VETERINARY · ILLUSTRATED GUIDE

VETERINARY ANGIOLOGY NOTES

Veterinary Angiology Notes: How the Heart and Vessels Are Built (PDF)

Angiology is the anatomy of circulation — the heart, the blood vessels and the lymphatic system, taught as one branch because they are one transport system.

Contents

The 11 sections of this guide, in order.

IN SHORT

Angiology is the anatomy of circulation — the heart, the blood vessels and the lymphatic system, taught as one branch because they are one transport system. These veterinary angiology notes are the general plan rather than a list of vessels: the three coats every vessel wall is built from and where that plan stops, why an artery near the heart is not the same kind of vessel as an artery in the leg, what an anastomosis and an end artery mean at the bedside, how the heart is built as an organ, the two circulations and the portal route that breaks their rule, and the lymphatic half that most accounts leave out — including the lymphocentre and the haemal node.

KEY POINTS

1. **Angiology is one branch, not three.** The heart, the blood vessels and the lymphatic vessels and organs are studied together because they form one continuous transport system, and because they share a structural plan.
2. **Almost every vessel is three coats around a lumen** — tunica intima, tunica media, tunica externa — and the definition carries its own exception: the vessels of the terminal circulation, where exchange happens, do not have three coats.
3. **The media classifies the vessel.** Elastic sheets make an elastic artery, which stores part of each stroke and gives it back between strokes; smooth muscle makes a muscular artery, which distributes and adjusts its own calibre.
4. **No artery can close completely; an arteriole can.** Its media is down to a single layer of muscle and its internal elastic lamina has broken into a network. The tap is at the arteriole, not at the artery.
5. **The arrangement of vessels decides what a blockage costs.** An anastomosis gives a region a second route; an end artery does not, so occluding it infarcts its territory.
6. **A portal vein runs between two capillary beds** instead of returning to the heart, which is why everything absorbed from the gut meets the liver first.
7. **The heart's wall follows the same three-layer idea** — epicardium, myocardium, endocardium — and its epicardium *is* the visceral layer of the serous pericardium.
8. **Learn lymphocentres, not lymph nodes.** Node location is remarkably constant across species; node number is not — one or two in the dog and ruminants, a group of many small ones in the pig and horse.

About the images

four figures are reproduced for educational reference, all from Nickel, Schummer and Seiferle's *The Anatomy of the Domestic Animals, Volume 3: The Circulatory System* — Figs. 2, 12, 1.52 and 13. Each is credited beneath it and copyright remains with the original authors and publishers. The other four figures are diagrams of our own, drawn for this guide from the sources named under them.

01 What angiology is, and what it is not

Angiology is the part of anatomy that deals with the organs of circulation — the heart and the vessels that carry blood and lymph. The word is Greek: *angion*, a vessel. It is one branch rather than three because the three parts are one continuous transport system, and because a student who learns them separately never sees that they are built on a shared plan.

That plan is what this page teaches. It is a page about **structure**: what a vessel wall is made of, what changes along the vascular tree, how vessels are arranged so that a blockage sometimes matters and sometimes does not, how the heart is built as an organ, what the two circulations actually are, and how the lymphatic system is organised. How any of it *works* — our guide to the cardiac cycle, the cardiac action potential, how blood pressure is regulated — is physiology, and each of those has a page of its own on this site.

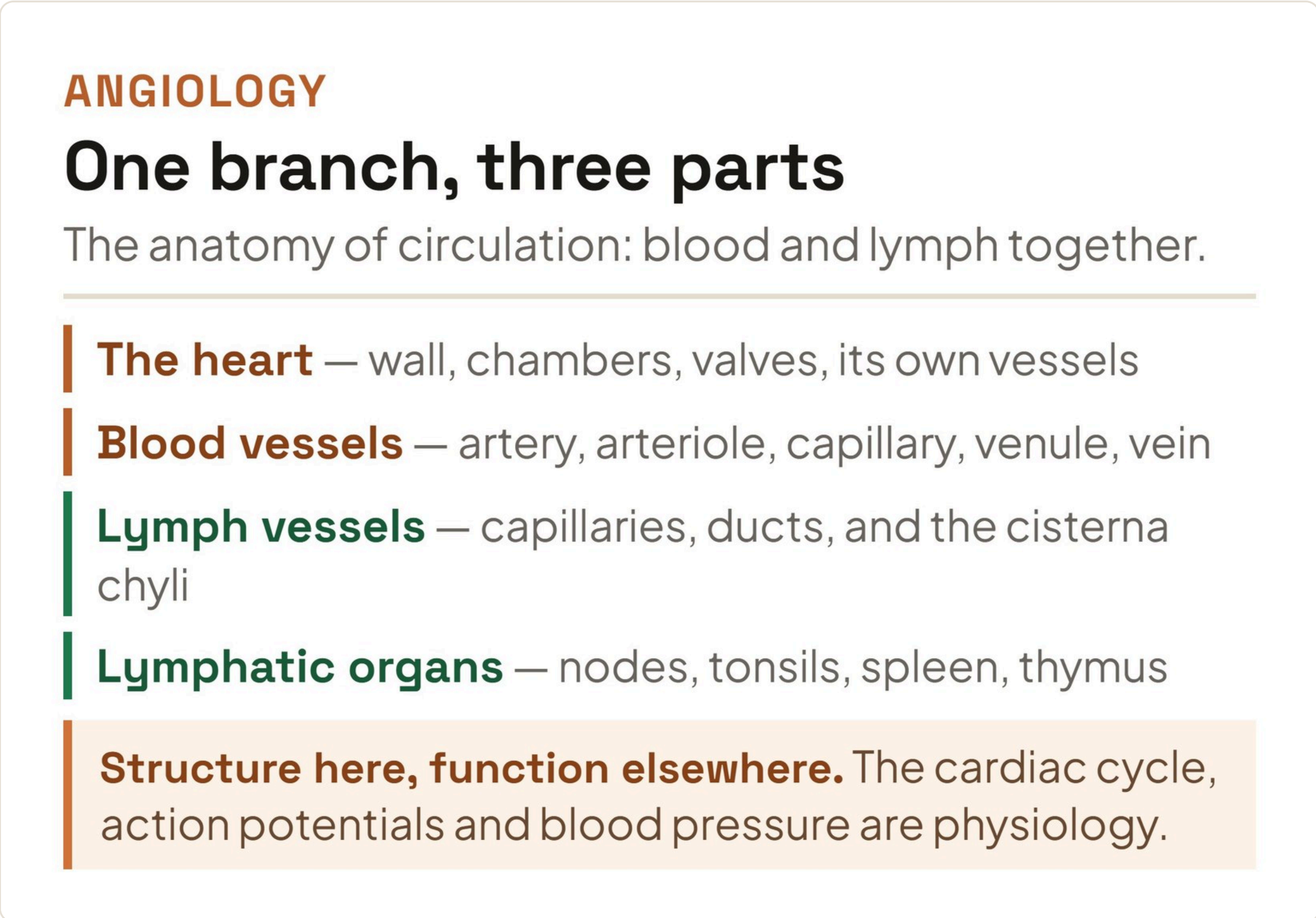

Fig 1 — One branch, three parts. Angiology covers the heart, the blood vessels and the lymphatic vessels and organs as one branch, because they are one continuous transport system. This page teaches how they are **built**; how they **work** — the cardiac cycle, the action potential, blood pressure — is physiology and has its own pages.

Diagram — Vet-eBooks.com, drawn for this guide. Data from König and Liebich, Veterinary Anatomy of Domestic Animals, 7th ed., §1.5 and ch. 13, and from Nickel R, Schummer A, Seiferle E. The Anatomy of the Domestic Animals, Vol. 3: The Circulatory System, the Skin and the Cutaneous Organs of the Domestic Mammals. Verlag Paul Parey, p. 7.

There is a good reason to teach the branch this way rather than as a list of vessels, and it is not our reason. König and Liebich put it in the textbook itself: for the student and the clinician, a working understanding of the vessels and a general knowledge of their topography matters more than detailed knowledge of every branch, because "the exact topography of every vessel down to minute detail is only of academic interest". The named arteries of the forelimb belong on a page about the forelimb. What belongs here is the plan they all follow.

02 One plan, three coats

Almost every vessel in the body is a tube built from three concentric layers, or *tunics*. From the lumen outwards they are the **tunica intima**, the **tunica media** and the **tunica externa**. Learn what each is made of and you can predict how a vessel behaves, because the three coats are not decorative — each one does a different mechanical job.

COAT	WHAT IT IS MADE OF	WHAT IT DOES	WHERE IT STOPS
Tunica intima *tunica interna s. intima*	Endothelium, a thin subendothelial layer, and an internal elastic lamina	The only layer in contact with blood, and the only one a capillary keeps	Nowhere — every vessel has an endothelial lining
Tunica media *tunica media*	Elastic sheets, smooth muscle, or a mixture — the proportion is what classifies the vessel	Sets the calibre. This is the layer that stores the stroke in an elastic artery and narrows the lumen in a muscular one	At the arteriole, where it thins to a single layer of muscle, and then ends
Tunica externa *tunica externa* (adventitia)	Collagen and elastic fibres, interwoven and crossed in a helix, plus an external elastic lamina	Takes the longitudinal pull, and fixes the vessel into the tissue around it	At the capillary, where pericytes take over

Figure 2 is worth a long look, because it puts the whole vascular tree on one plate with the coats opened: an artery and a vein at either side with every layer lettered, and between them an arteriole, a venule, a capillary network, a sinus capillary and an arteriovenous anastomosis. Everything the rest of this page says about vessels is visible somewhere on it.

The important qualification is in the definition itself, and it is the part students most often miss. The three-coat plan describes the vessels **excluding those of the terminal circulation**. Where the exchange actually happens — the arterioles, the capillaries and the venules — the wall is stripped down to almost nothing, because exchange needs the shortest possible distance between blood and tissue. The plan and its exception are the same idea seen from two ends.

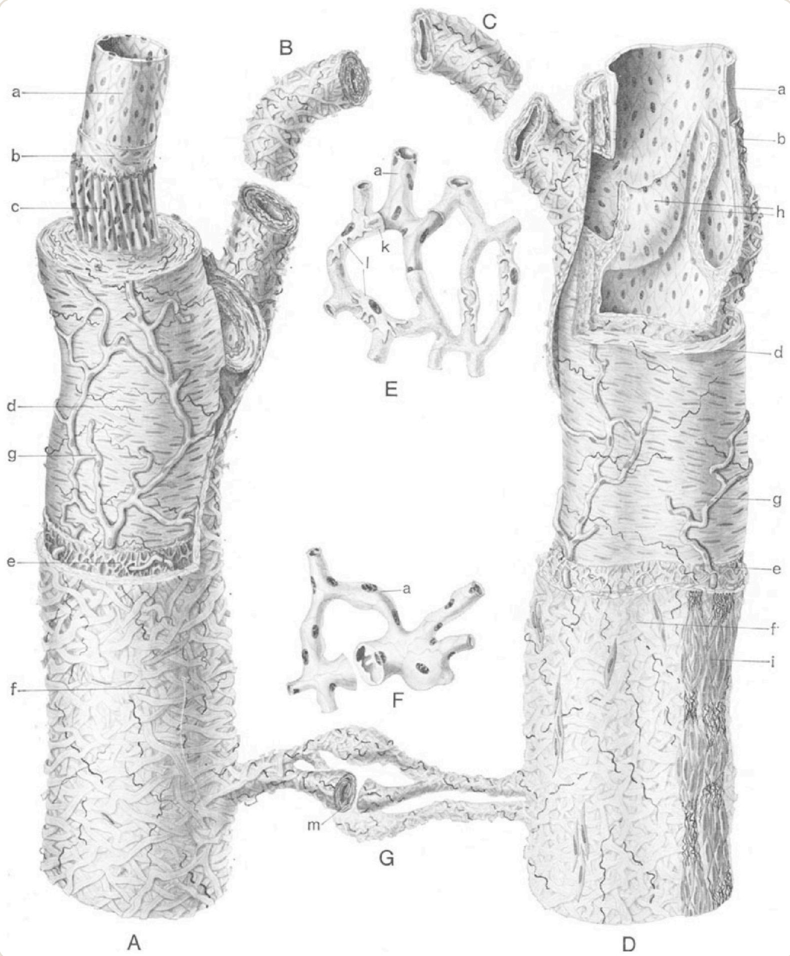

Fig 2 — Every kind of vessel, opened, on one plate. **A** artery · **B** arteriole · **C** venule · **D** vein · **E** capillary · **F** sinus capillary · **G** arteriovenous anastomosis. The wall layers are lettered on the artery and the vein: **a**–**c** the tunica intima (a endothelium, b subendothelial layer, c internal elastic lamina), **d** the tunica media, **e**–**f** the tunica externa (e external elastic lamina, f adventitia). Also keyed: **g** vasa vasorum, **h** a venous valve, **i** longitudinal muscle in the vein's adventitia, **k** the capillary basal membrane, **l** pericytes, **m** an intimal cushion.

Image — Nickel R, Schummer A, Seiferle E. The Anatomy of the Domestic Animals, Vol. 3: The Circulatory System, the Skin and the Cutaneous Organs of the Domestic Mammals. Verlag Paul Parey — Fig. 2, structure of the walls of blood vessels, after Grau and Walter. Reproduced for educational reference.

Reading a vessel name

The nomenclature builds most vessel terms out of the same few pieces, so a name usually tells you what kind of vessel it is before you find it. **Tunica** is a coat. The **-ole** and **-ule** endings in *arteriole* and *venule* are diminutives — a small artery, a small vein. **Vas** is a vessel, so *vasa vasorum* are the vessels of the vessels and *vasa afferentia* are the vessels carrying towards. And **anastomosis** means an opening between two things, which is why it is used for a join between arteries and again, with a qualifier, for the arteriovenous kind.

03 Why an artery near the heart is not the same as an artery in the leg

Arteries come in two structural types, and the difference is visible on a dissection table before any microscope is involved. The vessels near the heart — the aorta, the large branches leaving its arch, the pulmonary trunk — are yellowish and extraordinarily stretchy. Further out, arteries become reddish or white and distinctly thick-walled. The colour is elastin, and the proportion of elastin to smooth muscle in the media is what separates an **elastic artery** from a **muscular artery**. The change is a **gradual merging** rather than a boundary, so a large artery near the heart can be part elastic and part muscular; the two names describe the ends of a range.

	ELASTIC ARTERY	MUSCULAR ARTERY
Where	The aorta, its branches near the heart, the pulmonary trunk and its large branches	Everything further out — the named arteries you dissect
How it looks	Yellow, and extremely distensible	Reddish or white, and thick-walled
The media	Concentric elastic membranes, with muscle cells between them	Largely smooth muscle, in spiral layers
What it does	Works as an expansion chamber: it is stretched by the stroke and recoils between strokes, so a rhythmic output leaves the heart and a much more even stream arrives at the periphery	Distributes. It carries blood to the organ that needs it and adjusts its own calibre on the way
Can it close?	No	No — it can narrow considerably, but not occlude

The elastic artery earns its structure by doing something the heart cannot do for itself. The heart ejects in strokes; tissue needs a stream. When blood is driven into the aorta the elastic media is stretched and holds part of the energy of that stroke; between strokes the wall recoils and gives it back. An expansion chamber is the analogy the anatomists use, and it is exact. The practical consequence is that the pulse you feel at the femoral artery is a much smoothed version of what left the ventricle.

A muscular artery does the other job. Its media is smooth muscle arranged in spiral layers, so it can narrow or widen its own lumen and send blood towards the organ that is working. There is a limit, and it is worth stating precisely: an artery of any size can reduce its lumen considerably, but **an ordinary artery cannot close it completely**. That is why the fine control of flow to a tissue happens further down the tree, at the arteriole.

The exception the rule needs: throttle arteries

"No artery can close" is the rule, and it has a named exception on the same page of the same book. Some arteries carry **cushions of longitudinal muscle or epithelioid cells** — cells that look like epithelium without being it — in the wall which, on contracting, bulge the intima into the lumen and **close it completely**. The German name is the memorable one — *Drosselarterien*, **throttle arteries** — and they occur in the skin, the lungs, erectile tissue and some other organs. König describes the same idea as **barrier arteries**, which contract to interrupt flow to one capillary bed and so increase it to the next. If you look back at Figure 2, the structure is already there: **m** is an intimal cushion. So the honest form of the rule is that an *ordinary* artery cannot occlude, and the vessels that can are built differently and have their own name.

04 Where the wall runs out: arterioles, capillaries, venules

The vessel that can close completely is the **arteriole**. Its media is down to a single layer of muscle cells and its internal elastic lamina has broken up into a network, and between them those two changes let it shut its lumen entirely. That is the tap. An artery distributes; an arteriole decides.

Fig 3 — What changes as you travel down the tree. The bar is **wall thickness**, not the width of the lumen. Three coats hold from the aorta to the arteriole and from the venule back to the vena cava; across the exchange bed itself there are none. Two properties change with the media: only an arteriole can shut its lumen completely, and only a vein carries valves.

Diagram — Vet-eBooks.com, drawn for this guide. Schematic, not to scale. Data from Nickel R, Schummer A, Seiferle E. The Anatomy of the Domestic Animals, Vol. 3: The Circulatory System, the Skin and the Cutaneous Organs of the Domestic Mammals. Verlag Paul Parey, pp. 7–13, and König and Liebich, 7th ed., p. 54.

Past the arteriole the wall gives up the three-coat plan altogether. A **capillary** is an endothelial tube, a basal membrane and a scatter of *pericytes* — branched cells moulded to the outside of the membrane. Nothing else. Where a tissue needs an especially free exchange the same tube is simply made wider, and a wide capillary of that kind is a **sinus capillary** or *sinusoid* — the form found in the liver, the bone marrow and the pituitary. It is labelled **F** on Figure 2. The dimensions are small enough to be worth remembering: **6–30 µm** across, rarely up to 40 in the so-called giant capillaries, and **0.5–1.0 mm** long.

How densely a tissue is supplied with capillaries follows how hard that tissue works. Endocrine organs, the grey matter of the central nervous system, kidney, heart, skeletal muscle, skin and adipose tissue are richly supplied. Tendon, fascia, ligament and bone are not. Two tissues have no capillaries at all — the **cornea** and **hyaline cartilage** — and that single fact explains a great deal about why cartilage heals as badly as it does. Beyond the bed, blood is collected by **venules** and returned through veins of increasing calibre; only on the venous side do you meet **valves**, and only there is longitudinal muscle found in the adventitia.

What crosses the capillary wall, and why fluid leaves at one end of a bed and returns at the other, is a question of pressures rather than of structure. Our guide to Starling forces and oedema covers it.

The venous side is worth more than the sentence it usually gets, because two of its structural features do real mechanical work. The first is the **valves**. The second is where veins are placed: they lie in the connective tissue between and within muscles, so muscular activity alternately widens and squeezes them, and the valves turn that squeezing into one-way flow towards the heart. A third force is the chest itself — the negative pressure of the thoracic cavity, deepened at every inspiration, draws on the thin-walled great veins and holds them open. None of these is the heart pushing; all of them are structure being used.

A textbook explanation that turned out to be wrong

At many sites in the locomotor apparatus an artery and its accompanying veins are bound together inside a single connective-tissue sleeve — an **arteriovenous linkage**. The obvious inference was drawn for years: the arterial pulse must squeeze the veins rhythmically and, with the valves, drive blood towards the heart. Later experimental work found **no such functional interplay**. The structure is real and the mechanism was not, which is a useful thing to have met once — an arrangement that looks purposive is a hypothesis, not a finding.

05 The vessels that feed the vessels

A vessel wall is living tissue and has to be fed. In a small vessel that is not a problem: the wall is thin enough to be nourished by diffusion straight from the blood in its own lumen. In a thick-walled vessel it is a problem, because only the innermost layers can be supplied that way, and the bulk of the media is too far from the lumen to be reached.

The answer is a set of small vessels running in the wall itself, the **vasa vasorum** — literally the vessels of the vessels. The detail worth holding on to is where they come from. They do **not** branch off the lumen of the segment they supply. They arrive from outside, as recurrent branches of neighbouring arterial plexuses, and break up into capillaries inside the wall. A thick artery is therefore supplied from the outside in, not from the inside out — which is exactly why the adventitia is the layer that carries them, and why stripping a vessel clean of its surrounding tissue is not a neutral act.

06 Ways around: anastomoses, end arteries and portal systems

So far this has all been about how a vessel is built. The next question is how vessels are *arranged*, and it is the arrangement rather than the wall that decides what happens when one of them is blocked. Two arteries that join give a region a second way in, so losing one need not kill the tissue; a vessel with no such join is an **end artery**, and losing it is an infarct. Nothing about the wall of either vessel tells you which you are looking at.

ARRANGEMENT	WHAT IT MEANS	WHAT IT COSTS, OR SAVES, THE PATIENT
Anastomosis	Two arteries joining, so a region has more than one supply route	A blocked vessel need not mean a dead region: the neighbouring supply can take over
End artery	A vessel that is the only supply to its territory, with no useful join to its neighbours	Occlusion is infarction. This is why the same clot matters more in some organs than others
Arteriovenous anastomosis	A direct link from arteriole to venule that skips the capillary bed. Two forms: a **bridge** anastomosis and the more complex **glomus** type	Bridge anastomoses divert blood to or from the skin, so they are a main route of temperature control — extremities, the pinna, the nose
Portal system	A vein that begins in one capillary bed and ends in another instead of returning to the heart	Everything absorbed from the gut meets the liver before it meets the rest of the body

An **arteriovenous anastomosis** deserves a second look, because it is the most surprising structure on the list: a direct connection from the arterial to the venous side that misses the capillary bed entirely. The commoner form, the **bridge** anastomosis, is found in the gut wall, salivary glands, nasal mucosa, lung, endocrine organs, skin and the reproductive organs. When it is open it shifts blood from the high-pressure to the low-pressure side and relieves the capillary bed behind it, and by doing so in the skin of the extremities, the pinna, the nose and the comb it becomes one of the body's main routes for losing or conserving heat.

The second form, the **glomus** anastomosis, is a coiled, thick-walled structure with its own capsule, found in the terminal phalanges. It has been credited with several jobs over the years and the honest position is the one the source takes: because its coiled narrow veins cannot change calibre quickly, it has no haemodynamic action, and after the experimental work on a possible secretory role failed to confirm it, **the function of the glomus organs remains unresolved**. It is worth knowing that a named structure can still be an open question.

“End artery” is a spectrum, not a switch

It is tempting to sort vessels into two boxes and be done. In practice most territories have *some* collateral supply and very few arteries are end arteries in the strict sense, so the useful question is not **is this an end artery?** but **how much collateral does this territory have, and how fast would it have to open?** A supply that is adequate over weeks is not adequate over minutes. Say which you mean.

07 The heart as an organ, not as a pump

Every physiology course treats the heart as a pump, and it is one. Anatomically it is something more specific: a hollow muscular organ whose wall is built in three layers, exactly like the vessels it belongs to. From outside in they are the **epicardium**, the **myocardium** and the **endocardium**. The epicardium is not a separate invention — it *is* the visceral layer of the serous pericardium, which is why the heart's outer surface is smooth and glistening and why our guide to the body cavities and serous membranes is the page that owns the sac around it.

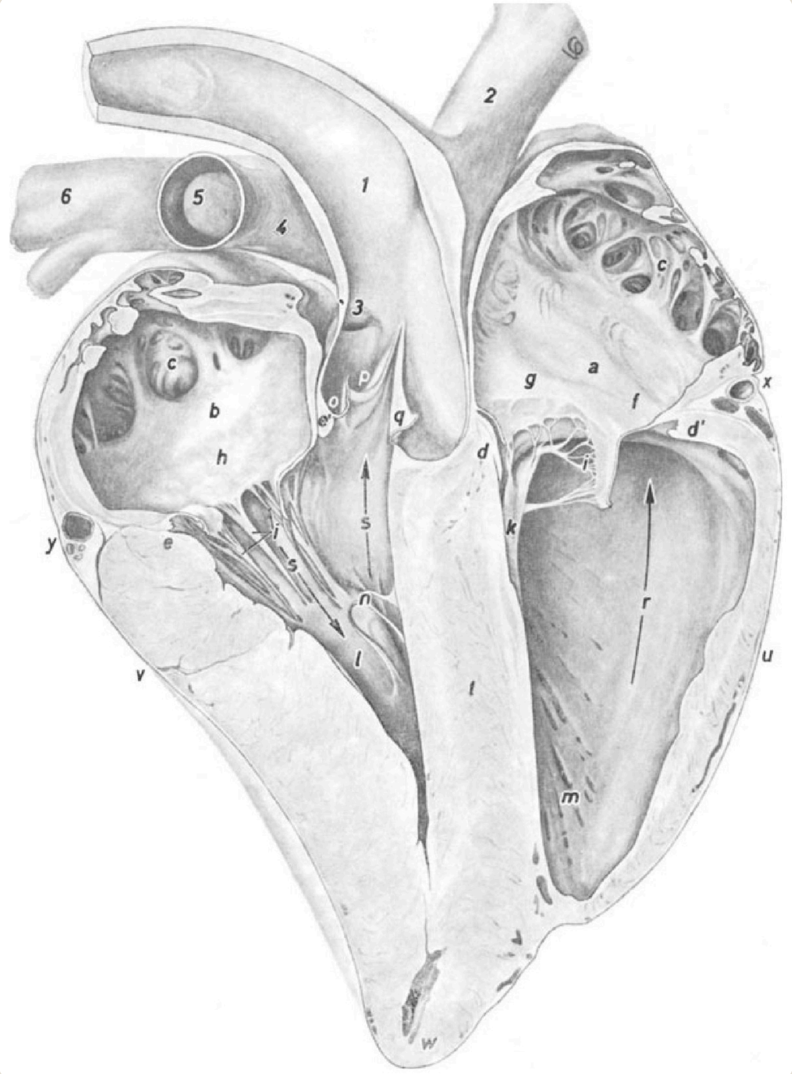

Fig 4 — The heart opened along its length. A sagittal section of the equine heart, left half, with both atria opened. Visible in one view: the two atrioventricular openings and their cusps, the **chordae tendineae** running from the cusp margins, the **papillary muscles** they arise from, the **trabeculae carneae** on the inner wall, the aortic valve with its semilunar cusps, and the **interventricular septum** between the two ventricles. The arrows mark the inflow and outflow tracts; the numbers at the top are the aortic arch and the great vessels leaving it.

Image — Nickel R, Schummer A, Seiferle E. The Anatomy of the Domestic Animals, Vol. 3: The Circulatory System, the Skin and the Cutaneous Organs of the Domestic Mammals. Verlag Paul Parey — Fig. 12, sagittal section through the heart of a horse, left half. Reproduced for educational reference.

Figure 4 shows why a section along the length of the heart is worth more than any diagram of it: the two atrioventricular openings, the cusps, the chordae tendineae, the papillary muscles they run to and the **interventricular septum** between the two ventricles are all in one view.

Inside, the four chambers are arranged as two pumps in series that happen to share a wall. The right ventricle receives blood at low pressure and sends it a short distance to the lung; its wall is about **half as thick** as the left ventricle's, and the reason is simply that its work load is lower. Its cavity has two functionally distinct parts — an **inflow route** running from the atrioventricular opening towards the apex, and an **expulsion route** that starts at the apex and leads up into the conus arteriosus and the pulmonary trunk. The muscular ridges called *trabeculae carneae* are well developed in the inflow route and absent from the expulsion route, which is a good example of a structure whose distribution is telling you what it is for.

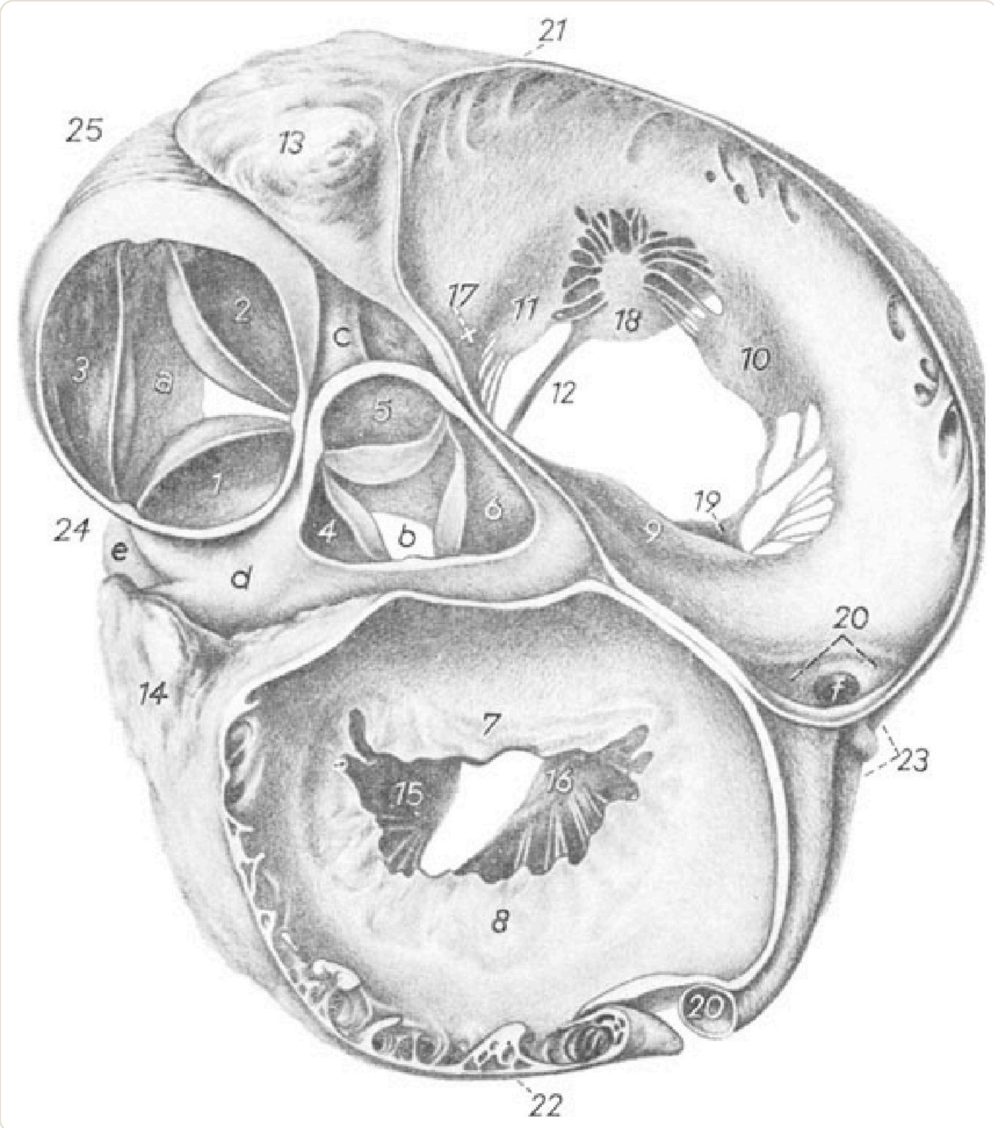

Fig 5 — All four valves, in one plane. The base of a bovine heart with the chambers cut away, so the four openings sit in the plane they actually occupy. Upper left, the **pulmonary valve** with its three semilunar cusps; centre, the **aortic valve** with its three; lower, the wide **left atrioventricular opening** with the two cusps of the mitral valve and the cut papillary muscles below it; upper right, the **right atrioventricular opening** with the three cusps of the tricuspid. The two **coronary arteries** are seen leaving the aorta at its root, which is why they are the first branches of the systemic circuit.

Image — Nickel R, Schummer A, Seiferle E. The Anatomy of the Domestic Animals, Vol. 3: The Circulatory System, the Skin and the Cutaneous Organs of the Domestic Mammals. Verlag Paul Parey — Fig. 13, base of the bovine heart, basal aspect, after Preuss. Reproduced for educational reference.

One part of the heart's structure is easy to leave out of an anatomy page because its name sounds like physiology: the **excitation and conducting system**. How it fires belongs to the cardiac action potential, but what it is made of belongs here. It is modified cardiac muscle, not nerve, and it runs from the **sinuatrial node** in the wall of the right atrium to the **atrioventricular node**, then into the **atrioventricular bundle**, which divides into a right and a left crus and ends in **Purkinje fibres**. Two things about it are gross anatomy rather than histology. In the larger species the sinuatrial node can be found by dissection, because it is paler than the atrial muscle around it; in small species it takes a microscope. And the *trabecula septomarginalis* — the moderator band, labelled **n** on Figure 4 — is not merely a strut across the ventricle: it **carries part of the conducting system** from the septum to the base of the papillary muscles. In cattle and horses the Purkinje fibres themselves reach 80–100 µm across, against about 10 µm for ordinary cardiac muscle fibres.

The four valves are easiest to understand from above, with the chambers removed, as in **Figure 5**, because they sit almost in one plane and are held there by the connective tissue skeleton of the heart. Two of them are **atrioventricular**, with cusps tethered by *chordae tendineae* to the **papillary muscles** of the ventricular wall — an arrangement that stops a cusp from inverting when the ventricle contracts. The other two are **semilunar** — the **aortic valve** and the **pulmonary valve**, at the openings of the aorta and the pulmonary trunk — and they need no tethering because their three cusps close against one another.

The heart's own arteries leave the aorta immediately above its valve, which makes them the very first branches of the systemic circulation. They are the **coronary arteries** (*aa. coronariae*), and the name is topographical rather than functional: they run in the **coronary groove** that encircles the heart between the atria and the ventricles, like a crown. The right one arises from the right sinus of the aortic bulb and the left from the left. Their blood does not leave the heart by a vein of its own — it collects into the **coronary sinus**, a short tubular dilatation opening straight into the **right atrium** beneath the opening of the caudal vena cava. Both coronary arteries are visible at the aortic root on **Figure 5**.

08 Where the heart sits, and why you cannot examine it like a human's

A branch page has to be useful at the animal, and this is the point where anatomy becomes an examination technique. The heart lies in the middle mediastinal space, and its craniocaudal extent is stated by rib number — a number that differs by species and is worth learning as a set rather than one at a time.

SPECIES	THE HEART LIES BETWEEN THESE RIBS	LEFT OF THE MEDIAN PLANE
Dog	3rd (4th) to 6th (7th)	4/7 left, 3/7 right
Cat	4th to 7th	—
Pig	3rd to 6th	—
Ox	3rd to 5th (6th)	5/7 left, 2/7 right
Sheep and goat	2nd to 5th	—
Horse	3rd (2nd) to 6th	3/5 left, 2/5 right

Two things follow from that table. The first is that the heart is not centred: more of it lies to the left than to the right in every species measured, so the left thoracic wall is the closer approach. The second is the harder lesson. In a human the heart is accessible to palpation, percussion and auscultation from the front of the chest. In the domestic mammals it is not, because the cranial part of the thorax is covered by the shoulder-girdle musculature and by the mass of the triceps, whose caudal border reaches down as far as the 4th or 5th intercostal space. The technique you were taught on a human model does not transfer, and the reason is entirely anatomical.

09 Two circulations, and the one that breaks the rule

The vessels form two circuits in series, described by König and Liebich as a figure of eight with the heart in the centre. The **systemic** circulation is the larger: oxygenated blood from the left side of the heart to every organ, and deoxygenated blood back to the right. The **pulmonary** circulation is the smaller: deoxygenated blood from the right side to the exchange tissue of the lung, returned oxygenated to the left. It is worth saying out loud that the pulmonary artery therefore carries deoxygenated blood and the pulmonary veins oxygenated blood — the one place where a vessel's name and its content come apart.

TWO CIRCUITS

A figure of eight, heart in the middle

SYSTEMIC — THE LARGER CIRCUIT

left ventricle → aorta → body capillaries → venae cavae → right atrium

PULMONARY — THE SMALLER CIRCUIT

right ventricle → pulmonary trunk → lung capillaries → pulmonary veins → left atrium

PORTAL — BETWEEN TWO CAPILLARY BEDS

gut capillaries → portal vein → liver capillaries → hepatic veins → caudal vena cava

Fig 6 — Two circuits, and the one route that breaks the rule. The systemic and pulmonary circuits run in series, in a figure of eight with the heart at the centre. The third route is the exception that defines a portal system: the **portal vein** begins in one capillary bed and ends in another, so blood from the gut is filtered by the liver before it reaches the heart at all.

Diagram — Vet-eBooks.com, drawn for this guide. Schematic, not to scale. Data from König and Liebich, Veterinary Anatomy of Domestic Animals, 7th ed., pp. 471 and 493.

Two numbers make the system concrete. Blood volume is about **6–8% of bodyweight** in the domestic mammals — with the notable exception of the **cat, at about 4%**. And the time a blood cell takes to travel from a jugular vein around the body and back depends largely on the size of the animal: roughly **30 seconds** in a large animal and about **seven seconds** in a cat.

Then there is the exception. Almost every vein in the body runs from one capillary bed towards the heart. A **portal vein** is defined by not doing that: it is a vein that runs *between two capillary beds*. The hepatic portal vein collects from the capillaries of the stomach, intestine, pancreas and spleen and delivers into the capillary bed of the liver, where the blood is filtered a second time before hepatic veins finally carry it on to the caudal vena cava. Everything absorbed from the gut therefore meets the liver before it meets anything else.

The fetus runs a third arrangement, and the wall plan explains how it stops

Before birth the lungs are not ventilated, so most blood by-passes them: through the **foramen ovale** between the atria, and through the **ductus arteriosus**, which carried blood from the pulmonary trunk straight into the aorta. Both leave a trace you can find in an adult — the *oval fossa* on the interatrial septum, and the *ligamentum arteriosum*. What closes the ductus is worth noticing here rather than in a physiology course: immediately after birth, when the newborn starts to breathe, **the tunica media of the ductus contracts** and its inner coat begins to transform. The three-coat plan from §2 is doing the work. When it fails, a persistent ductus arteriosus leaves a left-to-right shunt, and oxygen-rich aortic blood mixes into the pulmonary artery.

10 The lymphatic system is the other half of this branch

Most accounts of angiology fade out after the veins, and that is the largest gap in the subject as it is usually taught. Lymph is not a footnote to circulation; it is the second half of the same transport system, and it is where a great deal of clinical anatomy actually lives.

Anatomically the system divides in two. There is a **cellular** component — the lymphoreticular tissue that every lymphatic organ is built from — and a **vascular** component, the lymph vessel system itself. The vascular half supports the venous side of the blood circulation, and the relationship between the two is close enough to be visible in their development and preserved in the lymphovenous anastomoses where lymph finally re-enters the bloodstream. But the lymph vessels also do something no vein does: their terminal parts resorb fluid and protein from the tissue spaces, and they have a motor ability of their own.

LYMPH

Learn the drainage area, not the nodes

A lymphocentre names the area, so it survives a species change.

ONE WAY ONLY — AND IT ENDS IN A VEIN

drainage area → vasa afferentia → node → vasa efferentia → duct → vein

In primary lymph · **out** secondary: filtered, lymphocyte-rich

The by-pass. Afferents can skip the nearest node.

Fig 7 — Where lymph goes, and what changes on the way. Lymph runs one way only and ends in a vein, not in the heart directly. It arrives at a node as **primary lymph** through the vasa afferentia and leaves as **secondary lymph** through two to four vasa efferentia, filtered and enriched with lymphocytes. Afferent vessels can by-pass the nearest node and enter the next, which is why the node that swells is not always the closest one to the lesion.

Diagram — Vet-eBooks.com, drawn for this guide. Schematic, not to scale. Data from Nickel R, Schummer A, Seiferle E. The Anatomy of the Domestic Animals, Vol. 3: The Circulatory System, the Skin and the Cutaneous Organs of the Domestic Mammals. Verlag Paul Parey, pp. 269 and 307.

The route is the thing to learn, and every term on it is used clinically. Lymph is collected from a **drainage area** by lymph capillaries and carried in **vasa afferentia** to a **regional lymph node** — defined as the filtration point that receives and controls the *primary lymph* of a given organ or region. Two to four **vasa efferentia** leave the node carrying *secondary lymph*, which has been filtered and enriched with lymphocytes. From there it may pass through further nodes before reaching a collecting duct and, finally, a vein.

Why the regional node is the one you examine

A regional lymph node is defined as the filtration point that receives and controls the primary lymph of one organ or region. That definition is doing clinical work: if such a node is involved, the source says plainly that **the organ ahead of it is diseased**. This is the reason a physical examination palpates named nodes in a fixed order rather than hunting for lumps, and the reason a node's drainage area is the first thing to ask about when one is found enlarged.

The system also has **organs**, and they are the part a list of vessels leaves out. Besides the lymph nodes themselves, the lymphoreticular tissue is gathered into the **tonsils**, the **spleen**, the **thymus** and the aggregated follicles of the gut wall — Peyer's patches. A student asked to name the lymphatic organs is being asked for those.

Where the lymph finally goes is worth learning as one route. From the abdomen it collects into the **cisterna chyli**, the chyle cistern lying beside the aorta, and from there into the **thoracic duct**, which passes through the diaphragm alongside the aorta, continues **dorsally** through the thorax, and empties into the venous system at the **left venous angle** — where the internal jugular and the left subclavian vein converge. And there are places lymph vessels do not go at all: not into epithelium, not into the central nervous system, not into dental pulp, bone, cartilage or the placenta. That is the same kind of fact as the cornea having no capillaries, and it is worth holding beside it.

Two complications matter at the bedside. Nodes are strung in chains along the great vessels, so a node that is not at the extreme periphery is simultaneously the *primary stage* for its own drainage area and the *secondary stage* for the node before it. And afferent vessels sometimes **by-pass** the nearest node and enter the next one along, while nodes at the same level are cross-connected to each other. Lymph nodes are linked in parallel as well as in series. The practical consequence is that the enlarged node is not always the one nearest the lesion — and that the same lateral connections which increase the number of filters also give a disease process more routes to travel.

11 Lymphocentres, and the node that is not a lymph node

Here is the idea that makes the veterinary lymphatic system learnable, and it is the reason veterinary anatomy uses a term human anatomy does not. The **nomenclature of the lymph nodes is based on their location**, and that location is remarkably constant across the domestic species — constant enough that comparisons between species are genuinely possible. What is *not* constant is how many nodes there are at each site. In the dog and the ruminants there are usually only one or two; in the pig and the horse the same site carries a group of many small nodes.

So the useful unit is not the node. It is the **lymphocentre**: the term for the functionally analogous group at one site, whatever number of nodes a given species happens to put there. Learn the lymphocentres and their drainage areas and the knowledge transfers from the dog to the horse; learn a list of individual nodes and it does not.

The same reasoning explains a question that otherwise has no good answer — what a normal lymph node should measure. There is practically no absolute norm, because within any one area the **number and the size of the nodes vary inversely**. A pig's many small nodes and a dog's one large one are the same quantity of lymphatic tissue arranged differently, and a size that is unremarkable in one species is not informative in another.

It is worth saying what a node is built from, because the next paragraph turns on it. A lymph node has a connective-tissue **capsule**; beneath it a **cortex** holding the rounded **lymph follicles** in which lymphocytes are produced; and inside that a **medulla** of lymphoreticular tissue. Lymph arrives through afferent vessels at the surface, filters through the organ and leaves through efferent vessels at the **hilus**. Figure 8 labels all of it.

Fig 8 — A lymph node in section, with the vessels that define it. The capsule, the **cortex** with its lymph follicles, and the **medulla** of lymphoreticular tissue inside it. The two labels that matter most for this page are on the vessels: the **afferent lymph vessels** arriving at the surface, and the **efferent lymph vessels** leaving at the hilus. Those two are the whole difference between this and a haemal node.

Image — König HE, Liebich H-G. Veterinary Anatomy of Domestic Animals: Textbook and Colour Atlas, 7th ed. Thieme — Fig. 1.52, lymph node of a sheep in longitudinal section. Reproduced for educational reference.

One species difference is worth adding to the number rule, because it reverses the direction a student has just learned. In most of the domestic mammals lymph enters a node through afferent vessels at its surface and leaves through efferent vessels at the hilus, as Figure 8 shows. **In the pig it is the other way round**: the vasa afferentia reach the node at the hilus and the vasa efferentia leave from the cortex. The pig is the exception twice over — many small nodes instead of one or two, and the flow through each of them inverted.

One structure is left, and it is the one most likely to be misidentified. **Haemal nodes** (haemolymph nodes) are small, dark red or bluish nodules found particularly in ruminants, along the aorta and the caudal vena cava among other places. They look like small lymph nodes that have bled.

	LYMPH NODE	HAEMAL NODE
The one reliable difference	Has **vasa afferentia and vasa efferentia** connecting it to the lymph vessel system	**Has neither.** It sits on a blood vessel and is not part of the lymph route at all
Colour	Pale, grey or fawn	Bluish-red, shining red, dark red, pink or brownish

	LYMPH NODE	HAEMAL NODE
Where	Every species, in named groups along the great vessels	Ruminants especially — along the aorta and caudal vena cava, and in several other regions
Size and number	Number and size vary inversely within a region; no absolute norm	1 to 20 mm; rarely over 5 mm in small ruminants or 10 mm in cattle. The sheep is said to have between 30 and 300
The trap	—	A lymph node that has taken up red cells after bleeding in its drainage area turns reddish for a time. It is still a lymph node, and its afferent and efferent vessels prove it

The distinction is not a matter of judgement. A true lymph node has afferent and efferent lymph vessels connecting it to the lymph vessel system; **a haemal node has neither**. That is the reliable criterion, and it also settles the trap: a lymph node that has taken up red cells after haemorrhage in its drainage area turns reddish for a time and looks the part, but its afferent and efferent vessels are still there.

12 Test yourself

Twenty-two 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 does angiology cover, and what does it deliberately leave to physiology?**

ANSWER It covers the organs of circulation of blood and lymph — the heart, the blood vessels and the lymphatic vessels and organs — as **structure**. How that structure works (the cardiac cycle, the action potential, blood-pressure regulation) is physiology and is taught separately.

2 **Name the three coats of a vessel wall from the lumen outwards, and say what each is made of.**

ANSWER **Tunica intima** — endothelium, a thin subendothelial layer and an internal elastic lamina. **Tunica media** — elastic sheets, smooth muscle or a mixture. **Tunica externa** — collagen and elastic fibres crossed in a helix, with an external elastic lamina.

3 **Which vessels does the three-coat plan NOT describe, and why not?**

ANSWER The vessels of the **terminal circulation** — arterioles, capillaries and venules. Exchange needs the shortest possible distance between blood and tissue, so where it happens the wall is stripped back to an endothelial tube, a basal membrane and pericytes.

4 **What separates an elastic artery from a muscular artery, and where is each found?**

ANSWER The composition of the **media**. Elastic arteries — the aorta, its branches near the heart, the pulmonary trunk and its large branches — have concentric elastic membranes and are yellow and highly distensible. Muscular arteries, everything further out, have a media of smooth muscle in spiral layers and are reddish or white and thick-walled.

5 **Explain the expansion-chamber idea in one sentence.**

ANSWER Blood driven into the aorta stretches its elastic media, which stores part of the energy of the stroke and returns it by recoiling during the pause, so the heart's rhythmic output reaches the periphery as a much more even stream.

6 **Can an artery close its lumen completely? Which vessel can, and why?**

ANSWER An **ordinary** artery cannot — it can narrow considerably but not occlude. The **arteriole** can, because its media is reduced to a single layer of muscle cells and its internal elastic lamina has broken up into a network. There is also a named exception among the arteries themselves: **throttle arteries** carry intimal cushions that bulge into the lumen and close it, in skin, lung and erectile tissue.

7 **Give the diameter and length of a capillary, and name two tissues that have none.**

ANSWER **6–30 µm** in diameter (rarely up to 40 in giant capillaries) and **0.5–1.0 mm** long. The **cornea** and **hyaline cartilage** are entirely devoid of capillaries.

8 **What are the vasa vasorum, and what is the one thing students get wrong about them?**

ANSWER They are the small vessels supplying the wall of a large vessel — the vessels of the vessels. The point most often missed is that they do **not** arise from the lumen of the segment they supply: they arrive from outside, as recurrent branches of neighbouring arterial plexuses.

9 **Define an end artery, and say why the term needs care.**

ANSWER An artery that is the only supply to its territory, with no useful anastomosis to its neighbours, so occluding it infarcts the region. It needs care because it is a spectrum rather than a switch: most territories have some collateral, and the real question is how much collateral there is and how quickly it would have to open.

10 **What is an arteriovenous anastomosis, and what is the main job of the bridge type?**

ANSWER A direct connection from arteriole to venule that by-passes the capillary bed. The **bridge** type shifts blood from the arterial to the venous side and relieves the capillary bed behind it; in the skin of the extremities, pinna, nose and comb this makes it a principal route of **temperature regulation**.

11 **Name the three layers of the heart wall, and say what the epicardium actually is.**

ANSWER Epicardium, myocardium and endocardium. The epicardium **is** the visceral layer (*lamina visceralis*) of the serous pericardium, which is why the heart's outer surface is a smooth, glistening serosa.

12 **Why is the right ventricular wall thinner than the left, and what are its two functional parts?**

ANSWER Its work load is lower — it sends blood a short distance at low pressure to the lung — so its wall is about **half as thick**. Its cavity has an **inflow route** running towards the apex and an **expulsion route** leading from the apex into the conus arteriosus; trabeculae carneae are well developed in the first and absent from the second.

13 **What holds an atrioventricular cusp from inverting, and why do the semilunar valves not need the same arrangement?**

ANSWER **Chordae tendineae** running from the cusp margins to the **papillary muscles** of the ventricular wall. The semilunar cusps of the aortic and pulmonary valves close against one another and are not tethered.

14 **Between which ribs does the heart lie in the dog, the ox and the horse?**

ANSWER Dog, the **3rd (4th) to the 6th (7th)**; ox, the **3rd to the 5th (6th)**; horse, the **3rd (2nd) to the 6th**. In all of them more of the heart lies left of the median plane than right — 4/7 in the dog, 5/7 in the ox, 3/5 in the horse.

15 **Why can the heart of a domestic mammal not be examined from the front of the chest the way a human's can?**

ANSWER Because the cranial part of the thorax, which holds the heart, is covered by the shoulder-girdle musculature and by the mass of the triceps, whose caudal border reaches the 4th or 5th intercostal space. The left thoracic wall is the practical approach.

16 **What defines a portal vein, and what is the consequence for anything absorbed from the gut?**

ANSWER A vein that runs **between two capillary beds** rather than from a capillary bed back to the heart. Blood from the stomach, intestine, pancreas and spleen therefore passes through the capillary bed of the liver before it reaches the heart at all.

17 **Trace lymph from a drainage area to the bloodstream, naming the vessels and the two kinds of lymph.**

ANSWER Lymph capillaries in the **drainage area** collect **primary lymph**, which reaches a regional node through the **vasa afferentia**. Two to four **vasa efferentia** carry away **secondary lymph**, filtered and enriched with lymphocytes, to further nodes and then to a collecting duct, which empties into a vein.

18 **Why do veterinary anatomists name lymphocentres rather than individual nodes, and how do you tell a haemal node from a lymph node?**

ANSWER Because node **location** is remarkably constant between species while node **number** is not — one or two at a site in the dog and ruminants, a group of many small ones in the pig and horse — so the lymphocentre is the unit that transfers. A haemal node is told apart by one reliable feature: a true lymph node has **afferent and efferent lymph vessels** connecting it to the lymph vessel system, and a haemal node has neither.

19 **What is a throttle artery, and why does it matter to the rule about arteries and occlusion?**

> ANSWER An artery carrying **cushions of longitudinal muscle or epithelioid cells** in its wall which, on contracting, bulge the intima into the lumen and close it completely. They occur in skin, lung and erectile tissue. They matter because they are the named exception to "an artery cannot occlude" — König calls the same idea a **barrier artery**.

20 **Name the parts of the excitation and conducting system, and give two things about it that are gross anatomy rather than histology.**

> ANSWER Sinuatrial node → atrioventricular node → atrioventricular bundle (a right and a left crus) → Purkinje fibres, all of it **modified cardiac muscle, not nerve**. Gross: in larger species the sinuatrial node can be found by dissection because it is **paler** than the surrounding atrial muscle; and the *trabecula septomarginalis* (moderator band) is not just a strut — it **carries part of the conducting system** to the papillary muscles.

21 **Name the lymphatic organs, and trace lymph from the abdomen to the bloodstream.**

> ANSWER The lymph nodes themselves, plus the **tonsils**, the **spleen**, the **thymus** and the aggregated gut follicles (Peyer's patches). From the abdomen lymph collects in the **cisterna chyli**, passes into the **thoracic duct**, which crosses the diaphragm beside the aorta and runs dorsally through the thorax, and enters the blood at the **left venous angle**.

22 **In which species is the direction of flow through a lymph node reversed, and how?**

> ANSWER The **pig**. In the other domestic mammals the vasa afferentia reach the node at its surface and the vasa efferentia leave at the hilus; in the pig the **afferents arrive at the hilus and the efferents leave from the cortex**. The pig is the exception twice over, because it also has many small nodes at a site where the dog and ruminants have one or two.

13 Veterinary Angiology — frequently asked questions

What is angiology in veterinary anatomy?

It is the branch of systematic anatomy that deals with the organs of circulation of blood and lymph — the heart, the arteries, capillaries and veins, and the lymphatic vessels and lymphatic organs. The name is from the Greek *angion*, a vessel. It is the structural half of the subject: how the pump and the pipes are built and named. How they work is physiology.

What are the three layers of a blood vessel?

From the lumen outwards: the **tunica intima** (endothelium, a subendothelial layer and an internal elastic lamina), the **tunica media** (elastic sheets, smooth muscle or a mixture) and the **tunica externa** or adventitia (collagen and elastic fibres, plus an external elastic lamina). The one qualification that matters: this describes the vessels *excluding* those of the terminal circulation, where the wall is reduced to an endothelial tube, a basal membrane and pericytes.

What is the difference between an elastic artery and a muscular artery?

What the media is made of. An **elastic artery** — the aorta, its large branches near the heart, the pulmonary trunk — has a media of concentric elastic membranes; it is yellow, highly distensible, and works as an expansion chamber that smooths the heart's rhythmic output into a steady stream. A **muscular artery**, which is most of what you dissect further out, has a media largely of smooth muscle in spiral layers; it distributes blood and adjusts its own calibre. The change from one to the other is a **gradual merging**, not a boundary. Neither type can close its lumen completely, though a **throttle artery** — an artery carrying intimal cushions — can.

What is a lymphocentre?

A lymphocentre is the functionally analogous **group** of lymph nodes at one site, named for its location and its drainage area rather than for the nodes themselves. Veterinary anatomy uses the term because node location is remarkably constant across the domestic species while node number is not: the dog and the ruminants usually have one or two nodes at a site where the pig and the horse have a group of many small ones. Learning the lymphocentre and its drainage area is knowledge that survives a change of species.

What is a haemal node, and how do you tell it from a lymph node?

A haemal (haemolymph) node is a small, dark red or bluish nodule found particularly in ruminants, along the aorta and caudal vena cava among other sites, measuring 1–20 mm. The reliable distinction is not colour: a true lymph node has **afferent and efferent lymph vessels** linking it into the lymph vessel system, and a haemal node has neither. That also settles the common trap — a lymph node that has taken up red cells after bleeding in its drainage area turns reddish for a time but keeps its lymph vessels.

Is the heart part of angiology or of splanchnology?

Both conventions exist and it is worth knowing which one your course follows. The classical veterinary treatment — the one these notes follow — puts the heart in angiology, because it is the central organ of the circulatory system and is described in the same volume as the vessels. Some syllabi teach it under splanchnology instead, on the grounds that it is a thoracic viscus. Nothing anatomical turns on the choice; only the order of the lectures does.

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