BASIC SCIENCES · ANATOMY · NEUROANATOMY

VETERINARY NEUROANATOMY NOTES

Veterinary Neuroanatomy Notes: Brain, Spinal Cord and Cranial Nerves (PDF)

Neuroanatomy is the map; neurology is what you do on it. This guide is the map: how the nervous system is divided and why two divisions are needed, what it is built from, the parts of the brain and the spinal cord, the pathways running between them, the coverings around them, the twelve cranial nerves and where the domestic species differ. Inside: Ten labelled figures, nine reference tables and an 83-question self-test.

Contents

The 13 sections of this guide, in order.

IN SHORT

Neuroanatomy is the map; neurology is what you do on it. These veterinary neuroanatomy notes give the map: the two ways the nervous system is divided and why you need both, what a neuron and a neuroglial cell are, how the whole system is built from a plate into a tube and then into five brain divisions, the parts of the brain and the spinal cord, how a pathway's name tells you its route, the meninges and the spaces and the fluid between them, the twelve cranial nerves with their components and their foramina, how a spinal nerve and a plexus are put together, the two autonomic outflows, and where the domestic species genuinely differ. Signs, reflexes and lesion grading are left to the clinical pages.

KEY POINTS

1. **The system is divided twice, and you need both cuts.** By place, into the central nervous system of brain and cord and the peripheral nervous system of nerves and ganglia. By job, into afferent and efferent, each somatic or visceral, and the afferent side again into general and special. Every structure has a label from each.
2. **Nucleus and ganglion are the same object; tract and nerve are the same object.** The only difference is which side of the boundary of the central nervous system it sits on. That is why the optic nerve is anatomically a brain tract, and why the cell bodies of sensory neurons sit in a swelling outside the cord.
3. **Grey outside in the brain, grey inside in the cord.** Grey matter is cell bodies, white matter is myelinated axons. The cerebrum and cerebellum wear their grey as a surface cortex with white beneath; the spinal cord has grey in the middle and white around it.
4. **The adult arrangement is a developmental one.** The three layers of the neural tube become ependyma, grey matter and white matter, in that order from the lumen outwards; the alar plate becomes the sensory dorsal horn and the basal plate the motor ventral horn; and three brain vesicles become five divisions whose names the adult brain still carries.
5. **A pathway's name is its route.** First half where it starts, second half where it ends — spinothalamic from cord to thalamus, corticospinal from cortex to cord. If the second half is *spinal*, it descends. A few names, the medial lemniscus among them, describe shape instead, and there the rule does not apply.
6. **There is no epidural space inside the skull.** The cranial dura is fused to the periosteum, which obliterates the space and encloses the venous sinuses in the fused layer. Around the cord the dura is a free tube with a real epidural space outside it, full of fat and veins. Everything you can do with a needle follows from that one difference.
7. **Twelve cranial nerves in three groups.** Special sense (I, II, VIII, all purely sensory); nerves to head muscles of somitic origin (III, IV, VI, XII); and pharyngeal arch nerves (V, VII, IX, X, XI). Somatic efferent fibres are in every cranial nerve except the three purely sensory ones.
8. **Root before the junction, ramus after it.** The two roots are pure — dorsal sensory, ventral motor. Every ramus is mixed. And a plexus recombines the ventral rami of several segments, which is why a named limb nerve never matches a single spinal segment.

9. **The autonomic nervous system is defined as wholly efferent.** Sympathetic is the thoracolumbar outflow with ganglia near the cord; parasympathetic is the craniosacral outflow, confined to cranial nerves III, VII, IX and X and the pelvic nerves, with ganglia at the target organ. That difference in ganglion position is why one response is diffuse and the other precise.
10. **Where the cord ends is a species fact, and a variable one.** Usually L7 in the dog but sometimes L6, and S1 in some breeds; L7 in the cat and pig; S1 or S2 in the horse; S1 in the adult ox but S3 in the calf. Quoting one figure as if it were fixed is quoting it wrongly.

About the images

Nine figures are reproduced for educational reference: one from Dyce, Sack and Wensing's *Textbook of Veterinary Anatomy*, 5th ed. (Fig. 8.3), two from Thomson and Hahn's *Veterinary Neuroanatomy: A Clinical Approach* (Fig.s 2.3A and 3.10), four from Evans and de Lahunta's *Miller and Evans' Anatomy of the Dog*, 5th ed. (Fig.s 14.13, 14.14, 16.15 and 17.1) and two from McCracken, Kainer and Spurgeon's *Color Atlas of Small Animal Anatomy* (Plates 1.30C and 1.30B). Each is credited beneath it and copyright remains with the original authors and publishers. The other two figures are diagrams of our own, drawn for this guide from the sources named under them.

01 What veterinary neuroanatomy is, and what this page leaves alone

Neuroanatomy is the branch of anatomy that deals with the nervous system: how it is built, what its parts are called, and where each one sits. It is not neurology. Neurology is what you do with a patient; neuroanatomy is the map you do it on, and a clinical sign is only useful to someone who can already say what lives where.

That distinction is the reason this page exists in the shape it does. If you have already met our guide to upper and lower motor neuron signs, you have met the method — the reasoning that turns a set of signs into a place in the nervous system. This page is the other half: the place itself. It names the divisions of the brain, the parts of the spinal cord, the pathways running between them, the coverings around them, the twelve cranial nerves and the way a spinal nerve is put together, and it stops there. No disease, no examination, no grading of a deficit.

What this page owns, and what it hands on

Here: the structural map of the central and peripheral nervous systems — divisions, development, cells, pathways by name and route, meninges and cerebrospinal fluid, the cranial nerves, spinal nerves and plexuses, the autonomic outflows, and where the species differ. **Handed on:** upper and lower motor neuron signs, reflex testing, lesion grading and every neurological disease go to the upper versus lower motor neuron page and to the clinical pages. How a neuron generates and conducts an impulse goes to how a nerve cell fires. This page tells you what a neuron *is*; that one tells you what it *does* electrically.

A branch of anatomy is a way of cutting up one animal, not a separate animal. Neuroanatomy sits alongside osteology, arthrology, myology, angiology and splanchnology in the classical scheme, and our veterinary anatomy notes sets out how the branches fit together. What makes this one feel different is that its subject is continuous: there is no natural break between the brain and the spinal cord, and the peripheral nerves are the same tissue running out into the body. The Latin word for the whole continuous thing is the *neuraxis*, and it is a useful word precisely because it refuses the division.

Three things make neuroanatomy hard, and none of them is the amount of material. The first is that the vocabulary is doubled: almost every part has an everyday name and a developmental one, and textbooks switch between them without warning. The second is that the same word means different things in different places — a **nucleus** inside the central nervous system and a **ganglion** outside it are the same object with two names, and both collide with words you already know from cell biology. The third is that the adult arrangement looks arbitrary until you have seen how it was built. This page takes those three in order, because each one makes the next easier.

One practical note before you start. Everything here assumes you are comfortable with directional terms — rostral, caudal, dorsal, ventral, median — and with the idea of a section through a structure. If those are shaky, the planes and directions covers them, and the Latin and Greek roots behind the names explains why so many of the names below are Latin. It is worth ten minutes: the nervous system is the part of the body where a misread direction changes the meaning of a whole sentence.

02 Two ways to divide the nervous system — and you need both

The nervous system is divided twice, along two different axes, and the two schemes are not alternatives. One tells you **where** a part is; the other tells you **what it carries**. Every **pathway** named in the rest of this page has an answer under each, and being able to give both is most of what it means to know your way around. A structure that is not a pathway — a meninx, a ventricle — takes only the first cut.

HOW IT IS DIVIDED

Two cuts, one system

Every part gets a label from each.

CNS brain and spinal cord

PNS cranial and spinal nerves

Afferent carries in, to the CNS

Efferent carries out, to muscle or gland

Somatic / visceral body wall / organs

Fig 1 — Two cuts through one system. These are not rival schemes and you do not choose between them. The first cut is **where a part is** — inside the brain and cord, or outside them. The second is **what it carries**, and it applies twice over: in or out, and body wall or organ. Every structure on this page has a label from each cut, and a structure you can label both ways is a structure you can place.

Diagram — Vet-eBooks.com, drawn for this guide. Data from Dyce KM, Sack WO, Wensing CJG. Textbook of Veterinary Anatomy, 5th ed. Saunders/Elsevier, pp. 439–440.

The first cut: central and peripheral

Dyce calls this *the most fundamental division*, and it is made on anatomical grounds alone. The **central nervous system** is the brain and the spinal cord. The **peripheral nervous system** is everything else: the spinal nerves that travel out through the body and limbs, the cranial nerves that travel in the head, and the ganglia associated with them.

The two work together so closely that the boundary can look like bookkeeping, but it is not. They have distinct embryological origins, which the next section but one takes up. And they respond differently to injury: the peripheral nervous system has **some capacity for regeneration** of damaged fibres, and the central nervous system does not regenerate. That single difference is why a crushed peripheral nerve carries a prognosis that a comparable injury inside the cord does not.

The second cut: what the fibre carries

The peripheral nervous system is then divided **functionally**, and this is where students lose their footing, because the division happens three times over.

First, by direction. **Afferent** fibres conduct impulses *towards* the spinal cord and brain; this is the sensory component. **Efferent** fibres conduct impulses *away* from them; this is the motor component. The words are worth learning as a pair with their Latin sense — *ad-ferre*, to carry to; *ex-ferre*, to carry out — because in a system where everything is a two-way street the direction is the only thing keeping the pathways straight.

Second, each of afferent and efferent divides into **somatic** and **visceral**. The somatic system deals with the relationship of the animal to the outside world: sensation from the skin and the tissues of the limbs and body wall, and behaviour such as locomotion. The visceral system deals with the internal organs — blood pressure and heart rate, glandular activity, digestion. Dyce notes that the somatic system is *sometimes referred to as the voluntary system*, and hedges it exactly as it should be hedged: not because visceral function is involuntary in some absolute sense, but because there is greater conscious awareness and greater voluntary control on the somatic side.

Third, the afferent side divides once more, into **general** and **special**. General afferent pathways sense pressure, stretch, temperature and noxious stimuli from tissues all over the body and head — the last of those, the detection of tissue-damaging stimuli, being **nociception**. Special afferent pathways carry the five senses of the head: vision, hearing, taste, smell and balance.

Seven components, and why the list is worth memorising

Multiply those out and you get the classical **functional components** — the labels that a cranial nerve table usually carries, generally abbreviated to their initials. They are worth learning here, once, because §9 leans on them entirely.

COMPONENT	DIRECTION	WHAT IT CARRIES	WHERE YOU MEET IT
General somatic afferent GSA	In	Touch, pressure, temperature and noxious stimuli from skin, and stretch and tension from muscles and joint capsules — the proprioceptive category	All spinal nerves, and cranial nerve **V**
Special somatic afferent SSA	In	Vision, hearing and balance — from the retina and the inner ear	Only **two** cranial nerves: **II** and **VIII**
General visceral afferent GVA	In	Mostly stretch and pressure from vessels, glands and viscera; a minority are chemoreceptors responding to blood carbon dioxide	Cranial nerves **III, V, VII, IX, X** and all spinal nerves
Special visceral afferent SVA	In	Smell and taste	Smell in **I**; taste in **VII**, **IX** and **X**
Somatic efferent SE / GSE	Out	To striated muscle — in the body from somites, in the head from somites and from the pharyngeal arches	All spinal nerves, and every cranial nerve **except I, II and VIII**
General visceral efferent GVE — the autonomic system	Out	To smooth muscle of vessels and viscera, to cardiac muscle, and to glands	Sympathetic: thoracolumbar spinal nerves. Parasympathetic: **III, VII, IX, X** and the sacral nerves
Special visceral efferent SVE, in schemes that separate it	Out	To the striated muscle that develops from the pharyngeal arches — the muscles of mastication and of facial expression, and the pharyngeal and laryngeal muscles	**V, VII, IX, X, XI**. Some texts fold this into somatic efferent; both usages are current

Two entries in that table repay a second look, because they are the ones that make the cranial nerve table predictable rather than arbitrary. **Special somatic afferent** fibres are found in only **two** cranial nerves — the optic (II) and the vestibulocochlear (VIII) — because only two organs, the retina and the inner ear, produce that kind of information. And **somatic efferent** fibres are present in *all* spinal nerves and in every cranial nerve **except the three that are purely sensory**: I, II and VIII. Learn those two facts and a third of the cranial nerve table becomes derivable instead of memorised.

> **The exam-shaped version**
>
> Any fibre you are asked about has three labels, in this order: **central or peripheral**, **afferent or efferent**, **somatic or visceral** — and if it is afferent, **general or special**. A fibre carrying pain from the skin of the flank is peripheral, afferent, somatic and general. A fibre carrying taste is peripheral, afferent, visceral and special. Practise on the awkward ones and the rest look after themselves.

One more thing belongs here, because it is the commonest confusion in the whole subject. The **autonomic nervous system** is not a fourth division alongside these. It is the name given to the **visceral efferent** pathways — one line of the seven functional components, not a separate system. Section 11 comes back to why it is defined that way, and to the one thing that follows from it.

03 The cell, its company, and four pairs of words that trip everyone

Before the parts, the material. The nervous system is built from two families of cell: the **neurons**, which conduct, and the **neuroglia**, which do everything else. Neither of those words appears anywhere in the rest of our anatomy library, which is a fair measure of how easy it is to write about the nervous system without ever saying what it is made of.

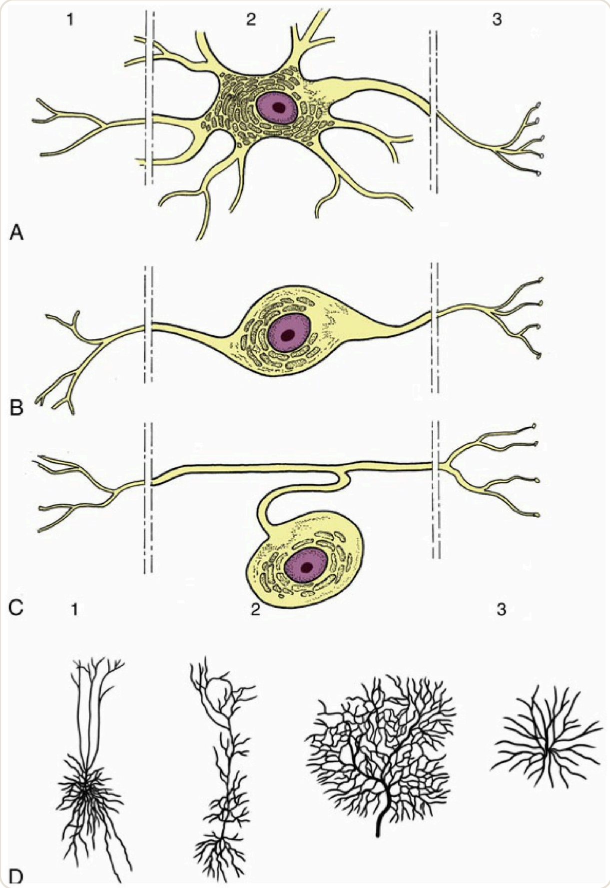


Fig 2 — Three shapes, and then what they really look like. Panels **A**, **B** and **C** are the three shapes, all drawn the same way and all keyed the same way: **1** the receptor side, the dendrites; **2** the cell body, the perikaryon; **3** the effector side, the axon. Read them as one picture and the difference is only *where the cell body sits on the line* — in the middle in A and B, off to one side on a short stalk in C. Panel **D** is the honest correction: real neurons are far more branched than any of the three, and the schematic is a simplification you are being shown on purpose.

Image — Dyce KM, Sack WO, Wensing CJG. Textbook of Veterinary Anatomy, 5th ed. Saunders/Elsevier — Fig. 8.3, schematic diagrams of multipolar, bipolar and unipolar neurons, with drawings of actual neurons. Reproduced for educational reference.

The neuron, in three parts and three shapes

A neuron has a cell body — the **perikaryon** — containing the nucleus, and from it extend processes of two kinds. **Dendrites** are multiple and highly branched, and they transmit impulses *towards* the cell body. The **axon** is always single at its origin and conveys impulses *away*. That is the whole of the basic plan, and the three shapes below are variations on where the cell body sits relative to the line the signal travels along.

- **Multipolar** — many branching dendrites joining the cell body at scattered points. Most neurons are this shape, the motor neurons of the ventral horn among them.
- **Bipolar** — the dendrites join in a common trunk before reaching the cell body, which sits away from the origin of the axon. Found in the retina of the eye and in the olfactory epithelium.
- **Unipolar** — dendrites and axon are directly continuous along a single process, and the cell body hangs off it by a short stalk. **All sensory neurons of the peripheral nervous system are this shape**, which is why the cell bodies of sensory neurons sit in a swelling *beside* the nerve rather than in its line. You will also meet the name **pseudounipolar** for it, from the way it develops out of a bipolar cell.

In both the bipolar and the unipolar shape the new electrical signal is generated where the dendrites converge, not at the cell body — a small point that explains why a sensory cell body can sit off the pathway without slowing anything down.

The company it keeps

Neurons are supported by other specialised cells, and there are far more of them than there are neurons. Collectively they are the **neuroglia**, or glia, and the ones worth knowing by name are these.

- **Astrocytes** — the general support cell of the central nervous system: nutrition, maintenance of the extracellular environment, and a part in neurotransmission. Their processes end on capillaries as the perivascular feet that contribute to the blood–brain barrier.
- **Oligodendrocytes** — these wrap their own cell membrane concentrically around axons *within* the brain and spinal cord to form **myelin**, which insulates the axon and speeds conduction. One oligodendrocyte serves several axons.
- **Schwann cells** — the same job in the peripheral nervous system, but one cell to one internode of one axon. The gap between two successive cells along an axon is a **node of Ranvier**.
- **Microglia** — the resident immune cells of the central nervous system.
- **Ependymal cells** — the epithelium lining the ventricles of the brain and the central canal of the cord. They are the direct descendants of the innermost layer of the embryonic neural tube, which is why they are still there lining its lumen in the adult.

What myelin does to the speed of conduction, and how saltatory conduction works, belongs to how a nerve cell fires, which covers it properly. The structural point that matters here is simpler: myelin is white, cell bodies are grey, and that single fact organises the whole of the next few sections.

⭐ Four pairs of words, and why each pair exists

More students lose marks to these four pairs than to any anatomy on this page. In each case the two words name **the same kind of object in two different places**, and the place is the whole of the difference.

THE PAIR	INSIDE THE CNS	OUTSIDE THE CNS	WHAT BOTH WORDS ACTUALLY NAME
Cell bodies	**Nucleus** as in *the nucleus of the abducent nerve*	**Ganglion** as in *the spinal ganglion*	A collection of neuronal cell bodies. Only the side of the boundary differs — and this *nucleus* is not the organelle you already know
Bundles of axons	**Tract** also fasciculus, funiculus, lemniscus	**Nerve** with its epineurium, perineurium and endoneurium	A bundle of axons running together. It is why the optic *nerve* is really a tract
The two matters	Both, arranged differently	—	**Grey** is cell bodies; **white** is myelinated axons. Grey is **outside** in the cerebrum and cerebellum, as a cortex, and **inside** in the spinal cord
Before and after the junction	—	**Root** before, **ramus** after	A **root** is pure — dorsal sensory, ventral motor. A **ramus** is always **mixed**, because the two have already joined

The first pair is the one to fix first. A **nucleus**, in this subject, is a collection of neuronal cell bodies *inside* the central nervous system. A **ganglion** is a collection of neuronal cell bodies *outside* it. This collides head-on with the cell-biology sense of nucleus that you already have, and there is no help for that beyond knowing it happens: when a neuroanatomy text says *the nucleus of the abducent nerve*, it means a cluster of cell bodies in the brain stem, not an organelle.

The second pair works the same way for axons. A bundle of axons running together inside the central nervous system is a **tract**; the same bundle outside it is a **nerve**. This is why the optic nerve is a slight lie, and §9 comes back to it.

The third pair is grey and white matter. **Grey matter** is where the cell bodies are; **white matter** is where the myelinated axons are, and the white is the colour of the myelin. And here is the part that catches people: **the arrangement is reversed between the brain and the cord**. In the cerebral hemispheres and the cerebellum the grey matter is on the outside, as a surface *cortex*, with white matter deep to it. In the spinal cord the grey matter is on the inside and the white matter surrounds it. Thomson and Hahn put it plainly — in the cerebrum *this is the opposite of the spinal cord arrangement*. Anywhere in the brain where grey matter sits deep instead, as the basal nuclei do, it is called a nucleus, by the rule above.

The fourth pair, root and ramus, belongs with the spinal nerve and is taken up in §10. It is listed here because the four are a set and it is worth meeting them together.

04 From a plate to a tube: how the whole thing is built

This section is out of place if you are looking for a tour of the adult. It is exactly in place if you want the adult to be memorable, because almost every name in the next four sections is a developmental name, and the arrangement of grey and white matter, the position of the ventricles and the reason the back of the cord is sensory all come straight out of the process below.

Plate, groove, tube

The nervous system appears very early, as an elongated thickening of the ectoderm called the **neural plate**, lying over the notochord and the paraxial mesoderm. The lateral parts of the plate rise into **neural folds** on either side of an axial crease, the **neural groove**. The folds lean towards each other, meet and fuse, and the groove becomes the **neural tube** — the primordium of the brain and spinal cord. The tube then sinks beneath the surface, and the non-neural ectoderm closes over it.

Fusion begins in the region that will become the junction of brain and cord, and spreads both ways, leaving two temporary openings: the **rostral** and **caudal neuropores**. The rostral one closes first. Where either fails to close, nervous tissue is left exposed on the surface of the body — rostrally as anencephaly, with malformation of the forebrain and midbrain and associated skull defects, and caudally as **spina bifida**, with defective closure of the vertebral arches. That is why a defect of the vertebral arches and a defect of the nervous system turn out to be the same event.

The neural crest, which is not part of the tube

As the folds fuse, a population of cells at the crest of each fold separates and forms continuous cords running along the dorsolateral aspect of the tube. These are the **neural crest**, and they are the reason the peripheral nervous system has a different origin from the central one.

Crest cells that stay next to the tube become the neurons of the **peripheral ganglia** — the peripheral sensory neurons, and the neurons of the visceral motor system. Crest cells that migrate away become an oddly assorted list: the neurons of the **enteric nervous system**, the medullary part of the adrenal glands, glia, the melanocytes of the skin, and a variety of craniofacial connective tissues. It is worth knowing that list, because it explains a set of conditions that otherwise look unrelated to one another.

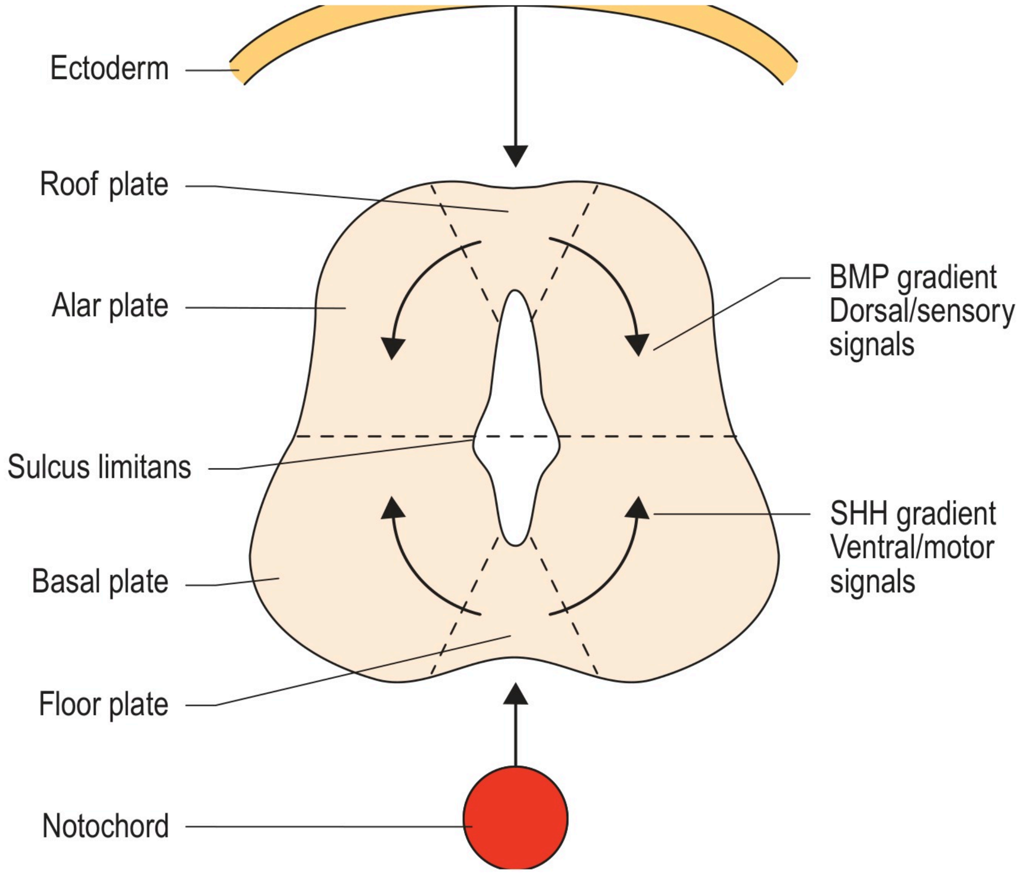


Fig 3 — Why the back of the cord is sensory and the front is motor. The tube is a cylinder with a groove down each inner wall, the **sulcus limitans**, and that groove divides it into a dorsal half, the **alar plate**, and a ventral half, the **basal plate**. The two arrows are the reason the halves differ: a signal from the overlying ectoderm above and one from the **notochord** below, pushing the cells at each end towards sensory and motor fates respectively. Everything about the adult arrangement follows from this one picture — and it is worth knowing that the two signals were named long after the anatomy was described.

Image — Thomson C, Hahn C. Veterinary Neuroanatomy: A Clinical Approach. Saunders/Elsevier — Fig. 2.3A, dorsoventral differentiation of the neural tube. Reproduced for educational reference.

Three layers, and the grey and the white

Cut across the newly formed tube and there are three concentric layers, and each one becomes something you can name in the adult.

- The innermost **neuroepithelial layer**, lining the lumen, persists as the **ependyma** that lines the central canal and the ventricles.
- The middle **mantle layer**, made of cells that migrated outwards from it, becomes the **grey matter** — the cell bodies.
- The outer **marginal layer**, made of the axons those cells grow, becomes the **white matter**.

That is the whole explanation of why the cord has grey in the middle and white outside: the cell bodies never left the middle layer, and their axons grew outwards past them.

Alar and basal: why the back is sensory

The mantle layer then bulges into the lumen as a dorsal and a ventral column on each side, separated by a longitudinal groove, the *sulcus limitans*. The dorsal bulge is the **alar plate** and it becomes the **dorsal horn** of the adult grey matter, whose neurons receive input from sensory axons. The ventral bulge is the **basal plate** and it becomes the **ventral horn**, which holds the cell bodies of motor neurons. Both also contain many interneurons.

Within those two columns the neurons then sort themselves into four groups arranged from dorsal to ventral, in the order you would now predict: somatic afferent, visceral afferent, visceral efferent, somatic efferent. That is the same list as the functional components of §2, arranged in space. It is the single tidiest thing in the subject.

The heading above promises a reason, and the reason is a pair of signals rather than anything the cells do on their own. Two **morphogens** diffuse across the tube from opposite sides. **Sonic hedgehog** comes from the **notochord** beneath it, and pushes the cells of the ventral half towards becoming motor neurons. **Bone morphogenetic protein** comes from the **overlying ectoderm** above, and pushes the cells of the dorsal half towards becoming sensory neurons. Because both diffuse, what a cell becomes depends on where in the tube it sits, which is why the transition between the two fates is a graded one at a groove rather than a line.

And each signal is handed on. Sonic hedgehog is taken over by the **floor plate** and bone morphogenetic protein by the **roof plate** — which is what those two thin strips are for. They look like the parts of the tube that were left over, and they are the parts that keep the instruction running after the notochord and the surface ectoderm are no longer next to the tissue they are instructing. Worth knowing, and worth knowing in the right order: the two signals were named long after the anatomy they explain was described, so the anatomy does not depend on them.

The roof and floor plates, meanwhile, stay thin and provide the crossings — **commissures** — through which fibres pass from one side to the other.

Three vesicles, then five

The part of the tube that becomes the brain is wider from the start and shows swellings before the tube has finished closing. There are three of them, the **primary brain vesicles**:

- **Prosencephalon**, the forebrain;
- **Mesencephalon**, the midbrain;
- **Rhombencephalon**, the hindbrain.

The brain then grows faster than the tissues enclosing it, and three **flexures** appear that fold it into the shape it keeps: one at the junction with the cord, one at the level of the midbrain, and a third, dorsal one that folds the hindbrain back on itself. This is why rostral and caudal stop being simple directions inside a brain, and it is worth knowing before you try to orient yourself on a median section.

Two of the three vesicles then divide, giving the **five secondary divisions** that the adult brain is named after.

PRIMARY VESICLE	SECONDARY DIVISION	ADULT DERIVATIVE	ITS CAVITY
Prosencephalon forebrain	**Telencephalon**	The paired cerebral hemispheres, their cortex and basal nuclei, and the olfactory bulbs	The two **lateral ventricles**
	Diencephalon	Thalamus, hypothalamus and the related structures; the retina and optic nerve are outgrowths of it	The **third ventricle**
Mesencephalon midbrain	Undivided — it stays one	The midbrain: tectum from the alar region, tegmentum from the basal region	The **mesencephalic aqueduct**
Rhombencephalon hindbrain	**Metencephalon**	The **pons** from the basal plate and the **cerebellum** from the alar plate	The **fourth ventricle**
	Myelencephalon	The **medulla oblongata**	The fourth ventricle, narrowing to the central canal

Read the right-hand column of that table and you have the adult brain. Read the left-hand column and you have why it is called what it is called. Section 5 puts the two together on one picture.

One thing the table cannot show

The **cerebellum** and the **pons** come from the same vesicle, the metencephalon — the alar plate expanding dorsally becomes the cerebellum, the basal plate becomes the pons. They are developmental siblings, and yet the cerebellum is conventionally excluded from the brain stem while the pons is included. That is not an error in the convention; it is a reminder that the brain stem is a **topographical** term, not a developmental one.

05 The brain, division by division

The brain, *encephalon*, is an irregular organ whose shape conforms roughly to the cranial cavity that holds it. It is continuous with the spinal cord without any clear demarcation, and the line between them is a convention rather than a boundary you could find in the tissue.

Its size does not scale linearly with the animal. Dyce puts the brain-to-body mass ratio *of the order of* 1:50 in the human, 1:200 in the dog and 1:800 in the horse — the hedge is his and it is kept here, because these are illustrative magnitudes and not measurements you should quote as data. He adds a second observation that is easy to misread: domestication tends to produce a smaller brain-to-body ratio than in undomesticated animals of the same kind, and the process is not reversed by returning domesticated animals to the wild.

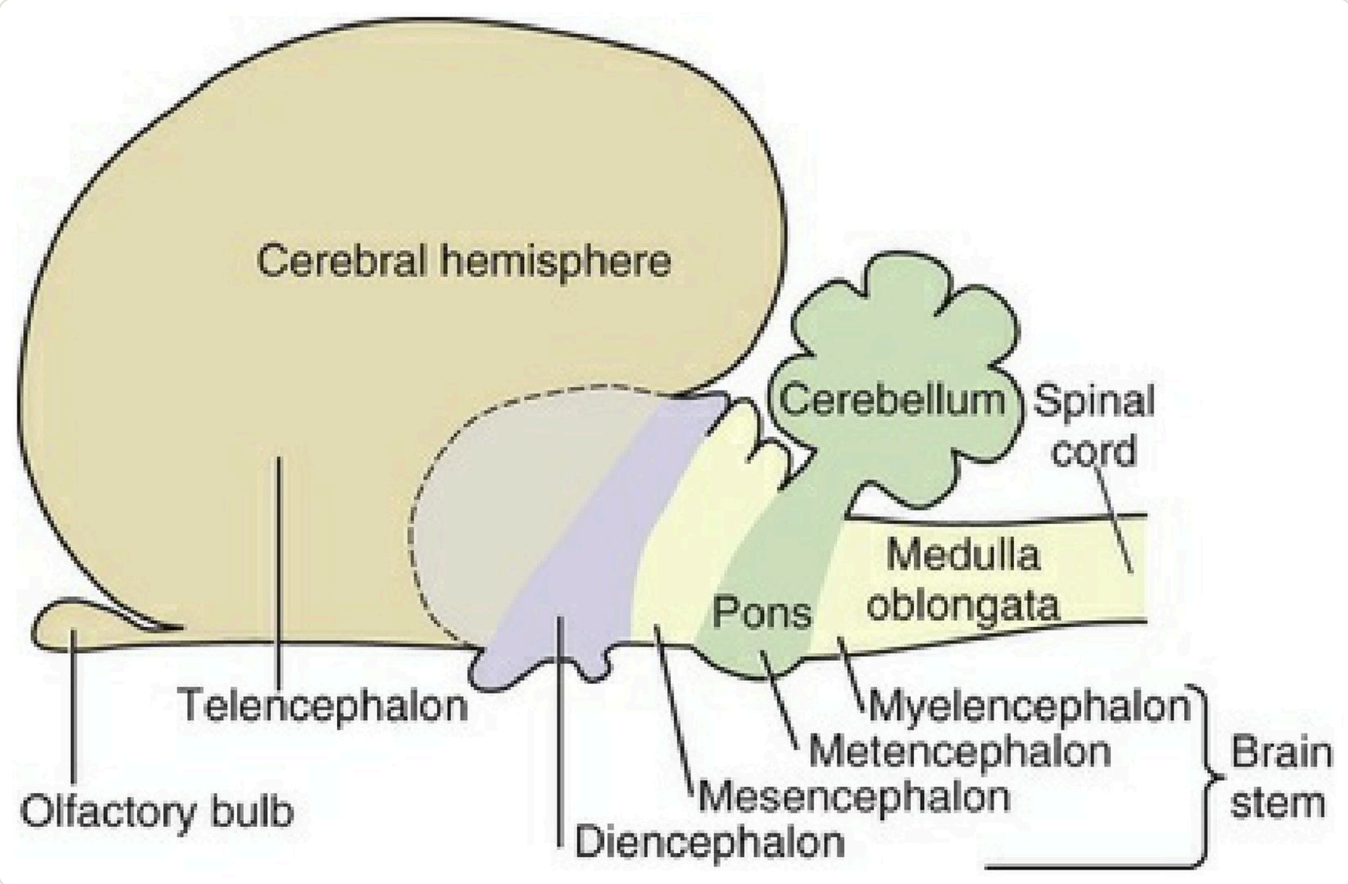


Fig 4 — One brain, two sets of names, drawn together. This is the single most useful picture on the page, because it is the only one that puts **both** vocabularies on the same outline. The names along the top are what you say out loud; the names along the bottom are what you are examined on and what the textbooks index by. Notice what the bracket includes and what it leaves out: the **brain stem** here is diencephalon, mesencephalon, the ventral part of the metencephalon (the pons) and the myelencephalon — and the cerebellum is *not* in it, although it develops from the same vesicle as the pons.

Image — Evans HE, de Lahunta A. Miller and Evans' Anatomy of the Dog, 5th ed. Elsevier — Fig. 14.13, schematic representation of the major parts of the brain. Reproduced for educational reference.

Reading the surface first

From above, the **cerebral hemispheres** and the **cerebellum** dominate, and only a small part of the **medulla oblongata** shows between the cerebellum and the cord. A deep longitudinal fissure separates the hemispheres from each other and a transverse fissure separates them from the cerebellum; in the living animal both are occupied by folds of dura.

The surface of each hemisphere is thrown into ridges and grooves — *gyri* and *sulci*, one ridge being a **gyrus** and one groove a **sulcus** — in patterns that differ significantly between species. The cerebellum is folded even more finely, into *folia*, and for the same reason: folding buys surface area, and surface area is where the processing happens, because in both structures the grey matter is on the outside. Section 12 returns to the species differences in that folding, which are larger than most students expect.

Turn the brain over and the divisions are much clearer, which is why a ventral view is the one atlases use to teach them. From the back forwards: the **medulla oblongata** widens rostrally and ends at a prominent transverse ridge, which is the ventral surface of the **pons** — the ridge is made of the transverse pontine fibres, which can be followed round the side of the brain stem to the cerebellum. In front of the pons is the **midbrain**, represented ventrally by two diverging columns, the **crura cerebri** or cerebral peduncles, separated by a shallow midline depression, the interpeduncular fossa. Rostral to that is the forebrain, whose most obvious ventral features on the midline are the **hypothalamus**, with the pituitary gland hanging from it by a stalk, and the **optic chiasm**. Flanking the crura are the rounded piriform lobes, and right at the front are the **olfactory bulbs** with their tracts.

The brain stem, defined by subtraction

There is a neat definition of the brain stem and it is worth having, because the term is used loosely everywhere. Take the cerebral hemispheres away and take the cerebellum away, and what remains is the **brain stem**, directly continuous with the spinal cord. On the outline in Figure 4, that is the diencephalon, the mesencephalon, the ventral part of the metencephalon — the pons — and the myelencephalon.

The brain stem carries the nuclei of most of the cranial nerves, the ascending and descending pathways running between the cord and the forebrain, and the **reticular formation**, a diffuse mixture of grey and white matter running through its core. It is a small structure with a great deal in it, which is why brain stem lesions are the ones clinicians treat with most respect — though what those lesions look like belongs to the clinical pages and not here.

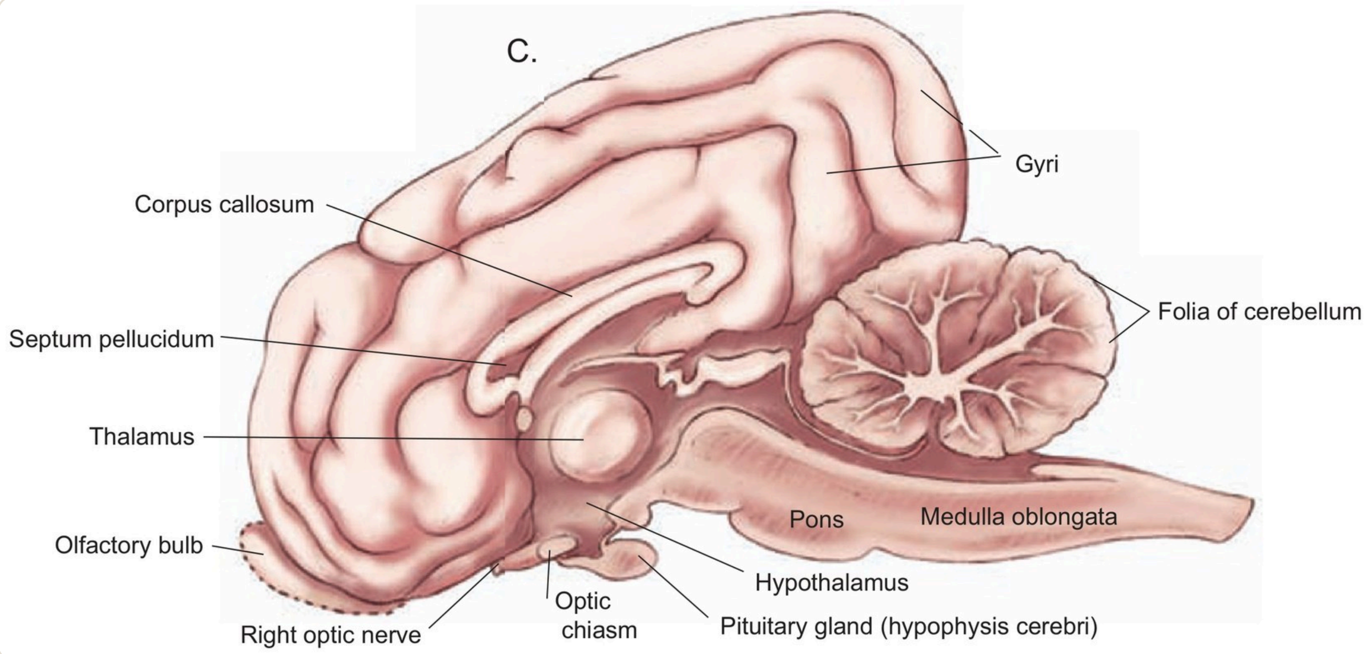


Fig 5 — The same brain, cut down the middle. The schematic above gives you the divisions; this gives you the structures inside them. Three things are worth finding before you move on. The **corpus callosum** is the thick arched band above the middle — the bridge between the two hemispheres, and a structure our own library had never named until this page. The **thalamus** is the rounded mass below it, sitting at the centre of everything. And the **cerebellum** is cut open, so its white matter branches into the grey like a tree: the *folia* are the leaves.

Image — McCracken TO, Kainer RA, Spurgeon TL. Color Atlas of Small Animal Anatomy: The Essentials. Blackwell — Plate 1.30C, midsagittal view of the dog brain. Reproduced for educational reference.

The five divisions, one at a time

The telencephalon is the paired cerebral hemispheres and their basal nuclei. Its surface is the **cerebral cortex**, a sheet of grey matter thrown into gyri; deep to it is white matter, and deep to that are the **basal nuclei**, which are grey matter sitting inside white. Between the hemispheres runs the **corpus callosum**, the great commissure that carries axons from one hemisphere to the other — you can see it on the median section above as a thick arched band. Below the corpus callosum, the thin **septum pellucidum** separates the two lateral ventricles.

Part of the telencephalon is also given over to the **limbic system**, a ring of cortex on the medial surface of the hemisphere together with a set of subcortical nuclei — among them the hippocampus, the amygdala and the septal area. Dyce describes it as controlling somatic and visceral behaviour associated with strong emotions, and notes that it is often thought of as a *visceral brain*, because so much of what it does is expressed through visceral motor activity. The hippocampus is concerned with memory. Of all sensory inputs, olfaction has the most profound effect on the system, which is a fair anatomical reason why smell drives so much behaviour in the animals we treat.

The diencephalon is the unpaired median part of the forebrain, and it is largely hidden by the hemispheres that grew back over it. It contains the **thalamus** — the relay through which almost every ascending pathway passes on its way to the cortex — and, below it, the **hypothalamus**. The third ventricle is the cavity between the two halves of the diencephalon, and in domestic mammals the two thalami are joined across it by the interthalamic adhesion.

The hypothalamus is small and does a great deal. Dyce lists its functions as the control of biological rhythms, appetite, water balance, body temperature, cardiovascular performance, sexual behaviour and activity, sleep and emotion, and describes it as an integration centre working to keep the animal alive. Structurally, only its caudal parts — the tuber cinereum and the mammillary bodies — are exposed on the ventral surface. Attached to it by the infundibulum is the **hypophysis**, the pituitary gland, which is in two parts of different origin: the neurohypophysis is an outgrowth of the brain itself, and the adenohypophysis develops from oral ectoderm.

The mesencephalon, the midbrain, is the one vesicle that never divided. Its alar region becomes the **tectum**, the roof, and its basal region the **tegmentum**. Its cavity is narrowed to the mesencephalic aqueduct, which links the third ventricle to the fourth — a detail with more clinical weight than its size suggests, because a narrow channel is an easy one to block.

The metencephalon gives the **pons** ventrally and the **cerebellum** dorsally. The cerebellum sits over the fourth ventricle, attached to the brain stem by three pairs of peduncles, and its grey matter is again outside, folded into folia, with the white matter branching into it — the arrangement that gives a median section its tree-like appearance.

The myelencephalon becomes the **medulla oblongata**, continuous caudally with the spinal cord. It holds the nuclei of the caudal cranial nerves and the centres that regulate breathing and cardiovascular function, and it is where several of the great pathways cross the midline.

DIVISION	WHAT IS IN IT	GREY MATTER ARRANGEMENT	IN THE BRAIN STEM?
Telencephalon	Cerebral cortex, basal nuclei, corpus callosum, septum pellucidum, hippocampus and the rest of the limbic system, olfactory bulbs and tracts	Cortex **outside**, with deep nuclei inside the white matter	No
Diencephalon	Thalamus, hypothalamus, pituitary gland by its stalk, interthalamic adhesion	Nuclei, deep	Yes
Mesencephalon	Tectum, tegmentum, crura cerebri, the nuclei of cranial nerves III and IV	Nuclei, deep	Yes
Metencephalon	**Pons** ventrally; **cerebellum** dorsally, with its three pairs of peduncles	Pons: nuclei. Cerebellum: cortex **outside**, folded into folia, with deep nuclei	The pons yes; the cerebellum **no**
Myelencephalon	Medulla oblongata; nuclei of most of the caudal cranial nerves; the pyramids, where the great motor pathways cross the midline	Nuclei, deep, within the reticular formation	Yes

A way to hold the five

Say them from the front backwards, in pairs, and the shape of the brain comes with them: **telencephalon** and **diencephalon** make the forebrain; **mesencephalon** is the midbrain and stays alone; **metencephalon** and **myelencephalon** make the hindbrain. Then attach the cavity to each — lateral ventricles, third ventricle, aqueduct, fourth ventricle, fourth ventricle — and you have the ventricular system in the same breath.

06 The spinal cord: segments, horns and funiculi

The spinal cord, *medulla spinalis*, is an elongated and roughly cylindrical structure, somewhat flattened dorsoventrally, lying inside the vertebral canal. Compared with the brain it is regular and uniform, and its few departures from that uniformity are the ones worth knowing.

Two swellings and a taper

The cord is thicker where the limb nerves come from. These thickenings are the *intumescentiae* — a **cervical intumescence** for the forelimb and a **lumbar intumescence** for the hindlimb — and they are thicker for the obvious reason: a limb needs a great many motor neurons and receives a great deal of sensation, and both need cell bodies. Past the lumbar intumescence the cord tapers to the ***conus medullaris***, the cone at its end.

Segments, and the one place the count does not match

The cord is divided along its length into **segments**, and a segment is defined entirely by its nerves: one segment is the length of cord that gives rise to one pair of spinal nerves. Each spinal nerve is formed by the union of a **dorsal root**, arising from the dorsolateral margin of the cord and carrying sensory afferent fibres, and a **ventral root**, arising ventrolaterally and carrying motor efferent fibres.

The segments are named by region, from cranial to caudal: cervical, thoracic, lumbar, sacral and caudal. The number in each region equals the number of vertebrae in that region for that species, with one exception — and it is a favourite examination question:

There is always one more cervical spinal segment than cervical vertebra

Every other region matches vertebra for vertebra. The cervical region does not, in any species: the first cervical nerve emerges in front of the atlas, so a dog with seven cervical vertebrae has **eight** cervical spinal nerves. That is why a lesion described as C6–T2 covers a stretch of vertebral column that is shorter than the segment names suggest.

The cord is shorter than the canal

The cord does not run the whole length of the vertebral canal. The vertebral column grows faster than the cord during development, so the caudal segments are drawn forwards relative to the vertebrae they are named for — the Latin name for this is *ascensus medullae spinalis*. The relationship between a spinal *nerve* and the vertebra it exits at stays constant, so those caudal nerves have to run backwards inside the canal before they can leave.

The bundle they form is the ***cauda equina***, named for its resemblance to a horse's tail. It carries the innervation of much of the perineum, the tail and the pelvic viscera, and its position — a mass of nerve roots in a canal with no cord in it — is what makes the caudal end of the vertebral column a convenient place to reach those nerves with a needle. Section 12 gives the species figures; §8 gives the layers you pass through.

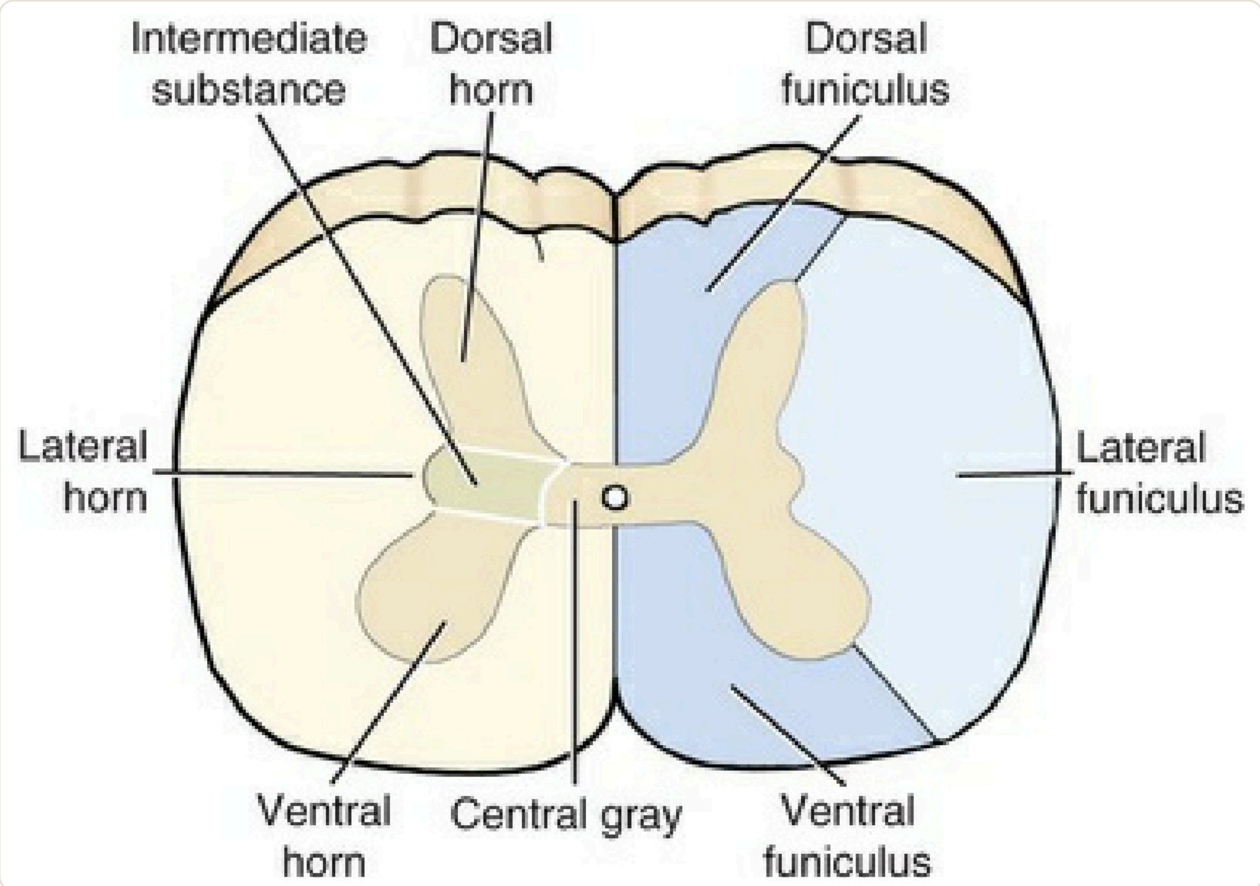


Fig 6 — Grey on one side, white on the other, in one section. An economical piece of teaching: the same section, labelled twice. The **left half** names the grey matter — the butterfly in the middle, and its **horns**. The **right half** names the white matter around it, divided into three **funiculi** by where the nerve roots attach. Hold the two halves together and you have the whole cross-sectional anatomy of the cord: cell bodies inside, axons outside, and the boundaries between the funiculi set by the roots rather than by anything visible in the tissue.

Image — Evans HE, de Lahunta A. Miller and Evans' Anatomy of the Dog, 5th ed. Elsevier — Fig. 14.14, major subdivisions of the gray and white matter of the spinal cord. Reproduced for educational reference.

Grey matter: the horns

In transverse section, the grey matter forms a central mass, crudely resembling a butterfly or the letter H, perforated on the midline by the small **central canal** — the surviving lumen of the embryonic neural tube.

The projections of that mass are conventionally called **horns**. Dyce points out that this is *a rather misleading term*, because the horns are not horns at all in three dimensions: they run the whole length of the cord, so they are columns, and they only look like horns because you are looking at a slice. The word is not going away, but knowing why it is wrong is what stops you picturing the cord wrongly.

- The **dorsal horn** is the alar plate's derivative. It contains neurons receiving afferent input from the sensory axons entering through the dorsal root, and a great many interneurons. Somatic sensory input synapses more dorsomedially, visceral afferent input more dorsolaterally.
- The **ventral horn** is the basal plate's derivative. It holds the cell bodies of the somatic efferent neurons that supply skeletal muscle, placed ventrally.
- The **lateral horn** holds the visceral efferent neurons, and it is **not present along the whole cord**: it is confined to the thoracolumbar and sacral regions. That restriction is not a curiosity — it is the anatomical statement of where the autonomic outflow leaves, and §11 depends on it.

White matter: the funiculi

The white matter surrounding the grey is divided on each side into three **funiculi**, and the divisions are made by where the roots attach rather than by anything you could see in the tissue itself:

- the **dorsal funiculus**, between the dorsal median sulcus and the line where the dorsal roots enter;
- the **lateral funiculus**, between the dorsal and ventral root lines;
- the **ventral funiculus**, between the ventral root line and the deep ventral median fissure, which is filled by a thickening of pia that appears on the surface as a glistening line.

Within the funiculi the fibres are gathered into bundles — **fasciculi**, or tracts — sharing an origin, a destination and a function. The composition differs a little between species, but as a generalisation the **dorsal funiculus is almost entirely ascending**, as are the most lateral parts of the lateral funiculus, while most of the lateral and the ventral funiculi carry both ascending and descending fibres. Which tracts those are is §7.

One last observation from the same figure: the *proportion* of grey to white changes along the cord. There is most grey where the limb plexuses arise, because that is where the cell bodies are, and most white in the cervical region, because every ascending fibre heading for the brain from anywhere caudal to it has to pass through.

07 White matter is a set of named roads

A tract is a bundle of axons inside the central nervous system that share an origin, a destination and a job. There are a great many of them, and the reason they are less frightening than they look is that they are named by a convention rather than after people.

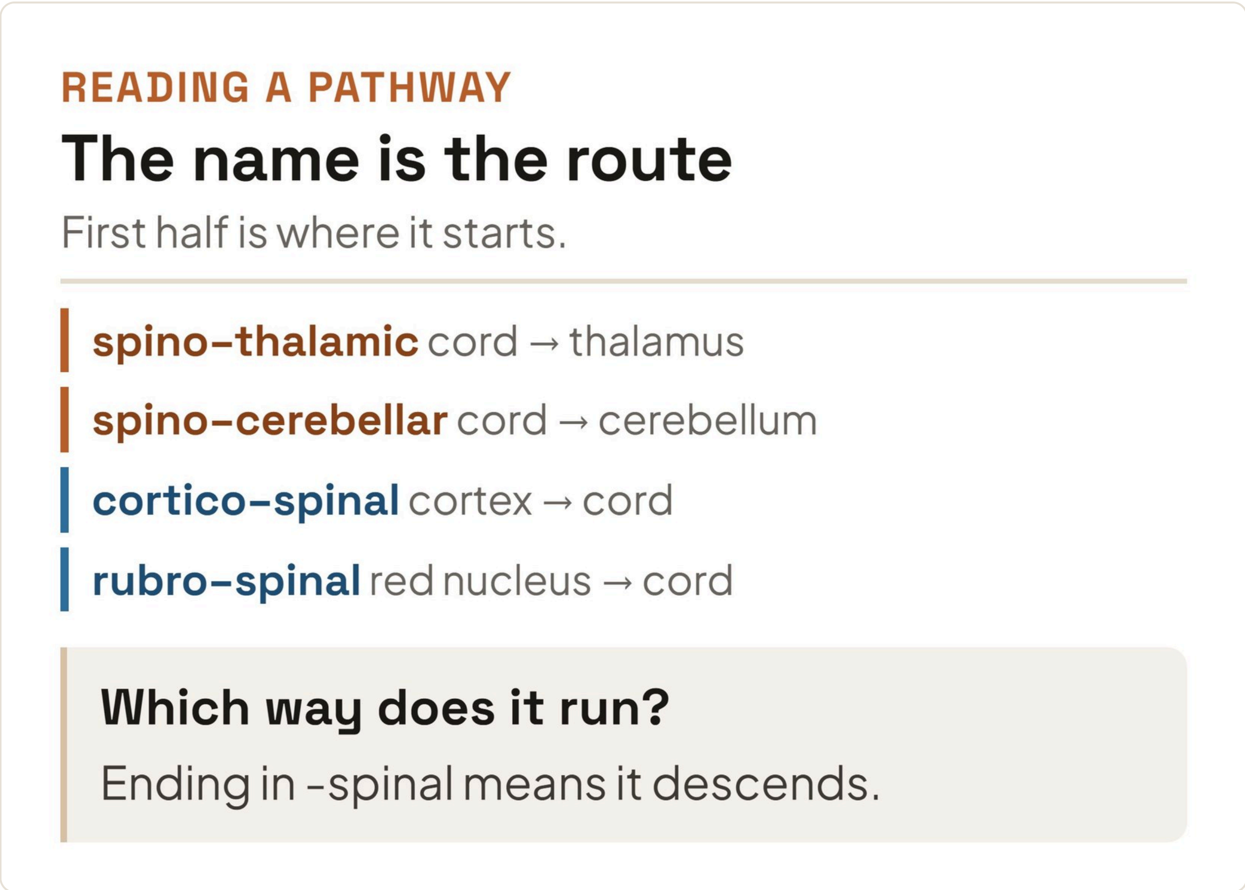


Fig 7 — The name tells you the route. Almost every named pathway in the central nervous system is built the same way: **first half, where it starts; second half, where it ends**. That is not a memory trick, it is the naming convention, and once you have it an unfamiliar tract stops being a new fact. The direction follows for free — if the second half is *spinal*, the pathway is heading for the cord, so it descends.

Diagram — Vet-eBooks.com, drawn for this guide. Schematic, not to scale. Data from Skerritt G. King's Applied Anatomy of the Central Nervous System of Domestic Mammals, 2nd ed. Wiley Blackwell, chs 8 and 10–13, and Dyce KM, Sack WO, Wensing CJG. Textbook of Veterinary Anatomy, 5th ed. Saunders/Elsevier, pp. 479–494.

The naming rule

In almost every case the name is built from two halves: **where the fibres start, then where they end**. The **spinothalamic** tract — written *spino-thalamic* to show the join — starts in the spinal cord and ends in the thalamus. *Cortico-spinal* starts in the cerebral cortex and ends in the spinal cord. The **rubrospinal** tract starts in the red nucleus — *ruber*, red — and ends in the cord, and the **vestibulospinal** starts in the vestibular nuclei. The **spinocerebellar** tracts, by the same rule, run from the cord to the cerebellum.

The direction then comes free: second half *spinal* means it **descends**, first half *spino-* means it **ascends**.

Two honest caveats. The rule is a convention and not a law — a few pathways, the **medial lemniscus** among them, are named for their shape or position instead. And a name gives you the endpoints, not the journey: many pathways involve two or three neurons in series, and the name describes only the segment it is attached to.

Crossing over

Decussation is the word for a pathway crossing the midline, and where a pathway crosses matters more than that it crosses. The great descending motor fibres leave the cortex, funnel through the **internal capsule** — the sheet of white matter squeezed between the basal nuclei and the thalamus, and the narrowest point on their whole journey — and cross in the medulla oblongata at the **pyramids**, which is where the name pyramidal system comes from. Ascending pathways cross at various levels, and some do not cross at all.

The practical consequence is the one thing about tracts that a structural page should state plainly: because most of these pathways cross somewhere, a lesion above the crossing produces its effect on the opposite side of the body, and a lesion below it on the same side. Working out which side of which crossing a lesion sits on is clinical reasoning, and it is the business of the upper versus lower motor neuron page; the anatomy that makes the question answerable is this one.

The main pathways, by route

What follows is a route table, not a clinical one. It says where each pathway starts, where it ends, and what kind of information it carries. It says nothing about what happens when one is damaged.

PATHWAY	DIRECTION	FROM	TO	WHAT IT CARRIES
Spinothalamic	Ascending	Spinal cord grey matter	Thalamus, then cortex	General sensation reaching consciousness
Spinocerebellar dorsal and ventral	Ascending	Spinal cord	Cerebellum	Proprioceptive information that never reaches consciousness
Fasciculus gracilis and cuneatus the dorsal funiculus	Ascending	Dorsal roots, running up without synapsing	Nuclei in the medulla, then thalamus	Fine touch and conscious proprioception
Medial lemniscus named for its shape, not its route	Ascending	The medullary nuclei above	Thalamus	The continuation of the dorsal funiculus pathway, after it has crossed
Corticospinal the pyramidal system	Descending	Cerebral cortex	Spinal cord	Voluntary motor commands; crosses at the pyramids of the medulla
Rubrospinal	Descending	Red nucleus of the midbrain	Spinal cord	Motor control, especially of the limb flexors
Vestibulospinal	Descending	Vestibular nuclei of the medulla	Spinal cord	Balance and antigravity support
Reticulospinal	Descending	Reticular formation of the brain stem	Spinal cord	Background tone, posture and locomotor patterns

Two groupings are worth carrying away from that table rather than the individual rows. The ascending pathways divide by **what they are for**: those that reach the thalamus and then the cortex produce conscious sensation, and those that reach the cerebellum do not — the cerebellum uses proprioceptive information continuously without the animal ever being aware of it. And the descending pathways divide by **where they come from**: some from the cortex, the rest from a set of brain stem nuclei, and the older literature calls that second group the extrapyramidal system.

> **Where the pathways surface elsewhere**
>
> The clinical use of all of this — which tract produces which sign, how a deficit is graded, and how a lesion is localised along the cord — is covered on the upper versus lower motor neuron page, which is where this article deliberately stops. If you have come here after reading that one, this table is the map underneath it.

08 The wrappings and the fluid

The brain and spinal cord are wrapped in three continuous connective-tissue membranes, the **meninges**, and float in a fluid. Both matter structurally and both matter clinically, and the single most useful thing about the arrangement is that it is **not the same around the brain as it is around the cord**.

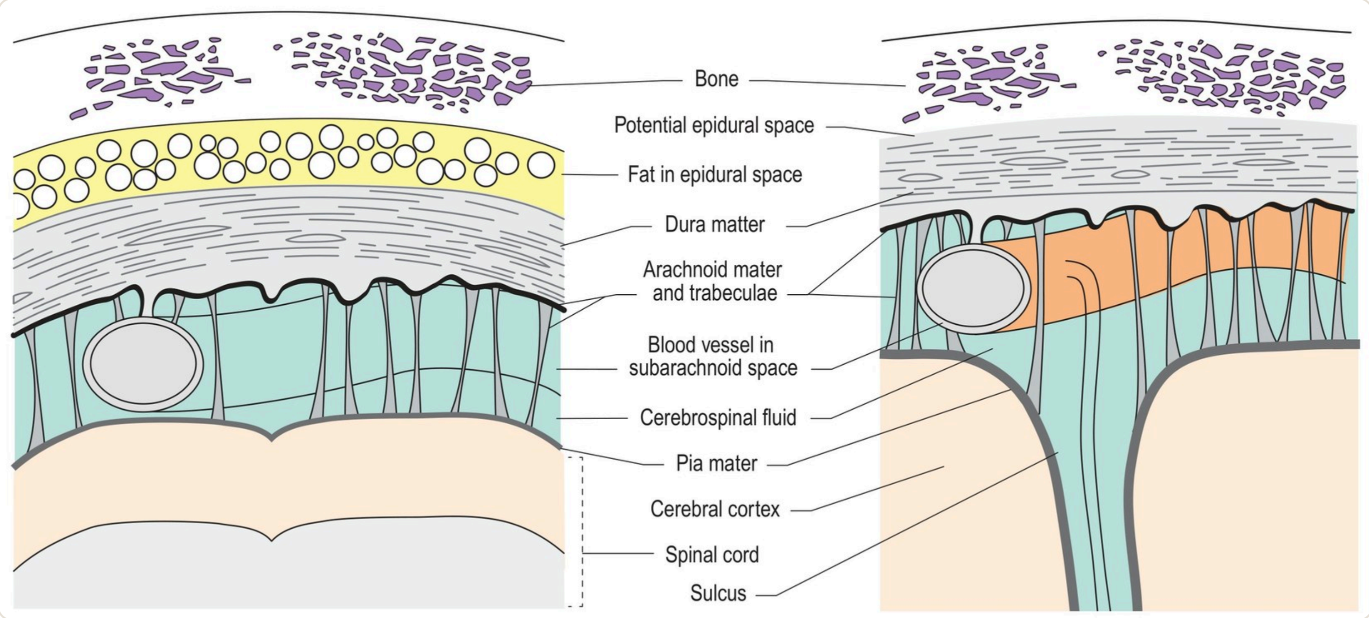


Fig 8 — The same three layers, arranged differently in two places. Read the two panels against each other rather than one at a time, because the labels are shared and the arrangement is not. On the **left**, around the cord, there is a real space outside the dura with **fat** in it. On the **right**, inside the skull, the same space is drawn as *potential* and there is no fat — because there the dura is fused to the bone. That single difference is why one injection site exists and the other does not, and it is the reason this figure shows both.

Image — Thomson C, Hahn C. Veterinary Neuroanatomy: A Clinical Approach. Saunders/Elsevier — Fig. 3.10, sections through the meninges surrounding the spinal cord and the brain. Reproduced for educational reference.

Three layers, outside in

Dura mater is the tough outermost membrane. Around the brain it is *fused with the inner periosteum of the skull*. At the margin of the foramen magnum it splits away from that periosteum and continues down the vertebral canal as a free tube, separated from the wall of the canal by a distinct space.

Arachnoid mater lies inside the dura. Its outer part is a continuous membrane moulded against the dural tube; its inner part is a mass of fine trabeculae and filaments crossing to the layer below, and it is that cobweb appearance that gave it the name.

Pia mater is the innermost layer. It covers the surface of the brain and cord and follows every contour, dipping into every sulcus. It is firmly attached, and the arteries that run in it carry sleeves of pia with them as they penetrate the tissue. In the cord, a thickening of pia fills the ventral median fissure, where it shows as a glistening line. The arachnoid and pia together are sometimes called the leptomeninges — the thin meninges — against the dura as the pachymeninx.

All three form cuffs around the roots of the cranial and spinal nerves where they leave, which is how an anaesthetic placed outside the dura can reach a nerve root.

⭐ Three spaces, and the one that only exists in one place

This is the part to get right, because the same three names describe different things in the two regions.

LAYER OR SPACE	AROUND THE SPINAL CORD	AROUND THE BRAIN	WHAT IS IN IT
Dura mater	A free tube inside the vertebral canal, separate from the bone	**Fused with the inner periosteum** of the skull	Tough fibrous tissue. The cranial dura also forms the *falx cerebri* and the *tentorium cerebelli*
Epidural space outside the dura	A **real space**	**Obliterated** — there is no epidural space in the skull	Fat, more fluid in life than post-mortem, and the internal vertebral venous plexus
Subdural space dura to arachnoid	A capillary, potential space, crossed by the **denticulate ligaments**	A capillary, potential space	A minute amount of clear lymph-like fluid. It can be opened by an effusion of blood
Arachnoid mater	Continuous outer membrane, trabeculae within	The same	Its inner trabeculae cross the subarachnoid space to the pia

LAYER OR SPACE	AROUND THE SPINAL CORD	AROUND THE BRAIN	WHAT IS IN IT
Subarachnoid space arachnoid to pia	Fairly uniform, **widening around the conus medullaris**	Uneven, with wide parts called **cisterns**	**Cerebrospinal fluid**, arachnoid trabeculae and blood vessels
Pia mater	Follows every contour; thickens into the ventral median fissure	Follows every gyrus and sulcus	Carries the vessels that penetrate the nervous tissue, in pial sleeves

The **epidural space**, outside the dura, is a real space in the vertebral canal. It contains fat — more fluid in life than it appears in a post-mortem specimen — and the internal vertebral venous plexus, and together those cushion the cord and let it accommodate movements of the neck and back. **Inside the skull there is no epidural space at all**: the fusion of the cranial dura with the periosteum obliterates it, and the venous sinuses of the head come to lie enclosed within the thickness of the combined periosteum and dura. That one difference is why epidural injection is a spinal procedure and not a cranial one.

The **subdural space**, between dura and arachnoid, is a capillary space containing only a minute amount of clear, lymph-like fluid. It is best thought of as a potential space, which can be opened by an effusion of blood after injury. In the cord it is crossed by a series of triangular **denticulate ligaments**, one alternating with each pair of spinal nerve origins, which attach the inner meninges to the dural tube and so suspend the cord within it along its whole length.

The **subarachnoid space**, between arachnoid and pia and crossed by the arachnoid trabeculae, is the one that holds the cerebrospinal fluid. It is much wider than the subdural space, and much less uniform — it has wide parts, called **cisterns**.

The two cisterns you can put a needle into

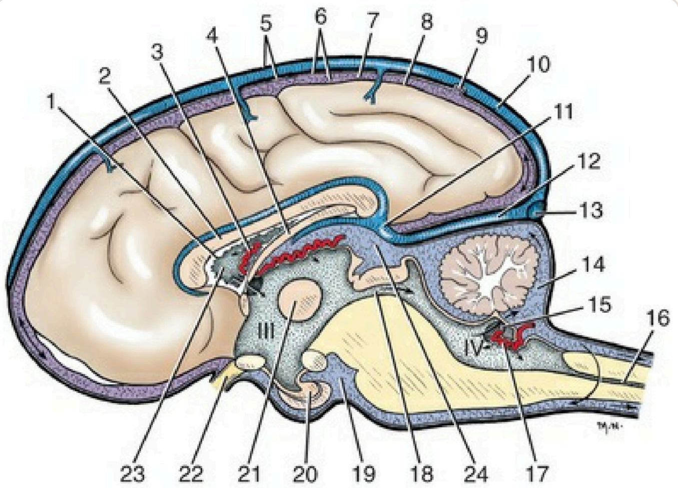
Around the brain, the widest parts of the subarachnoid space lie ventrally between the prominences of the ventral surface, and dorsally in the angle between the cerebellum and the medulla oblongata. That dorsal widening, the **cerebellomedullary cistern** — the *cisterna magna* — is especially large, and it can be reached in the living animal with a needle passed between the atlas and the skull, through the foramen magnum. That is **cisternal puncture**.

Around the cord, the subarachnoid space is fairly uniform but widens around the *conus medullaris* — which, as Dyce says, is a fortunate circumstance, because that is exactly where a dorsal approach through the lumbosacral intervertebral space can reach it. Both sites exist because of where the space is wide and where the cord is not, and both are structural facts before they are clinical ones.

The ventricles and where the fluid comes from

The **ventricles** are the adult derivative of the lumen of the neural tube, and they are easier to hold as a route than as a sentence, because that is what they are:

1. two **lateral ventricles**, one in each cerebral hemisphere;
2. the **third ventricle**, on the midline in the diencephalon, reached from each lateral ventricle through an **interventricular foramen**;
3. the narrow **mesencephalic aqueduct**, running through the midbrain;
4. the **fourth ventricle**, between the brain stem and the cerebellum;
5. and then the **central canal** of the spinal cord, which the fourth ventricle is continuous with.



1. Cut edge of septum pellucidum
2. Corpus callosum
3. Choroid plexus in lateral ventricle
4. Fornix of hippocampus
5. Dura mater
6. Arachnoid membrane and trabeculae
7. Subarachnoid space
8. Pia mater
9. Arachnoid villus
10. Dorsal sagittal sinus
11. Great cerebral vein
12. Straight sinus
13. Transverse sinus
14. Cerebellomedullary cistern
15. Lateral aperture of fourth ventricle
16. Central canal
17. Choroid plexus
18. Mesencephalic aqueduct
19. Interpeduncular cistern
20. Hypophysis
21. Interthalamic adhesion
22. Optic nerve
23. Lateral ventricle
24. Quadrigeminal cistern

Fig 9 — Where the fluid is made, and which way it goes. Follow the arrows and the whole system is one circuit. Fluid is made at the **choroid plexus** in each ventricle (**3** and **17**), passes from the **lateral ventricle** (**23**) into the **third** (**III**), through the narrow **mesencephalic aqueduct** (**18**) into the **fourth** (**IV**), and leaves through the **lateral apertures** (**15**) into the subarachnoid space — where the wide parts are the **cisterns** (**14**, **19**, **24**). Some continues down the **central canal** (**16**). It is returned to the blood at the **arachnoid villi** (**9**), which project into the venous sinuses (**10**, **12**, **13**). Note how narrow **18** is: a channel that size is an easy one to block.

Image — Evans HE, de Lahunta A. Miller and Evans' Anatomy of the Dog, 5th ed. Elsevier — Fig. 16.15, schema of the meninges and ventricles, with arrows indicating the flow of cerebrospinal fluid. Reproduced for educational reference.

Cerebrospinal fluid is produced mostly at the **choroid plexuses** — tufts of capillaries covered with ependyma that invaginate into the ventricles — with a further contribution from the pial vessels. It is formed from blood plasma by ultrafiltration across the blood–cerebrospinal fluid barrier, and because the ependymal cells of the plexus are joined by tight junctions, anything larger than water or a small lipophilic molecule has to be transported *through* the cells to get in.

That barrier is why the fluid has the composition it has: more potassium and calcium than plasma, less sodium, magnesium and chloride, rather little glucose, and very little protein. And it is why the last clause of Dyce's sentence on it is the one clinicians remember — the barrier is impermeable to larger molecules, *which of course include those of many antibiotics and other drugs*. Knowing that a compartment exists is anatomy; knowing that a drug may not enter it is what the anatomy is for.

Where the fluid goes, and how it gets back

Production is only half of it, and the half that is easier to picture. The dog makes about **30 mL an hour**, continuously, and it has to go somewhere. It first circulates through the ventricular system along the route above, moved by the filtration pressure behind it and by the **ciliary activity of the ependymal lining**. It then leaves the interior of the brain through the **lateral apertures of the fourth ventricle** — in some species there is a third, median opening as well — and enters the subarachnoid space, where it bathes the whole outer surface of the brain and cord and fills the cisterns.

It returns to the blood mostly through the **arachnoid villi**: projections of the arachnoid and its space that pierce the dura to open into the **dorsal sagittal venous sinus**, which is one of the sinuses enclosed in that fused cranial dura described above. They become more prominent with age. A smaller part percolates along the **meningeal cuffs** that surround the cranial and spinal nerves at their origins — the same cuffs that let an anaesthetic outside the dura reach a nerve root — and is absorbed by perineural lymphatics.

That closes the circuit, and it is worth holding as a circuit rather than as a list, because every part of it is a place something can go wrong: fluid is made whether or not it can drain, and the villi are as easy a thing to obstruct as the aqueduct is. What the obstruction then causes is clinical neurology, and it belongs on the clinical pages.

The dural folds

Two inward folds of cranial dura are worth naming because they divide the cranial cavity and limit movement of the brain within it. The ***falx cerebri*** extends ventrally from the dorsal and rostral cranial wall and separates the two cerebral hemispheres. Caudally it meets a transverse fold, the membranous ***tentorium cerebelli***, which separates the cerebellum from the cerebrum and is **ossified in its median part** in domestic mammals. A third specialisation surrounds the hypophysial fossa as a diaphragm around the infundibular stalk.

The body cavities covers the vertebral canal as one of the body's cavities; the meninges are what turns that canal into a container the cord can be suspended in.

09 The twelve cranial nerves

This is the section most people come for, and it is the one that most rewards a little structure. Twelve pairs of nerves leave the brain rather than the spinal cord. They are numbered with Roman numerals in **rostrocaudal order** — the order in which they arise, from the front of the brain backwards — and that is the only reason the numbering is worth remembering.

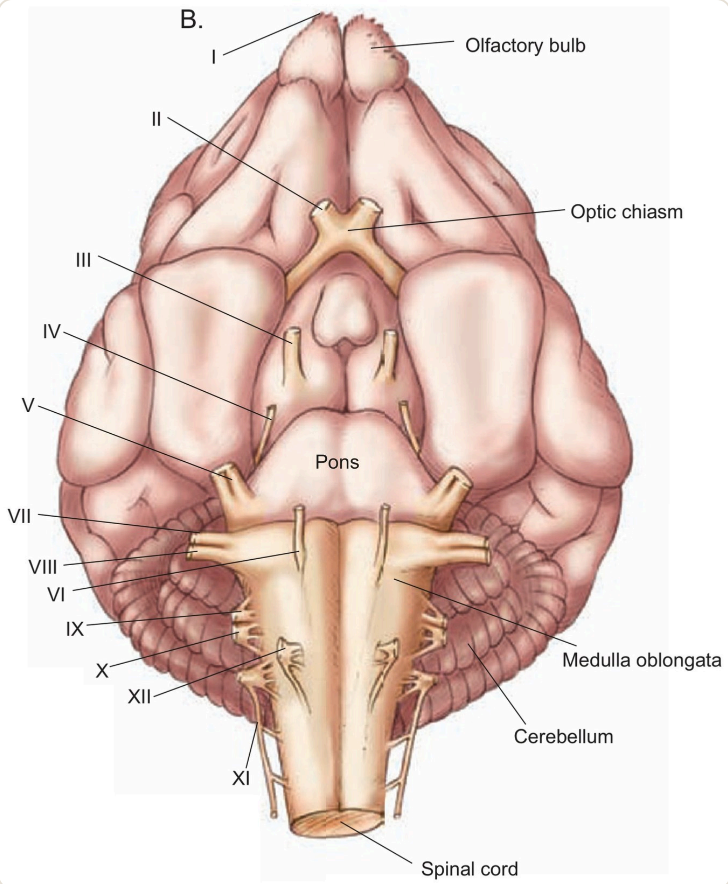


Fig 10 — Where each of the twelve actually leaves. Turn the brain over and the twelve are in front of you in order. Read the numerals from the front backwards and you are reading them **rostral to caudal**, which is exactly the order they are numbered in — that is the whole reason the numbering exists. Two things to notice. **IV** is marked here, but its fibres actually emerge on the *other* side of the brain stem and wrap round; it is the only one of the twelve you cannot see from below. And **XI** is drawn coming up from the cord rather than out of the brain, because most of it does.

Image — McCracken TO, Kainer RA, Spurgeon TL. Color Atlas of Small Animal Anatomy: The Essentials. Blackwell — Plate 1.30B, ventral view of the dog brain showing cranial nerves I–XII. Reproduced for educational reference.

Three groups, not twelve facts

Dyce points out that the twelve lack the uniformity of the spinal nerves but can still be arranged into three groups, and this is the single most useful organising idea available:

- **The special sense nerves** — olfactory (I), optic (II) and vestibulocochlear (VIII). These three are exclusively sensory, and they are exactly the three that carry no somatic efferent fibres at all.
- **The nerves to head muscles of somitic origin** — oculomotor (III), trochlear (IV), abducent (VI) and hypoglossal (XII). A **somite** is one of the paired blocks of mesoderm that segment the embryo along its length, and the muscles of the trunk come from them. Three of them move the eye; the fourth moves the tongue. All four supply muscles derived from somites, exactly like the muscles of the trunk.
- **The pharyngeal arch nerves** — trigeminal (V), facial (VII), glossopharyngeal (IX), vagus (X) and accessory (XI). The **pharyngeal** or **branchial arches** are a series of bars in the wall of the embryonic pharynx, each with its own nerve, and the muscles they give rise to keep that nerve wherever they end up. The trigeminal is the nerve of the first arch and supplies the muscles of mastication; the facial is the nerve of the second and supplies the muscles of facial expression.

Learn the groups and the table below stops being a list. A nerve in group one carries no motor fibres at all. A nerve in group two moves a muscle you can name. A nerve in group three does something to the pharynx, the larynx, the face or the jaw.

The table

NO.	NAME	FUNCTIONAL COMPONENTS	WHAT IT SERVES	LEAVES THE SKULL BY
I	Olfactory	SVA	Smell. Not one nerve but a set of filaments	The **cribriform plate** of the ethmoid
II	Optic	SSA	Vision. Anatomically a **brain tract**, wrapped in meninges	The **optic canal**
III	Oculomotor	SE + GVE	Dorsal, medial and ventral recti, ventral oblique and the levator of the upper eyelid; parasympathetic to the ciliary muscle and the pupillary sphincter	The **orbital fissure**
IV	Trochlear	SE	One muscle: the dorsal oblique. It **decussates inside the brain stem** and emerges dorsally	Usually the orbital fissure; a separate entrance in some species
V	Trigeminal	GSA + SE	The largest of the twelve. Sensation of the face through its ophthalmic, maxillary and mandibular divisions; motor to the muscles of first-arch origin — the jaw closers, and also the tensors of the soft palate and the eardrum	Ophthalmic: orbital fissure. Maxillary: **round foramen**. Mandibular: **oval foramen** in ruminants the first two openings are combined as the foramen orbitorotundum
VI	Abducent	SE	Lateral rectus, and the retractor bulbi — Dyce notes the exact innervation of the retractor is *still controversial*	The orbital fissure, or the foramen orbitorotundum
VII	Facial	SE + GVE + SVA	The nerve of the **second pharyngeal arch**: the muscles of facial expression; parasympathetic to the lacrimal, mandibular and sublingual glands; taste from the **rostral two-thirds** of the tongue	**Internal acoustic meatus**, then the facial canal, leaving at the **stylomastoid foramen**
VIII	Vestibulocochlear	SSA	Hearing and balance. Divides intracranially into its vestibular and cochlear parts	The **internal acoustic meatus**
IX	Glossopharyngeal	SE + GVE + SVA + GVA	Pharyngeal muscles; parasympathetic to the parotid gland through the otic ganglion; taste from the **root of the tongue** conventionally described as the caudal third	The **jugular foramen**
X	Vagus	SE + GVE + SVA + GVA	By far the most widespread distribution of any cranial nerve: pharynx and larynx, parasympathetic supply to the thoracic and abdominal viscera, and the third share of **taste** — from the epiglottis and the very back of the tongue	The **jugular foramen**
XI	Accessory	SE	Brachiocephalicus, omotransversarius, trapezius and sternocephalicus. Its main root comes from the **spinal cord**, not the brain	The **jugular foramen**, having entered through the foramen magnum
XII	Hypoglossal	SE	The intrinsic and extrinsic muscles of the tongue, which develop from occipital somites	The **hypoglossal canal**

The five that are not quite what their name says

I, the olfactory nerve, is not one nerve. It is a set of filaments — the central processes of the olfactory cells of the nasal mucosa — that traverse the cribriform plate separately to reach the olfactory bulb. Their short course and deep position protect them from casual injury; loss of the sense of smell is more often due to blockage of the air passages than to damage to the nerve. But the filaments are surrounded by meningeal sheaths enclosing extensions of the subarachnoid space, and those sheaths are a potential route for infection to travel from the nose into the cranial cavity.

II, the optic nerve, is not a nerve at all. By the rule in §3, a bundle of axons inside the central nervous system is a tract, and the optic nerve is one: it *is in fact a brain tract connecting the retina with the diencephalon*, from which the retina originated as an outgrowth. That is why it is enclosed in extensions of the meninges rather than in the connective-tissue sheaths of a true peripheral nerve, and why the dura blends with the sclera where it meets the eyeball.

IV, the trochlear nerve, comes out of the wrong side. Every other cranial nerve has its superficial origin visible on the *ventral* surface of the brain. The trochlear decussates inside the brain stem and emerges dorsally, from the rostral medullary velum, before curving round the edge of the tentorium to reach the floor of the cranial cavity. It is also the smallest, and it supplies one muscle: the dorsal oblique.

XI, the accessory nerve, mostly comes from the spinal cord. It is formed from two roots. The **spinal root** is made of axons that emerge from the side of the cord midway between the dorsal and ventral roots of the first five or so spinal nerves; they gather into a trunk that runs *forwards* inside the spinal subarachnoid space and enters the skull through the foramen magnum. The **cranial root** is formed by the most caudal rootlets of the glossopharyngeal and vagus series, and after brief contact with the spinal root it joins the vagus, to which it probably contributes the fibres that reach the laryngeal muscles through the recurrent laryngeal nerve. It is the spinal root that becomes the accessory nerve of descriptive anatomy, supplying the brachiocephalicus, omotransversarius, trapezius and sternocephalicus. Dyce adds a sentence worth keeping: *there is no convincing explanation for the curious detour made by the spinal fibres of this nerve*. Not everything in anatomy has a reason attached to it, and a good textbook says so.

V, the trigeminal, is the largest of the twelve, and the one whose branches a clinician handles most often. It is sensory to the skin and deeper tissues of the face through its ophthalmic, maxillary and mandibular divisions, and motor to the muscles of first-arch origin. Those are the jaw closers — and, easily forgotten, the **tensors of the soft palate and of the eardrum**, which is why a mandibular lesion is not only a chewing problem. Two of its terminal branches emerge from bony foramina where they can be palpated, compressed and blocked with local anaesthetic: the **infraorbital nerve** at the infraorbital foramen and the **mental nerve** at the mental foramen. The canine skull shows those foramina from the outside.

Where they leave the skull

Every one of the twelve has to get out of the cranial cavity, and each does so through a named opening. The cranial nerve table lists them; the canine skull is the page to read them against, because a foramen is much easier to remember when you have seen the bone it is in. The clinically busiest are the **orbital fissure**, through which III, IV, VI and the ophthalmic division of V pass together on their way to the orbit — which is why a single lesion there can affect all the eye movements at once — and the **jugular foramen**, through which IX, X and XI leave together.

A memory aid, and a warning about it

> **Remembering the order**
>
> The classical mnemonic for the twelve in order is **O**lfactory, **O**ptic, **O**culomotor, **T**rochlear, **T**rigeminal, **A**bducent, **F**acial, **V**estibulocochlear, **G**lossopharyngeal, **V**agus, **A**ccessory, **H**ypoglossal — and any sentence with those initials will do. **But use it only for the order.** The sensory/motor mnemonics that circulate alongside it are written for human anatomy, and the veterinary examiner is not asking you for the order: they are asking which muscle, which foramen and which functional component. The three-group scheme above gets you those; the initials do not.

10 The spinal nerve, taken apart

Spinal nerves are far more uniform than cranial nerves, and that uniformity is what makes them worth learning as a single pattern rather than one by one. In the dog there are usually **36 pairs**. Each one is built the same way.

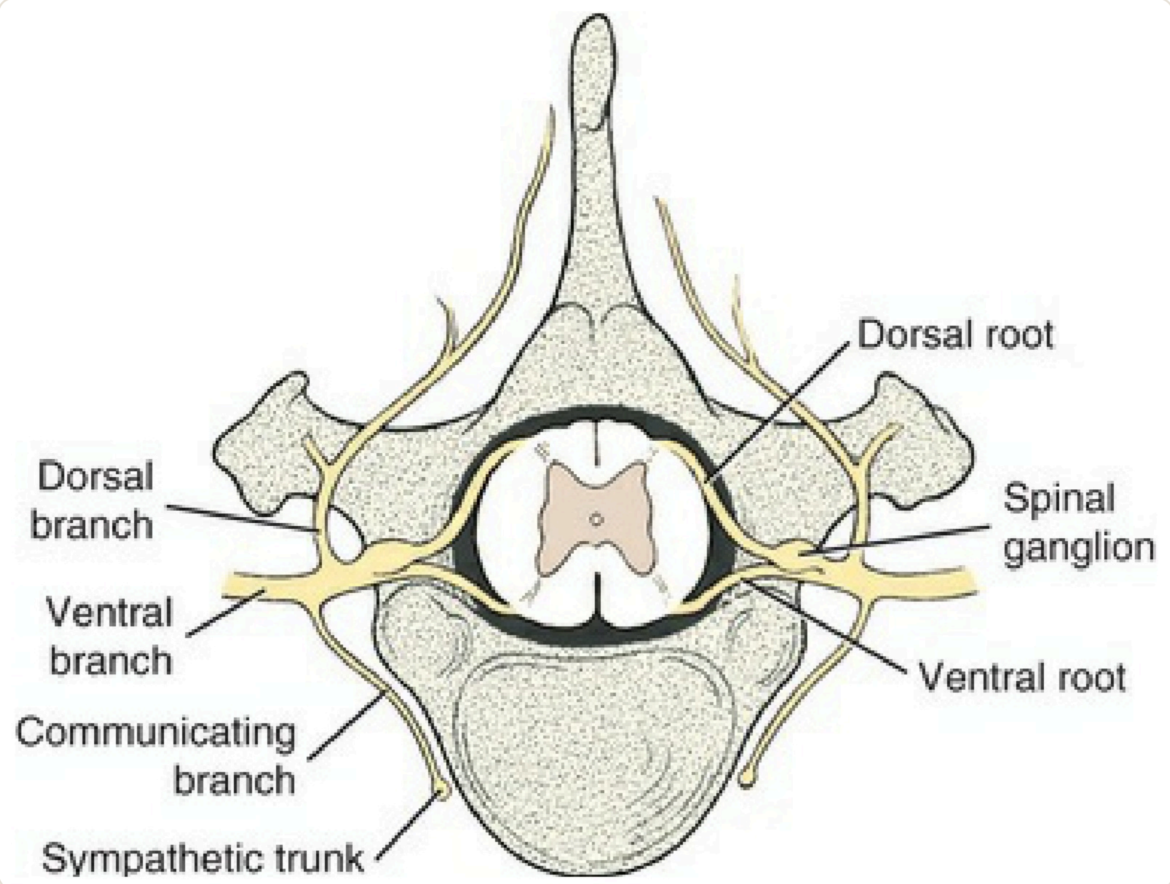


Fig 11 — One spinal nerve, taken apart on one vertebra. Follow it from the middle outwards and the vocabulary sorts itself out. Two **roots** leave the cord, one dorsally and one ventrally, and the dorsal one carries a swelling, the **spinal ganglion**. The two roots join, and only after they have joined is there a **spinal nerve**. It immediately divides into **branches** — a dorsal one, a ventral one, and a communicating one going to the sympathetic trunk. Root before the junction, branch after it: everything else in peripheral nerve naming rests on that.

Image — Evans HE, de Lahunta A. Miller and Evans' Anatomy of the Dog, 5th ed. Elsevier — Fig. 17.1, diagram of a spinal nerve. Reproduced for educational reference.

Roots, and the pair of words in §3 that was left over

Two **roots** attach each nerve to the cord. The **dorsal root** enters the dorsolateral surface and carries sensory afferent fibres. The **ventral root** leaves ventrolaterally and carries motor efferent fibres. Each root is made up of a variable number of rootlets. On the dorsal root, inside the intervertebral foramen, sits a swelling: the **spinal ganglion**, which holds the cell bodies of those sensory neurons — unipolar cells, by §3, which is exactly why their cell bodies can sit off to one side of the pathway. Miller and Evans note in the caption to the figure above that this structure *was formerly called the "dorsal root ganglion"*, and you will meet both names; they are the same thing.

The two roots then unite, and the fourth vocabulary pair from §3 falls out of that union:

- A **root** is what exists *before* the junction. There are exactly two, one sensory and one motor, and each is pure.
- A **ramus**, or branch, is what exists *after* it. Every ramus is **mixed**, carrying both sensory and motor fibres, because the two streams have already joined.

That is why you can cut a dorsal root and produce a purely sensory deficit, and why you cannot do the same to any named peripheral nerve in the limb.

Branches

Within the intervertebral foramen the nerve gives off a small **meningeal branch**, which turns back into the vertebral canal to supply the meninges. After emerging it divides into:

- a **dorsal branch** (dorsal ramus), which supplies the **epaxial** muscles — the ones lying dorsal to the vertebral transverse processes — and the skin of the back;
- a **communicating branch** (ramus communicans), connecting the nerve to the sympathetic trunk — §11 explains what travels along it in each direction;

- a **ventral branch** (ventral ramus), which is much the larger and supplies everything else: the muscles and skin of the body wall, and the whole of the limbs.

Both the dorsal and the ventral branches usually then divide again into medial and lateral branches, and those give rise to the smaller peripheral branches.

How a plexus makes a named nerve

In the neck and at the roots of the limbs, the ventral branches of neighbouring spinal nerves do not simply run out to their targets. They exchange fibres in a network — a **plexus** — and the named nerves emerge from the far side of the network carrying fibres from several spinal segments at once.

The two big ones are the **brachial plexus**, formed from the caudal cervical and first thoracic ventral branches and giving rise to the nerves of the forelimb, and the **lumbosacral plexus**, formed from the lumbar and sacral ventral branches and giving rise to the nerves of the hindlimb. This is the reason a named limb nerve, such as the radial or the sciatic, cannot be mapped onto a single spinal segment: it was assembled from several, and its cutaneous territory does not match the **dermatome** — the strip of skin supplied by one spinal segment — of any one of them.

> **Where the named limb nerves live**
>
> Which nerve supplies which muscle is a myology question, and our own guide to the dog's muscles carries it muscle by muscle. This page stops at the principle: a plexus mixes segments, a named nerve is the output of that mixing, and that is why segment and nerve are different units.

What a peripheral nerve is made of

A peripheral nerve is not a single cable but a bundle of bundles, and it has three named connective-tissue coats. From the inside out:

- **Endoneurium** — delicate connective tissue around each individual nerve fibre;
- **Perineurium** — a distinct sleeve around each bundle, or fascicle, of fibres. Its cells are joined by tight junctions and it forms a diffusion barrier;
- **Epineurium** — the outer sheath around the whole nerve, carrying its blood vessels.

The arrangement should look familiar: it is the same three-tier scheme as the epimysium, perimysium and endomysium of a skeletal muscle, and for the same mechanical reason. It also explains two clinical facts at once — why a nerve tolerates being stretched a little, and why a drug or an infection reaches nerve fibres less readily than the surrounding tissue would suggest.

Where the meninges meet the nerve roots, the dura becomes continuous with the epineurium at distinct cuff zones, and drugs placed in the epidural space diffuse into the roots more easily there. That is the structural basis of epidural anaesthesia, and it is a good illustration of why the layers in §8 and the layers here are worth learning as one system.

11 The autonomic nervous system: two outflows

Our library already explains what the sympathetic and parasympathetic systems *do* — how blood pressure is actually controlled is largely a description of them in action. What it has never said is how they are **built**. This section is the structure, and it starts with a definition that clears up more confusion than anything else on the page.

⭐ The autonomic nervous system is defined as wholly efferent

Visceral afferent fibres exist, in quantity, and they are presumed to be present in all cranial and spinal nerves if only because blood vessels are everywhere. But they are *in general indistinguishable in structure and arrangement from their somatic afferent counterparts*: one neuron, cell body in a ganglion, running straight in. There is nothing anatomically distinctive about them.

The efferent side is a different matter, and it is distinctive in three ways at once:

- **Two neurons in series**, not one. A **preganglionic** neuron with a myelinated axon synapses on a **postganglionic** neuron with a thinly myelinated one.
- **The second cell body is outside the central nervous system**, in a peripheral ganglion.
- **The first cell bodies are restricted** to particular brain stem nuclei and particular regions of the cord — not scattered along it as somatic motor neurons are.

Because only the efferent half has those features, Dyce writes that the term autonomic nervous system *was originally, and is still best, defined as wholly efferent*. So a question about "the autonomic supply" of an organ is a question about its motor supply, and visceral sensation is a separate matter that travels with the somatic sensory system.

Two divisions, defined by where they leave

	SYMPATHETIC	PARASYMPATHETIC
Where it leaves	**Thoracolumbar** — lateral horn of the thoracic and cranial lumbar segments; about T1 to L3 in the dog	**Craniosacral** — discrete brain stem nuclei, and the lateral grey column of sacral segments 2, 3 and possibly 4
Which nerves carry it	The thoracolumbar spinal nerves, then the sympathetic trunk	Only **III, VII, IX, X** and the **pelvic nerves**. No others
Where the ganglion sits	**Close to the CNS**: the paravertebral chain, or prevertebral ganglia on the aorta	**Close to, or inside, the target organ**
Fibre lengths	Short preganglionic, long postganglionic	Long preganglionic, short postganglionic
Named ganglia	Cranial cervical, middle cervical, cervicothoracic; coeliac, cranial mesenteric, renal, aorticorenal, gonadal, caudal mesenteric	Ciliary, pterygopalatine, mandibular and otic in the head; scattered intramural ganglia elsewhere
Character of the response	**General and less discrete** — the fibres radiate widely, and the adrenal medulla adds a bloodborne mass response	**Discrete** — the transmitter is released and destroyed locally, close to the target
Does it reach the limbs?	Yes — the body wall and limbs are supplied **only** by postganglionic sympathetic fibres, which join every spinal nerve	No

The **sympathetic** division is the **thoracolumbar** outflow. Its preganglionic cell bodies lie in the lateral horn of the thoracic and lumbar segments — in the dog, from about T1 to L3 — which is exactly the stretch of cord where §6 said the lateral horn exists. Their axons leave in the ventral roots, join the spinal nerves and pass to the **sympathetic trunk**, a chain of ganglia running along the ventral aspect of the vertebral column, through the myelinated (white) communicating branches.

Once in the chain, a preganglionic fibre has three possible fates: synapse in the ganglion it entered; run up or down the trunk and synapse in a ganglion further along; or pass straight through the chain without synapsing and continue as a **splanchnic nerve** to a second set of ganglia — the **prevertebral ganglia** — lying on the ventral face of the aorta at the origins of its visceral branches. Those are the coeliac, cranial mesenteric, renal, aorticorenal, gonadal and caudal mesenteric ganglia, and each is named after the artery it sits on.

Postganglionic fibres then rejoin the spinal nerves through unmyelinated (grey) communicating branches, and here is the detail worth carrying: **the body wall and the limbs are supplied only by these postganglionic sympathetic fibres**. Every spinal nerve, and many cranial nerves, carries them — to blood vessels, to sweat glands, to the arrector muscles of the hairs. The head receives its sympathetic supply from the **cranial cervical ganglion**, at the front of the chain.

The **parasympathetic** division is the **craniosacral** outflow. Its preganglionic cell bodies lie in a small number of discrete brain stem nuclei and in the lateral grey column of a short stretch of the sacral cord — the second, third and possibly fourth sacral segments. And because of that, the outflow is confined to a very short list of nerves: **the oculomotor, facial, glossopharyngeal and vagus nerves, and the pelvic nerves**. Only those carry parasympathetic fibres. If a question asks whether a given nerve has a parasympathetic component, that list is the whole answer.

Why one is diffuse and the other precise

The two divisions differ in the character of their responses, and the reason is anatomical before it is pharmacological.

Parasympathetic ganglia sit **close to, or even inside, the target organ**. The postganglionic fibre is therefore short, and the transmitter it uses is released and destroyed locally. The result is a narrowly localised, discrete effect.

Sympathetic ganglia sit **close to the central nervous system**, either in the chain beside the vertebral column or on the aorta. The postganglionic fibres are long and radiate widely before reaching their targets, so the effects are general rather than discrete. And there is a second route: the medulla of the adrenal gland — itself a neural crest derivative, from §4 — is in effect a modified sympathetic ganglion whose cells release their product into the bloodstream instead of onto a target, producing a mass response throughout the body at once.

The enteric division

The gut carries its own extensive network of neurons in the wall of the tract, derived from neural crest cells that migrated the whole way there. It is often treated as a third division of the autonomic nervous system, and it can generate and coordinate motility patterns without input from the brain or cord at all, though both divisions above modify what it does. The **enteric nervous system** is the reason a length of intestine removed from an animal still shows coordinated movement.

12 Where the species differ

Most of what has come before is general: a neuron is a neuron, a funiculus is a funiculus, and the twelve cranial nerves are twelve in every domestic mammal. A small number of differences are not general, and two of them change what you can safely do with a needle.

⭐ Where the spinal cord ends

Because the vertebral column outgrows the cord, the cord stops short of the end of the canal — but by how much varies. In domestic mammals it ends at about the lumbosacral junction; in the human it is relatively much shorter, ending at the first lumbar vertebra. The species figures matter because everything caudal to the cord's end is *cauda equina* in a canal, and a needle placed there meets nerve roots and fluid rather than cord.

SPECIES	SPINAL CORD ENDS AT	DURAL TUBE ENDS AT	NOTE
Dog	Usually **L7**; may reach only L6	S1 or S2	In some breeds, the German Shepherd among them, the cord may reach S1
Cat	**L7**	S1 or S2	—
Pig	**L7**	—	—
Horse	**S1 or S2**	S4	Lumbosacral puncture is feasible
Ox	**S1** in the adult; **S3** in the calf	S4	The lumbar subarachnoid space between L6 and S4 is relatively voluminous; CSF is drawn between L6 and S1
Sheep	**S1**	S3	Only **four** sacral vertebrae, so the dural tube ends a segment earlier than the ox's
Human, for contrast	**L1**	—	Relatively much shorter, which is why human lumbar puncture is done far forward of the site used in the ox

Read the Note column as carefully as the number beside it. The dog is a **range**, not a figure, and the calf is not the adult ox: quoting either as if it were fixed is quoting it wrongly.

The **dural tube** runs on past the end of the cord and ends within the sacrum, carrying the beginning of the *cauda equina* and the *filum terminale* inside it. It reaches as far as S4 in the ox and the horse, and S1 or S2 in the dog and cat. In the sheep, which has only four sacral vertebrae, it ends in segment S3.

What that means for a needle

In the ox the lumbar subarachnoid space between L6 and S4 is relatively voluminous, so cerebrospinal fluid can be withdrawn by lumbar puncture between L6 and S1. In an average adult ox that space measures about **3 to 4 mm dorsoventrally**, with about **7 cm** from skin to cord. Lumbosacral puncture is also feasible in the sheep, the pig and the horse.

Epidural injection in the ox is usually made between the first and second caudal vertebrae, and can be made at the lumbosacral junction instead. The anatomical hazards named by Skerritt are all structural: the needle should not pierce the *cauda equina*, because that may impair the nerve supply to the tail; overshooting can enter the longitudinal venous sinus of the canal, and an anaesthetic should not be injected into a vein; and injecting at or in front of the lumbosacral junction risks reaching the cerebrospinal fluid, in which local anaesthetics mix freely and spread much further forwards than intended.

> **These are anatomical facts, not a technique**
>
> The sites, depths and hazards above are given because they are properties of where the structures lie, and they are the clearest illustration on this page of why the species figures matter. They are not a description of how to perform any procedure, and the doses, approach and case selection are a clinical matter that belongs elsewhere.

⭐ Smooth brains and folded brains

The folding of the cerebral surface differs sharply between species, and the two words for it are ones a student meets and often cannot place.

- A **gyrencephalic** brain has a folded cortical surface, thrown into *gyri* and *sulci*. The dog, cat, horse, ox, sheep and pig are all gyrencephalic, and the pattern of the folds differs enough between them to be recognisable.

- A **lissencephalic** brain has a smooth cortex, without gyri. Thomson and Hahn name rodents, lagomorphs and birds as retaining a smooth cerebral cortex — so the rat, the mouse and the rabbit are lissencephalic, and a rabbit brain looks strikingly unlike a dog brain for that reason alone.

The difference is developmental: the folding depends on whether neurons continue to migrate outwards into the cortex after the basic form is laid down, and the timing of that migration is species-specific. It also correlates with how mature the newborn is — prey species born in the open must be able to stand and run almost immediately, and their brain development is correspondingly further advanced at birth than that of an altricial species born into a burrow or a nest. Thomson and Hahn make the same point about the cerebellum specifically: how well an animal can walk in its first days is directly related to how far cerebellar development has gone.

Two smaller differences worth carrying

The brain is supplied by a ring of vessels on its ventral surface, the **cerebral arterial circle** — the vessels themselves belong to angiology and not to this page, but the ring is worth naming here because one species difference is defined against it. In the ox, the sheep and the pig a **rete mirabile** — a network of small arteries formed from branches of the maxillary artery — replaces a single large vessel at the base of the brain. It changes where the blood supply to the brain comes from in those species, and it is one of the differences that matters in slaughter and in anaesthesia.

Seven domestic species compared sets the vertebral formulae of seven species side by side, and it is worth having open alongside this section — the sacral count is the reason the dural tube stops where it does.

13 From a map to a place: what the anatomy lets you localise

Everything on this page has been structure. This last section says what the structure is *for*, because that is the reason a student is asked to learn it, and then hands the method over to the page that owns it.

The whole of clinical neurology rests on one anatomical property: **a given function is carried by a structure that is only in one place**. If a pathway runs through a particular part of the brain stem and nowhere else, then losing that function means the lesion is there. If the cell bodies for a particular muscle group sit in a particular set of cord segments, then their loss puts the lesion in those segments. Nothing about that reasoning is clinical — it is a property of the map.

Three things from this page are what make it work.

- **Segmental organisation.** The cord is built in segments, each with its own pair of spinal nerves, and the cell bodies that supply a limb sit in the intumescence for that limb (§6). So a deficit that respects a limb points at a stretch of cord.
- **Decussation.** Most long pathways cross the midline at a known level (§7). So which side of the body a sign appears on tells you which side of a crossing the lesion is on.
- **The cranial nerves are anchored to the brain stem.** Each has a nucleus at a known level (§9), so a cranial nerve deficit combined with a limb deficit places the lesion in the brain stem rather than in the cord.

What this page deliberately does not do is take the next step. Which signs go with which lesion, how a deficit is graded, what a reflex finding means, how the upper and lower motor neuron systems differ in their effect on tone and reflexes, and how the cord is divided clinically into regions — all of that is the subject of our guide to upper and lower motor neuron signs, which is a full article on exactly that reasoning. Read that one with this one open, and the two halves fit.

Finally, if this material is not staying in your head, the problem is usually the method and not the memory. How to study anatomy so it stays sets out what actually works for anatomy of this kind, and the self-test below is built to be used the way that article describes: answer first, then look.

14 Test yourself

Eighty-four questions across every section above. Cover the answers first — looking at an answer is not the same as retrieving it, and only one of the two is revision.

1 **What is the difference between neuroanatomy and neurology?**

> ANSWER Neuroanatomy is the structural map — how the nervous system is built, what its parts are called and where each one sits. Neurology is what you do with a patient on that map. A clinical sign is only useful to someone who can already say what lives where.

2 **What does the Latin word *neuraxis* refer to, and why is it useful?**

ANSWER The whole continuous brain-and-spinal-cord as one object. It is useful precisely because it refuses the division: there is no natural break between brain and cord, and the line between them is a convention rather than something you could find in the tissue.

3 **Name the two ways the nervous system is divided, and say what each tells you.**

ANSWER By **place** — central (brain and spinal cord) versus peripheral (cranial and spinal nerves and their ganglia). And by **job** — afferent or efferent, and within each, somatic or visceral. The first says where a part is; the second says what it carries. They are not alternatives.

4 **Which division does Dyce call the most fundamental, and on what grounds?**

ANSWER The central/peripheral division, on **anatomical** grounds alone — not functional ones.

5 **Give one practical consequence of the central/peripheral distinction.**

ANSWER They respond differently to injury. The peripheral nervous system has some capacity for regeneration of damaged fibres; the central nervous system does not regenerate. That is why a crushed peripheral nerve carries a prognosis a comparable injury inside the cord does not.

6 **What do afferent and efferent mean, and how do the Latin roots help?**

ANSWER Afferent conducts **towards** the spinal cord and brain — the sensory component, from *ad-ferre*, to carry to. Efferent conducts **away** from them — the motor component, from *ex-ferre*, to carry out.

7 **What separates the somatic from the visceral system?**

ANSWER The somatic system deals with the animal's relationship to the outside world: sensation from skin, limbs and body wall, and behaviour such as locomotion. The visceral system deals with the internal organs — blood pressure, heart rate, glandular activity, digestion. Dyce notes the somatic system is *sometimes* called voluntary, and hedges it: the difference is in the degree of conscious awareness and control, not an absolute.

8 **Special somatic afferent fibres are found in how many cranial nerves, and which?**

ANSWER Only **two**: the optic (II) and the vestibulocochlear (VIII) — because only two organs, the retina and the inner ear, produce that kind of information.

9 **Which cranial nerves contain *no* somatic efferent fibres?**

ANSWER The three that are exclusively sensory: **I, II and VIII**. Somatic efferent fibres are present in all spinal nerves and in every other cranial nerve.

10 **Is the autonomic nervous system a third division alongside central and peripheral?**

ANSWER No. It is the name given to the **visceral efferent** pathways — one cell in the functional-components table, not a separate system.

11 **Name the three shapes of neuron and say where each is found.**

ANSWER **Multipolar** — many branching dendrites; most neurons, including every ventral horn motor neuron. **Bipolar** — dendrites joining in a common trunk; the retina and the olfactory epithelium. **Unipolar** (or pseudounipolar) — dendrites and axon continuous along one process with the cell body on a short stalk; **all** peripheral sensory neurons.

12 **Why can the cell body of a sensory neuron sit off to one side of the pathway without slowing anything down?**

ANSWER Because in a unipolar (and a bipolar) neuron the new electrical signal is generated where the dendrites converge, not at the cell body. The cell body hangs off the line rather than sitting in it.

13 **Name the five neuroglial cell types and give each one's job.**

ANSWER **Astrocytes** — nutrition, the extracellular environment, a part in neurotransmission, and perivascular feet contributing to the blood–brain barrier. **Oligodendrocytes** — myelin inside the central nervous system, one cell serving several axons. **Schwann cells** — myelin in the peripheral nervous system, one cell to one internode. **Microglia** — the resident immune cells. **Ependymal cells** — the lining of the ventricles and central canal.

14 **What are the nodes of Ranvier?**

ANSWER The gaps between successive Schwann cells along a peripheral axon.

15 **What is the difference between a nucleus and a ganglion in neuroanatomy?**

ANSWER None, except the side of the boundary. Both are collections of neuronal cell bodies: a **nucleus** is inside the central nervous system, a **ganglion** is outside it. Note that this sense of *nucleus* collides with the organelle you already know by that name.

16 **What is the difference between a tract and a nerve?**

ANSWER Again only the side of the boundary. Both are bundles of axons running together: a **tract** is inside the central nervous system, a **nerve** is outside it.

17 **Where is the grey matter in the cerebrum, and where is it in the spinal cord?**

ANSWER In the cerebrum — and the cerebellum — the grey matter is on the **outside**, as a surface cortex, with white matter deep to it. In the spinal cord it is on the **inside**, with white matter around it. Thomson and Hahn put it plainly: in the cerebrum this is the opposite of the spinal cord arrangement.

18 **Grey matter sitting deep inside the cerebral white matter is called what?**

ANSWER A nucleus — the basal nuclei, for example. The rule holds: cell bodies inside the central nervous system are a nucleus wherever they sit.

19 **Trace the nervous system from its first appearance to a closed tube.**

ANSWER An elongated thickening of ectoderm, the **neural plate**, forms over the notochord and paraxial mesoderm. Its lateral parts rise as **neural folds** either side of the **neural groove**; the folds meet and fuse, converting the groove into the **neural tube**, which then sinks below the surface ectoderm.

20 **Where does the neural tube begin to close, and which neuropore closes first?**

ANSWER Closure begins in the presumptive occipital region — the future junction of brain and cord — and spreads both ways. The **rostral** neuropore closes first.

21 **What happens if the rostral or the caudal neuropore fails to close?**

ANSWER Failure rostrally gives anencephaly, with malformation of the forebrain and midbrain and associated skull defects. Failure caudally gives **spina bifida**, with defective closure of the vertebral arches — which is why a vertebral defect and a nervous system defect are the same event.

22 **What does the neural crest give rise to?**

ANSWER Cells that stay beside the tube become the neurons of the **peripheral ganglia** — peripheral sensory neurons and the neurons of the visceral motor system. Cells that migrate away become the **enteric** neurons, the medullary part of the adrenal glands, glia, skin melanocytes and a variety of craniofacial connective tissues.

23 **Name the three layers of the neural tube wall and what each becomes.**

ANSWER **Neuroepithelial**, lining the lumen → the **ependyma** of the central canal and ventricles. **Mantle** → the **grey matter**. **Marginal** → the **white matter**. That is the whole explanation of why the cord has grey inside and white outside.

24 **What are the alar and basal plates, what separates them, what does each become — and *why* do the two halves differ?**

> ANSWER The **alar plate** is the dorsal bulge of the mantle layer and becomes the **dorsal horn**, receiving sensory input. The **basal plate** is the ventral bulge and becomes the **ventral horn**, holding motor cell bodies. The groove between them is the **sulcus limitans**. They differ because two morphogens diffuse in from opposite sides: **sonic hedgehog** from the notochord below, pushing the ventral cells towards motor fates, and **bone morphogenetic protein** from the overlying ectoderm above, pushing the dorsal cells towards sensory ones. The floor and roof plates then take those signals over.

25 **Name the three primary brain vesicles and the five secondary divisions.**

> ANSWER Primary: **prosencephalon** (forebrain), **mesencephalon** (midbrain), **rhombencephalon** (hindbrain). Secondary: prosencephalon → **telencephalon** + **diencephalon**; mesencephalon stays undivided; rhombencephalon → **metencephalon** + **myelencephalon**.

26 **Which two adult structures come from the metencephalon, and from which plate does each come?**

> ANSWER The **pons** from the basal plate and the **cerebellum** from the alar plate. They are developmental siblings — and yet the pons is counted in the brain stem and the cerebellum is not, because brain stem is a topographical term, not a developmental one.

27 **Why do three flexures appear in the developing brain?**

> ANSWER Because the brain grows faster than the tissues that surround and enclose it, so its form is remodelled: a flexure at the junction with the cord, one at the midbrain, and a dorsal one folding the hindbrain back on itself. It is why rostral and caudal stop being simple directions inside a brain.

28 **What is the brain stem, defined by subtraction?**

> ANSWER Take away the cerebral hemispheres and take away the cerebellum, and what remains is the brain stem: diencephalon, mesencephalon, the pons and the myelencephalon, directly continuous with the spinal cord.

29 **What are gyri, sulci and folia?**

> ANSWER **Gyri** are the ridges and **sulci** the grooves of the cerebral surface; **folia** are the much finer folds of the cerebellar surface. All three exist for the same reason: folding buys surface area, and the grey matter is on the surface in both structures.

30 **Which structure bridges the two cerebral hemispheres, and what lies just below it?**

> ANSWER The **corpus callosum**, the great commissure carrying axons from one hemisphere to the other. Below it, the thin **septum pellucidum** separates the two lateral ventricles.

31 **What does the diencephalon contain, and what is its cavity?**

> ANSWER The **thalamus** — the relay through which almost every ascending pathway passes on its way to the cortex — and, below it, the **hypothalamus**. Its cavity is the **third ventricle**, crossed in domestic mammals by the interthalamic adhesion.

32 **Give four of the functions Dyce attributes to the hypothalamus.**

> ANSWER Any four of: biological rhythms, appetite, water balance, body temperature, cardiovascular performance, sexual behaviour and activity, sleep, emotion. It is an integration centre working to keep the animal alive.

33 **The pituitary gland has two parts of different origin. Name them.**

> ANSWER The **neurohypophysis**, which is an outgrowth of the brain itself, and the **adenohypophysis**, which develops from oral ectoderm.

34 **What is the limbic system, and why is it called a visceral brain?**

> ANSWER A ring of cortex on the medial surface of the hemisphere together with subcortical nuclei — among them the hippocampus, the amygdala and the septal area — controlling somatic and visceral behaviour associated with strong emotions. It is often called a visceral brain because so much of what it does is expressed through visceral motor activity.

35 **What are the intumescences of the spinal cord, and why are they there?**

ANSWER The cervical and lumbar thickenings, at the origins of the nerves to the forelimb and hindlimb. A limb needs a great many motor neurons and returns a great deal of sensation, and both need cell bodies — so the grey matter, and with it the cord, is thicker there.

36 **How is a spinal cord segment defined?**

ANSWER Entirely by its nerves: a segment is the length of cord that gives rise to one pair of spinal nerves. There is nothing visible in the tissue that marks the boundary.

37 **In which region does the number of spinal segments *not* match the number of vertebrae?**

ANSWER The cervical region — and in every species. There is always **one more cervical spinal segment than cervical vertebra**, because the first cervical nerve emerges in front of the atlas. A dog with seven cervical vertebrae has eight cervical spinal nerves.

38 **What is the cauda equina, and why does it exist?**

ANSWER The bundle of last lumbar, sacral and caudal spinal nerves running caudally inside the vertebral canal before leaving at their own vertebrae. It exists because the vertebral column outgrows the cord, drawing the caudal segments forwards while the nerve-to-vertebra relationship stays constant.

39 **Why does Dyce call the term *horn* misleading?**

ANSWER Because the horns are not horns in three dimensions — they run the whole length of the cord, so they are columns. They only look like horns because you are looking at a slice.

40 **Which horn is present along only part of the cord, and where?**

ANSWER The **lateral horn**, which holds the visceral efferent neurons. It is confined to the thoracolumbar and sacral regions — and that restriction is the anatomical statement of where the autonomic outflow leaves.

41 **Name the three funiculi and say what sets their boundaries.**

ANSWER **Dorsal**, **lateral** and **ventral** funiculi. Their boundaries are set by where the nerve roots attach — the dorsal root line and the ventral root line — not by anything visible in the tissue.

42 **Which funiculus is almost entirely ascending?**

ANSWER The **dorsal** funiculus, as are the most lateral parts of the lateral funiculus. Most of the lateral and the ventral funiculi carry fibres running both ways.

43 **How is a pathway such as *spinothalamic* named?**

ANSWER First half where the fibres start, second half where they end. Spino-thalamic: spinal cord to thalamus. Cortico-spinal: cerebral cortex to spinal cord. Rubro-spinal: red nucleus (*ruber*) to spinal cord.

44 **A tract's name ends in *-spinal*. Which way does it run, and why?**

ANSWER It descends. The second half is the destination, and the destination is the cord, so the fibres are coming down from the brain.

45 **Name a pathway whose name does *not* follow the origin-destination rule.**

ANSWER The **medial lemniscus**, which is named for its shape and position rather than its route. The rule is a convention, not a law.

46 **What is decussation, and what follows from it clinically?**

ANSWER A pathway crossing the midline. The great descending motor fibres cross in the medulla oblongata at the **pyramids**. Because most long pathways cross somewhere, a lesion above the crossing shows its effect on the opposite side of the body and one below it on the same side.

47 **Which ascending pathways produce conscious sensation and which do not?**

> ANSWER Those reaching the thalamus and then the cortex produce conscious sensation. Those reaching the **cerebellum** — the spinocerebellar tracts — do not: the cerebellum uses proprioceptive information continuously without the animal being aware of it.

48 **Name the three meninges from outside in.**

> ANSWER **Dura mater**, **arachnoid mater**, **pia mater**. The arachnoid and pia together are the leptomeninges; the dura is the pachymeninx.

49 ⭐ **Where is there no epidural space, and why not?**

> ANSWER Inside the skull. The cranial dura is **fused with the inner periosteum**, which obliterates the space — and the venous sinuses of the head come to lie enclosed within the thickness of the fused layer. Around the cord the dura is a free tube with a real epidural space outside it.

50 **What is in the spinal epidural space?**

> ANSWER Fat — more fluid in life than in a post-mortem specimen — and the internal vertebral venous plexus. Together they cushion the cord and let it accommodate movements of the neck and back.

51 **What are the denticulate ligaments and what do they do?**

> ANSWER Triangular ligaments crossing the subdural space of the cord, one alternating with each pair of spinal nerve origins. They attach the inner meninges to the dural tube and so suspend the cord within it along its whole length.

52 **Name the two sites where cerebrospinal fluid is sampled, and say what makes each possible.**

> ANSWER The **cerebellomedullary cistern**, reached between the atlas and the skull through the foramen magnum — possible because the subarachnoid space is especially wide in the angle between cerebellum and medulla. And the **lumbosacral** space, reached by a dorsal approach — possible because the subarachnoid space widens around the conus medullaris and the cord has already ended.

53 **Where is cerebrospinal fluid produced, and how?**

> ANSWER Mostly at the **choroid plexuses** — tufts of capillaries covered with ependyma invaginating into the ventricles — with a further contribution from the pial vessels. It is formed from blood plasma by ultrafiltration across the blood-cerebrospinal fluid barrier, whose ependymal cells are joined by tight junctions.

54 **How does cerebrospinal fluid differ in composition from plasma, and why does it matter?**

> ANSWER More potassium and calcium, less sodium, magnesium and chloride, rather little glucose and very little protein. It matters because the barrier that produces that difference is impermeable to larger molecules — which include many antibiotics and other drugs.

55 **Where does cerebrospinal fluid leave the ventricular system, and how does it get back into the blood?**

> ANSWER It leaves through the **lateral apertures of the fourth ventricle** — some species have a third, median opening as well — into the subarachnoid space, where it bathes the brain and cord. It returns mostly through the **arachnoid villi**, projections of the arachnoid that pierce the dura to open into the dorsal sagittal venous sinus. A smaller part goes along the meningeal cuffs around the nerve roots to perineural lymphatics.

56 **Name the two great folds of cranial dura and what each separates.**

> ANSWER The **falx cerebri** separates the two cerebral hemispheres. The membranous **tentorium cerebelli** separates the cerebellum from the cerebrum, and is ossified in its median part in domestic mammals.

57 **Give Dyce's three groups of cranial nerves, with their members.**

> ANSWER **Special sense**: I, II, VIII — all exclusively sensory. **Head muscles of somitic origin**: III, IV, VI, XII. **Pharyngeal arch nerves**: V, VII, IX, X, XI.

58 **Why is the optic nerve not really a nerve?**

ANSWER Because it is inside the central nervous system: it is a brain tract connecting the retina with the diencephalon, from which the retina originated. That is why it is wrapped in extensions of the meninges rather than in the connective-tissue sheaths of a peripheral nerve, and why the dura blends with the sclera at the eyeball.

59 **Which cranial nerve emerges from the dorsal surface of the brain, and what does it supply?**

ANSWER The **trochlear (IV)**. It decussates inside the brain stem and emerges from the rostral medullary velum. It is the smallest of the twelve and supplies one muscle, the dorsal oblique.

60 **Why is the accessory nerve unusual?**

ANSWER Its main root comes from the **spinal cord**, not the brain: axons emerging from the first five or so cervical segments run forwards inside the spinal subarachnoid space and enter the skull through the foramen magnum. It supplies the brachiocephalicus, omotransversarius, trapezius and sternocephalicus. Dyce adds that there is no convincing explanation for the detour.

61 **Which nerves pass through the orbital fissure, and why does that matter?**

ANSWER III, IV, VI and the ophthalmic division of V. It matters because a single lesion there can affect all the eye movements at once.

62 **Which nerves leave through the jugular foramen?**

ANSWER IX, X and XI, together.

63 **Which nerves carry taste, and from which parts of the tongue?**

ANSWER The **facial (VII)**, through the chorda tympani, from the **rostral two-thirds**; and the **glossopharyngeal (IX)** from the **root of the tongue**, conventionally called the caudal third. The **vagus (X)** carries the rest, from the epiglottis and the very back of the tongue — so taste is in **three** cranial nerves, not two. General sensation from that same rostral two-thirds travels instead in the lingual branch of the trigeminal. *Note that the books split IX and X differently: Dyce gives the root of the tongue to IX, while Thomson and Hahn give IX the caudal third and the root to X. This page follows Dyce.*

64 **Which cranial nerves carry parasympathetic fibres?**

ANSWER Only **III, VII, IX and X**. No other cranial nerve does.

65 **What is unusual about the way the olfactory nerve is built, and what risk follows?**

ANSWER It is not one nerve but a set of filaments crossing the cribriform plate separately. Those filaments are surrounded by meningeal sheaths enclosing extensions of the subarachnoid space, which is a potential route for infection to spread from the nose into the cranial cavity.

66 **What is the difference between a root and a ramus?**

ANSWER A **root** exists before the two join, and is pure — the dorsal root sensory, the ventral root motor. A **ramus** exists after they have joined, and is always **mixed**. That is why cutting a dorsal root gives a purely sensory deficit and cutting a named limb nerve never does.

67 **What sits on the dorsal root, and what does it contain?**

ANSWER The **spinal ganglion** — formerly called the dorsal root ganglion, and you will meet both names. It contains the cell bodies of the sensory neurons, which are unipolar.

68 **Name the branches a typical spinal nerve gives off.**

ANSWER A small **meningeal branch** back into the vertebral canal; then a **dorsal branch** to the epaxial muscles and the skin of the back, a **communicating branch** to the sympathetic trunk, and a much larger **ventral branch** to the body wall and the limbs.

69 **What is a plexus, and what practical consequence does it have?**

> ANSWER A network in which the ventral branches of neighbouring spinal nerves exchange fibres, so the named nerves that emerge carry fibres from several segments at once. The consequence is that a named limb nerve cannot be mapped onto a single spinal segment, and its cutaneous territory does not match any one dermatome.

70 **Name the three connective-tissue coats of a peripheral nerve, from inside out.**

> ANSWER **Endoneurium** around each fibre, **perineurium** around each fascicle, **epineurium** around the whole nerve. The same three-tier scheme as endomysium, perimysium and epimysium in a skeletal muscle.

71 ⭐ **Why is the autonomic nervous system defined as wholly efferent?**

> ANSWER Because only the efferent side is anatomically distinctive: two neurons in series, the second cell body in a peripheral ganglion, and the first cell bodies restricted to particular nuclei and cord regions. Visceral afferent fibres exist in quantity but are in general indistinguishable from somatic afferent fibres in structure and arrangement.

72 **Where does the sympathetic outflow leave the cord, and where does the parasympathetic?**

> ANSWER Sympathetic is the **thoracolumbar** outflow — the lateral horn of the thoracic and cranial lumbar segments, about T1 to L3 in the dog. Parasympathetic is the **craniosacral** outflow — discrete brain stem nuclei, and the lateral grey column of sacral segments 2, 3 and possibly 4.

73 **Which nerves carry the parasympathetic outflow?**

> ANSWER Only the **oculomotor, facial, glossopharyngeal and vagus** nerves and the **pelvic** nerves. If a question asks whether a given nerve has a parasympathetic component, that list is the whole answer.

74 **What are the three possible fates of a preganglionic sympathetic fibre entering the trunk?**

> ANSWER Synapse in the ganglion it entered; run up or down the trunk and synapse further along; or pass straight through without synapsing and continue as a **splanchnic nerve** to a prevertebral ganglion on the aorta.

75 **Why is a sympathetic response diffuse and a parasympathetic one precise?**

> ANSWER Because of where the ganglion sits. Parasympathetic ganglia are close to or inside the target organ, so the postganglionic fibre is short and its transmitter acts locally. Sympathetic ganglia are close to the central nervous system, so the postganglionic fibres are long and radiate widely — and the adrenal medulla adds a bloodborne mass response.

76 **Which fibres supply the body wall and limbs autonomically?**

> ANSWER **Only** postganglionic sympathetic fibres, which join every spinal nerve through the unmyelinated communicating branches. There is no parasympathetic supply to the body wall or limbs.

77 **What is the enteric nervous system, and what is its origin?**

> ANSWER An extensive network of neurons in the wall of the gut, derived from **neural crest** cells that migrated the whole way there. It can generate and coordinate motility without any input from the brain or cord, which is why an isolated length of intestine still moves.

78 **Where does the spinal cord end in the dog, and how firm is that figure?**

> ANSWER Usually **L7**, but it may reach only L6, and in some breeds — the German Shepherd is the one named — it may reach S1. It is a range, not a fixed number, and quoting one figure as if it were fixed is quoting it wrongly.

79 **Where does the cord end in the horse, the ox and the calf?**

> ANSWER S1 or S2 in the horse. **S1 in the adult ox** but **S3 in the calf** — the same growth process caught at an earlier stage.

80 **Why does the sheep's dural tube end earlier than the ox's?**

> ANSWER Because the sheep has only **four** sacral vertebrae where most domestic mammals have five. Its dural tube ends in segment S3; the ox's reaches S4.

81 **What do gyrencephalic and lissencephalic mean, and give an example of each.**

ANSWER **Gyrencephalic** is a folded cortical surface — the dog, cat, horse, ox, sheep and pig. **Lissencephalic** is a smooth one, without gyri — Thomson and Hahn name rodents, lagomorphs and birds, so the rat and the rabbit.

82 **What is the rete mirabile and which species have it?**

ANSWER A network of small arteries replacing a single large vessel at the base of the brain, formed from branches of the maxillary artery, in the ox, the sheep and the pig. It changes where the blood supply to the brain comes from in those species.

83 **What single anatomical property makes lesion localisation possible?**

ANSWER That a given function is carried by a structure that is **only in one place**. If a pathway runs through one part of the brain stem and nowhere else, losing that function puts the lesion there.

84 **Name the three features of the map that make localisation work.**

ANSWER **Segmental organisation** of the cord, so a deficit that respects a limb points at a stretch of cord. **Decussation** at known levels, so the side of the sign tells you the side of the lesion relative to the crossing. And the **cranial nerve nuclei anchored to the brain stem**, so a cranial nerve deficit with a limb deficit places the lesion in the brain stem rather than the cord.

15 Veterinary Neuroanatomy — frequently asked questions

What are the 12 cranial nerves in animals?

In order from the front of the brain backwards: **I** olfactory, **II** optic, **III** oculomotor, **IV** trochlear, **V** trigeminal, **VI** abducent, **VII** facial, **VIII** vestibulocochlear, **IX** glossopharyngeal, **X** vagus, **XI** accessory, **XII** hypoglossal. They are the same twelve in all the domestic mammals. The numbering is rostrocaudal — it records the order in which they arise, which is the only thing it is really for. Section 9 above tabulates each one's functional components, what it serves and which opening in the skull it leaves by.

How do you remember the cranial nerves?

Use a mnemonic for the **order** and a scheme for everything else. Any sentence with the initials O-O-O-T-T-A-F-V-G-V-A-H will fix the sequence. But the sensory-and-motor mnemonics that circulate with it were written for human anatomy, and a veterinary examiner asks which muscle, which foramen and which functional component instead. Dyce's three groups answer those: the purely sensory special-sense nerves (I, II, VIII), the nerves to head muscles of somitic origin (III, IV, VI, XII), and the pharyngeal arch nerves (V, VII, IX, X, XI).

What is the difference between a nucleus and a ganglion?

Nothing except which side of the boundary of the central nervous system it sits on. Both words name a collection of neuronal cell bodies: **nucleus** inside the brain or cord, **ganglion** outside it. The same pairing applies to bundles of axons — **tract** inside, **nerve** outside — which is why the optic nerve is anatomically a tract. Be aware that this *nucleus* is not the organelle of the same name.

Where does the spinal cord end in dogs and other animals?

It ends short of the end of the vertebral canal, because the column outgrows the cord, and the level is species-specific. Usually **L7** in the dog, sometimes only L6, and in some breeds as far as S1; **L7** in the cat and pig; **S1 or S2** in the horse; **S1** in the adult ox but **S3** in the calf; **S1** in the sheep. Beyond the cord's end the canal contains the cauda equina and the dural tube, which itself runs on to S4 in the ox and horse and S1 or S2 in the dog and cat.

What does cerebrospinal fluid do, and where does it come from?

It forms a water jacket that buoys up and protects the brain and spinal cord inside the subarachnoid space. Most of it is produced at the **choroid plexuses**, tufts of capillaries covered with ependyma that invaginate into the ventricles, by ultrafiltration of blood plasma across a barrier of tight-junctioned cells. That barrier is why the fluid has more potassium and calcium and less sodium and protein than plasma — and why many drug molecules, antibiotics among them, do not readily cross into it.

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