in the wall of the digestive tract — large enough that it is sometimes called a third autonomic division. It can run digestion locally, while the other two divisions modulate it.

A common misconception

Fight or flight and rest and digest are useful labels, but they suggest the two systems take turns. They do not. Both are active continuously, in every state, and normal function depends on the ratio between them rather than on one being in charge.

NERVOUS SYSTEM

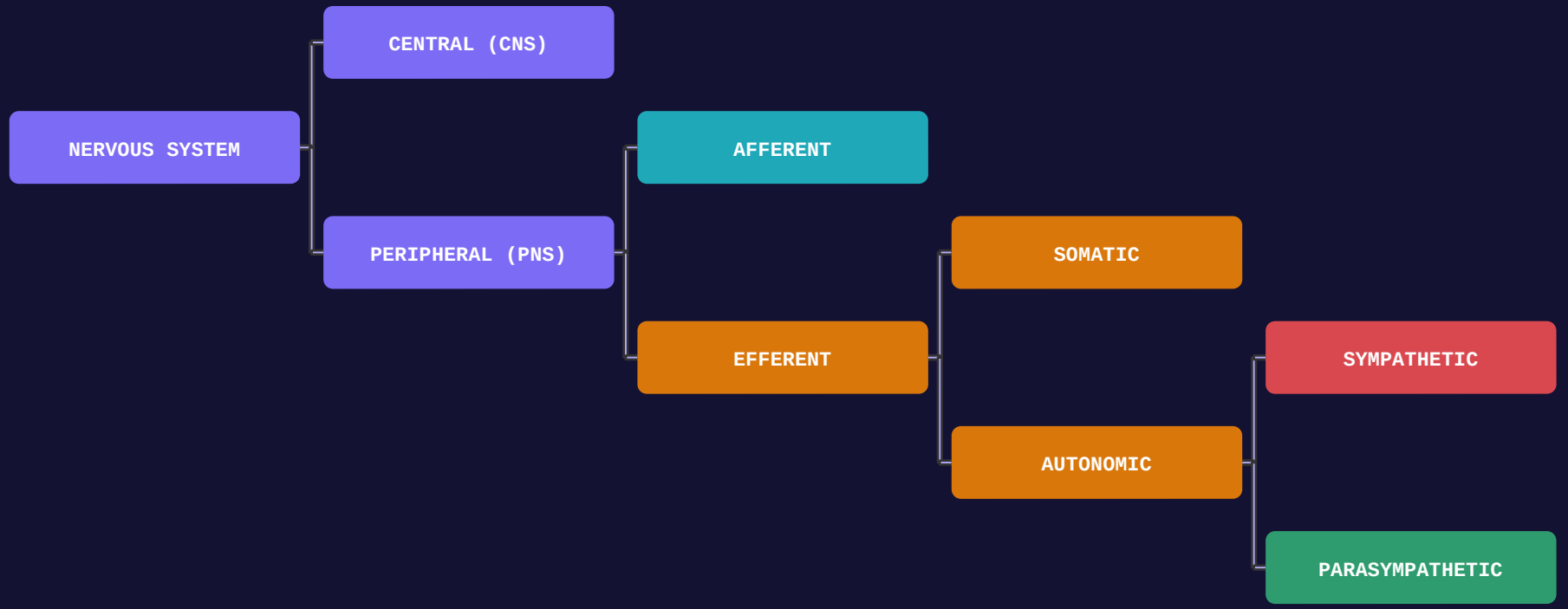
One event, traced through the whole tree

You step on something sharp. Follow the signal through every division in order.

01	PNS · AFFERENT	Nociceptors in the sole detect tissue damage. A sensory neuron carries the signal into the spinal cord.
02	CNS · INTEGRATION	The cord processes it immediately through an interneuron, and simultaneously relays it upward so the brain will register pain a moment later.
03	PNS · EFFERENT · SOMATIC	A motor neuron fires and the flexor muscles of that leg contract. The foot lifts before you are consciously aware of the injury.
04	PNS · EFFERENT · AUTONOMIC · SYMPATHETIC	Pain and alarm trigger a sympathetic surge: heart rate rises, pupils dilate, skin vessels constrict, epinephrine enters the bloodstream.
05	PNS · EFFERENT · AUTONOMIC · PARASYMPATHETIC	Once you have sat down and the threat has passed, parasympathetic activity increases again, heart rate settles and normal digestion resumes.

NERVOUS SYSTEM

The whole system on one page



Central or peripheral is about location.

Brain and cord inside the bony case; everything else outside it.

Afferent or efferent is about direction.

Arriving carries sensation in; exiting carries commands out.

Somatic or autonomic is about control.

Voluntary to skeletal muscle; involuntary to organs and glands.

Sympathetic or parasympathetic is about balance.

Both run continuously; the body shifts the ratio.