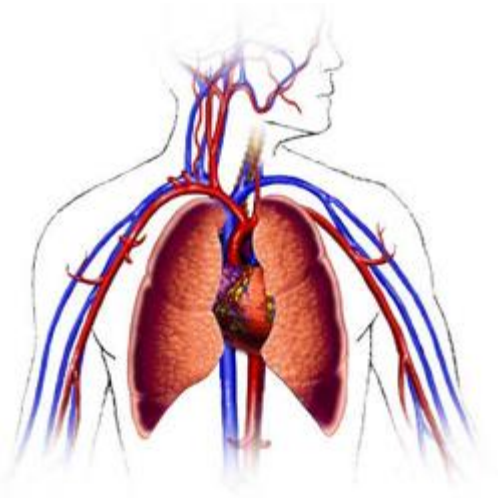
THE BLOOD TRANSPORT SYSTEM IN MAMMALS



"Ah, I see you've taken an interest in our blood plasma TV."

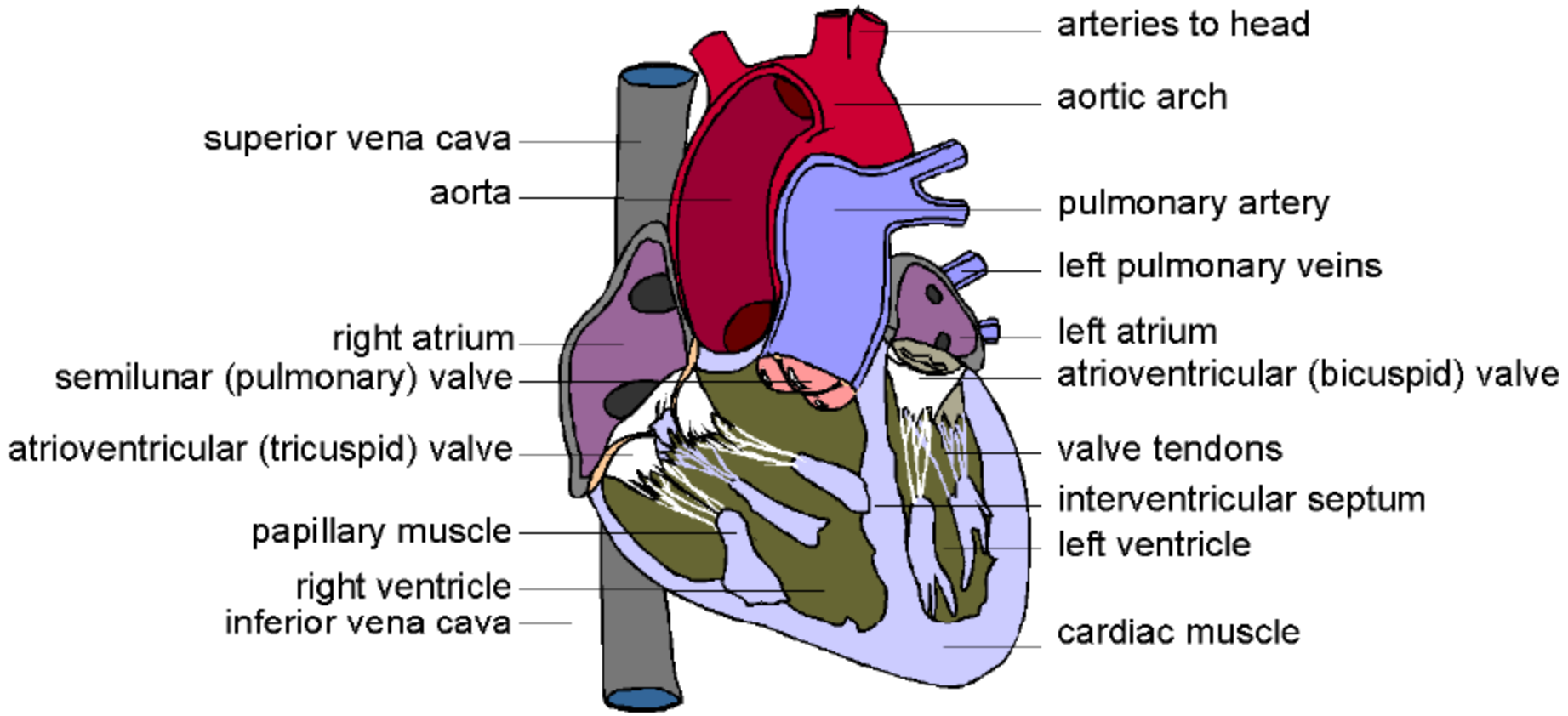
Heart structure revision from GCSE...

...what do you remember?

The human heart has four chambers: two thin-walled atria on top, which receive blood, and two thick-walled ventricles underneath, which pump blood. Veins carry blood into the atria and arteries carry blood away from the ventricles. Between the atria and the ventricles are atrioventricular valves, which prevent back-flow of blood from the ventricles to the atria. The left valve has two flaps and is called the bicuspid (or mitral) valve, while the right valve has 3 flaps and is called the tricuspid valve. The valves are held in place by valve tendons ("heart strings") attached to papillary muscles, which contract at the same time as the ventricles, holding the vales closed. There are also two semi-lunar valves in the arteries (the only examples of valves in arteries) called the pulmonary and aortic valves.

The left and right halves of the heart are separated by the inter-ventricular septum. The walls of the right ventricle are 3 times thinner than on the left and it produces less force and pressure in the blood. This is partly because the blood has less far to go (the lungs are right next to the heart), but also because a lower pressure in the pulmonary circulation means that less fluid passes from the capillaries to the alveoli.

The heart is made of cardiac muscle, composed of cells called myocytes. When myocytes receive an electrical impulse they contract together, causing a heartbeat. Since myocytes are constantly active, they have a great requirement for oxygen, so are fed by numerous capillaries from two coronary arteries. These arise from the aorta as it leaves the heart. Blood returns via the coronary sinus, which drains directly into the right atrium.



The mammalian circulatory system

- Blood passes through the heart twice in each circuit of the body; this is called double circulation
- The RHS of the heart pumps deoxygenated blood to the lungs (pulmonary circulation) and oxygenated blood returns to the LHS of the heart

- Pulmonary circulation is low pressure so blood is pushed slowly to the nearby lungs allowing more time for gas exchange and less chance of too much fluid leaking out OR OF DAMAGING THE DELICATE PULPMONARY CAPILLARIES

- The LHS of the heart pumps the oxygenated blood to the tissues (systemic circulation); deoxygenated blood then returns to the heart
- Systemic circulation is high pressure to ensure blood is pumped to all body organs and so that tissue fluid can form in each organ DELIVERING METABOLITES AND COLLECTING WASTE
- Arteries branch off the systemic circulation to supply each organ with oxygen and a vein brings blood back to the heart from the organs

Remember!

The heart muscle also needs its own supply of blood to provide it with oxygen and nutrients; this is called coronary circulation. The coronary arteries arise from the base of the aorta

The Flow of Blood Through the Body

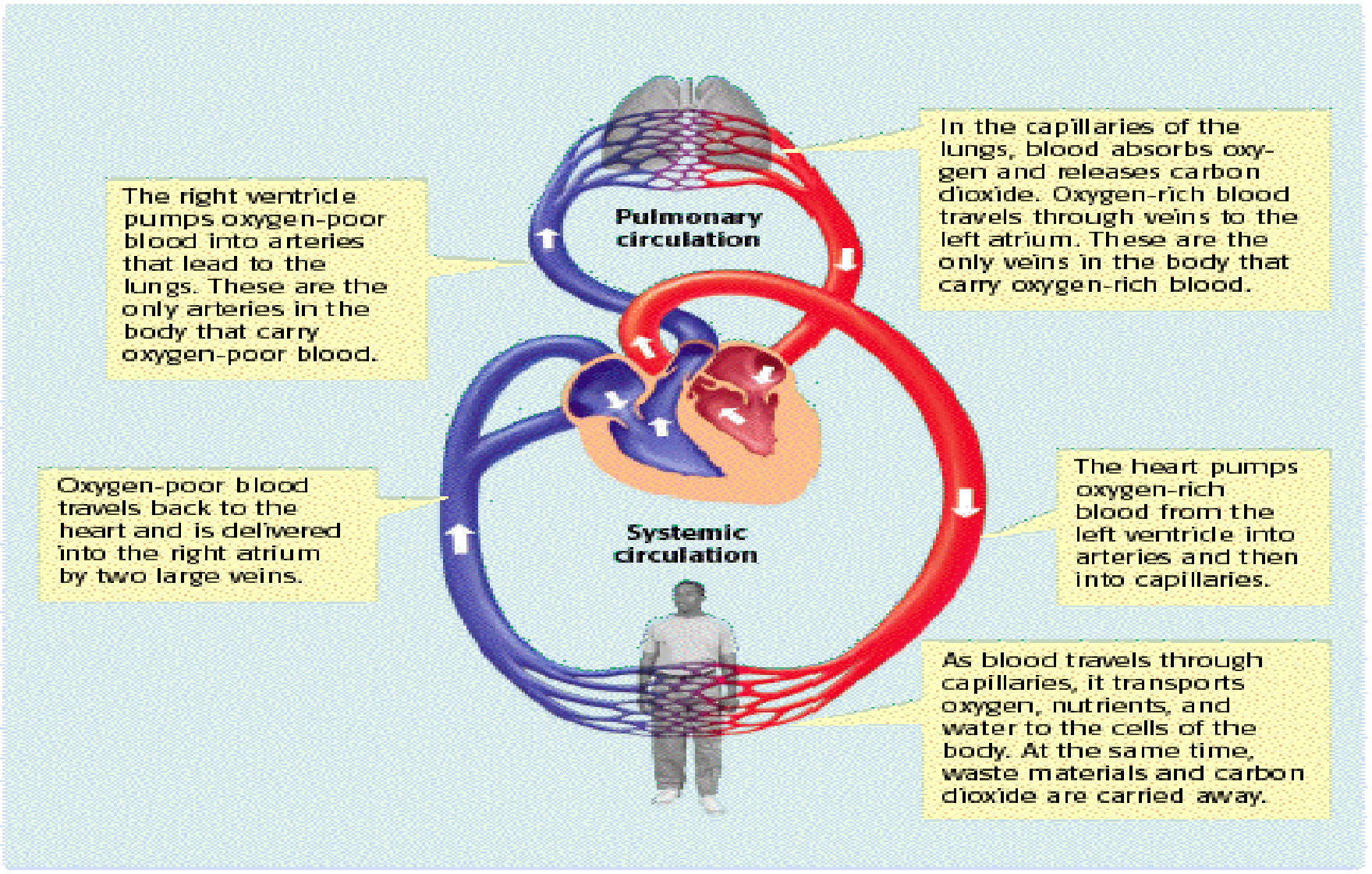
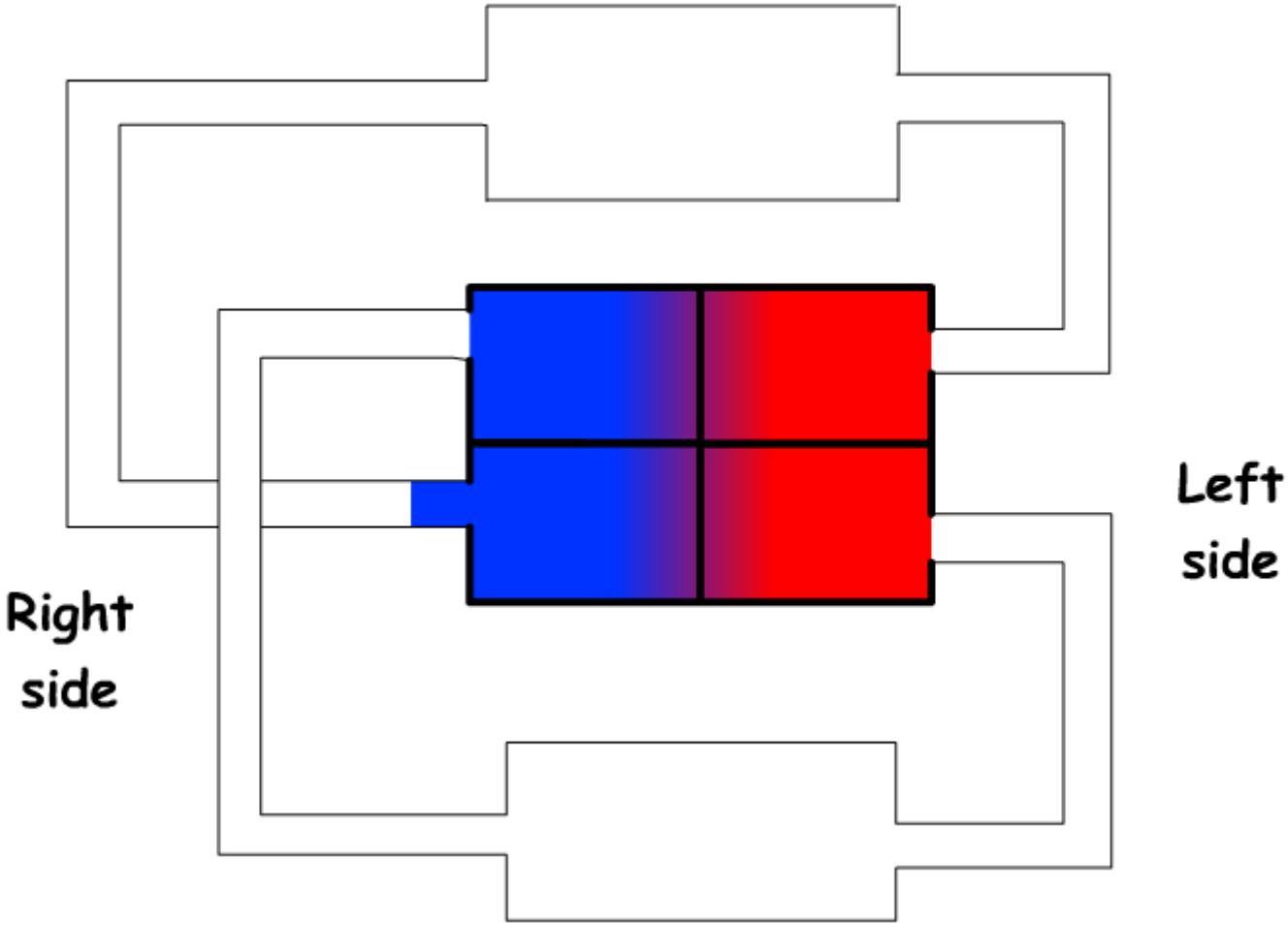
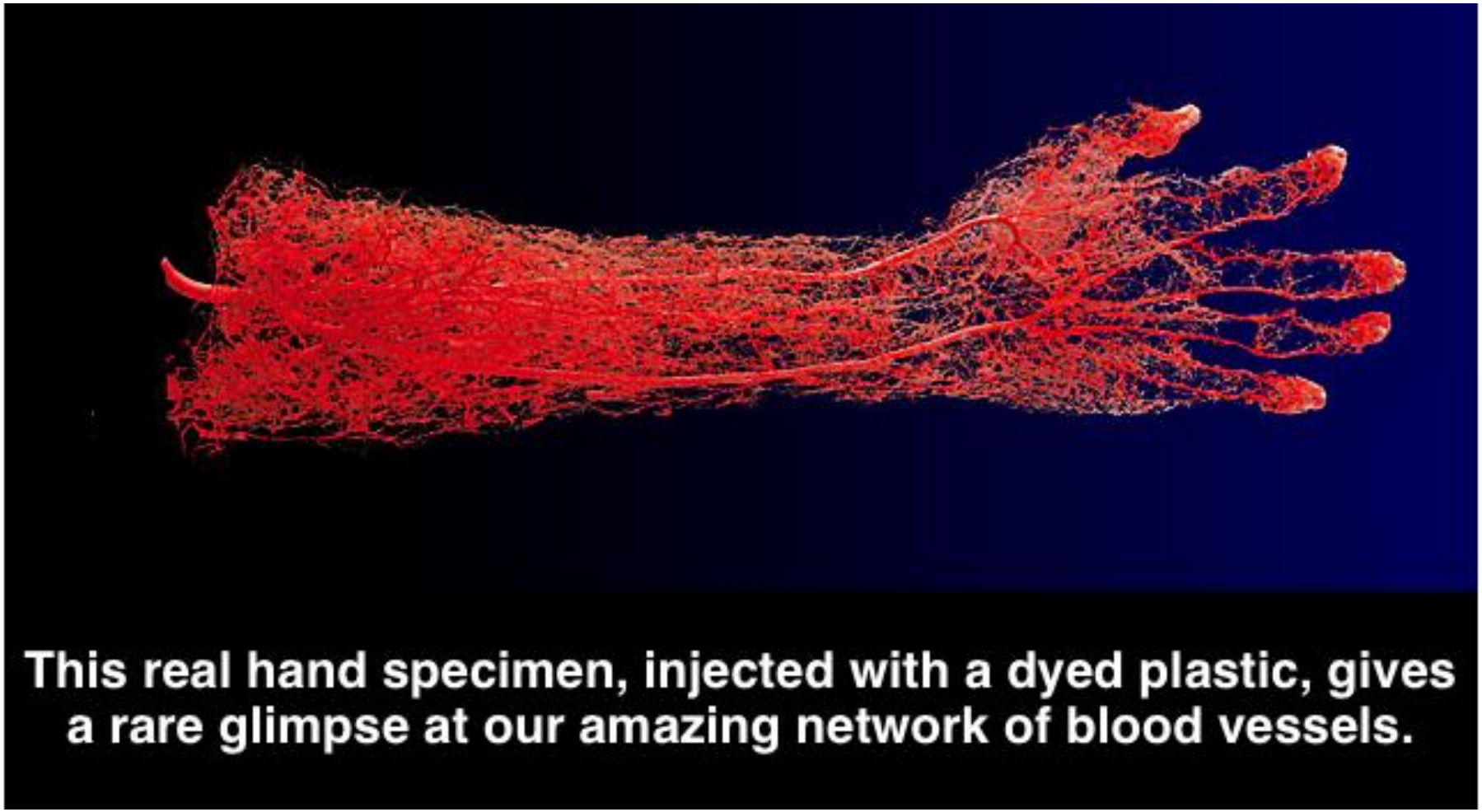


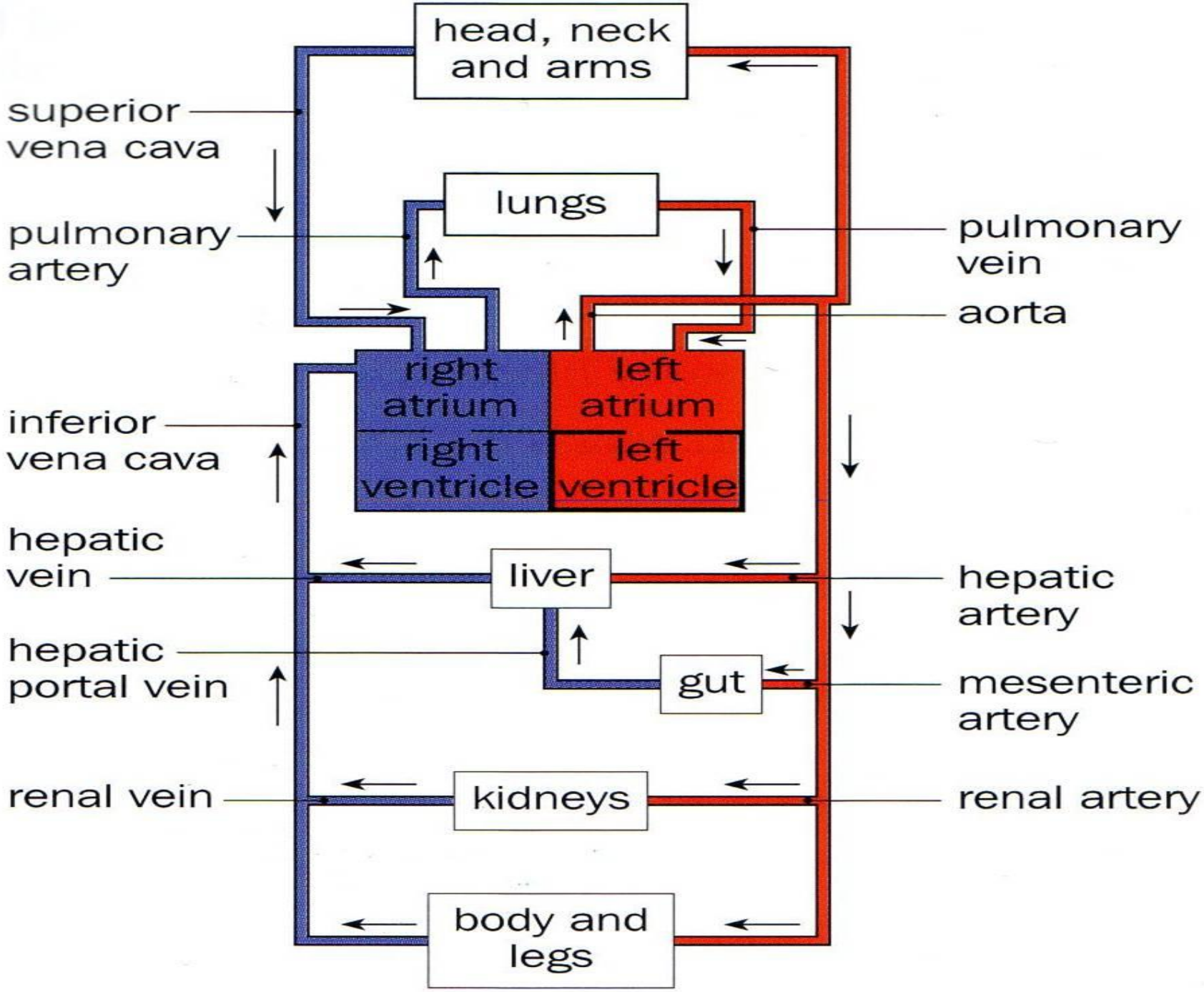
Diagram - Double Circulatory System

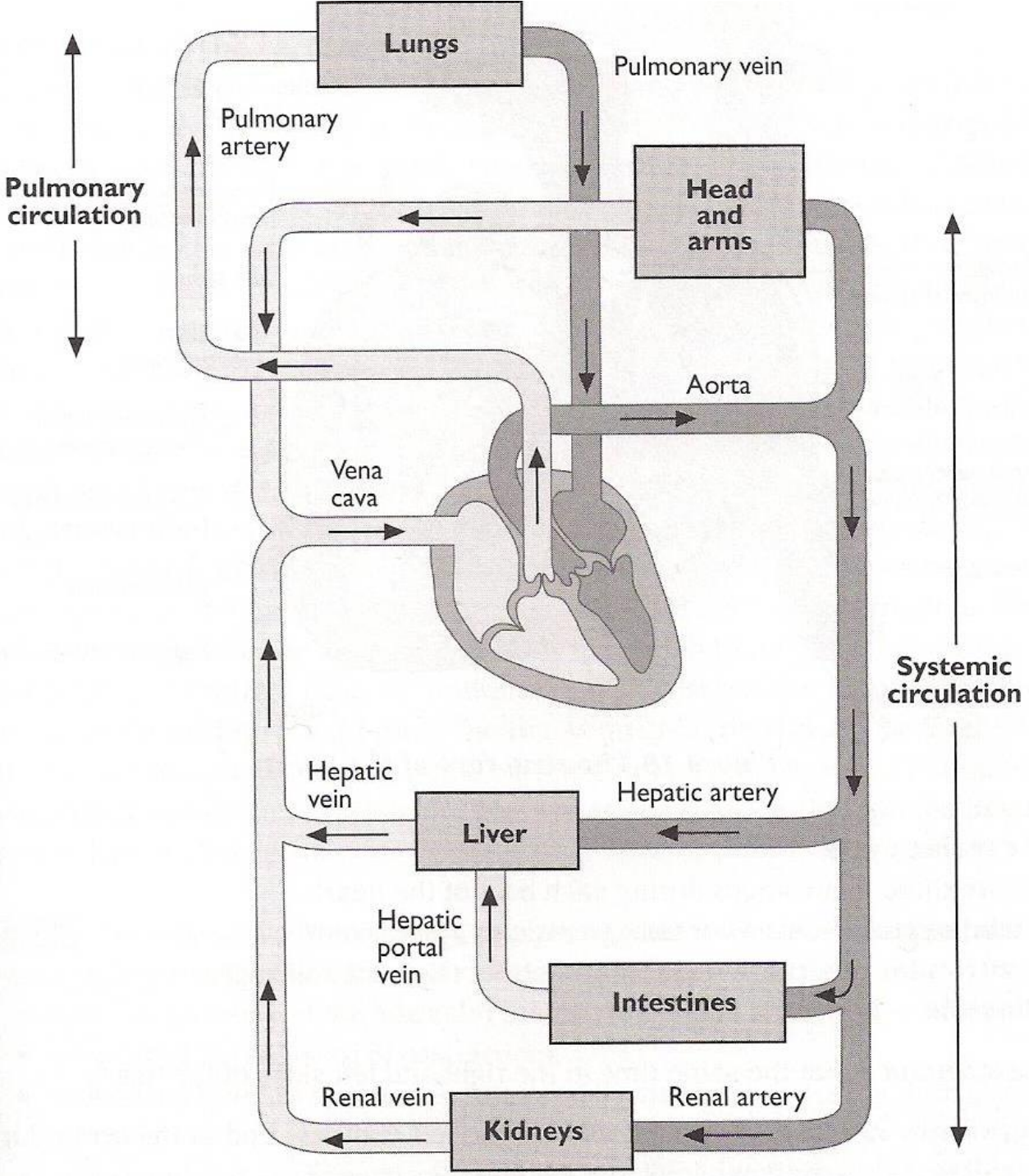


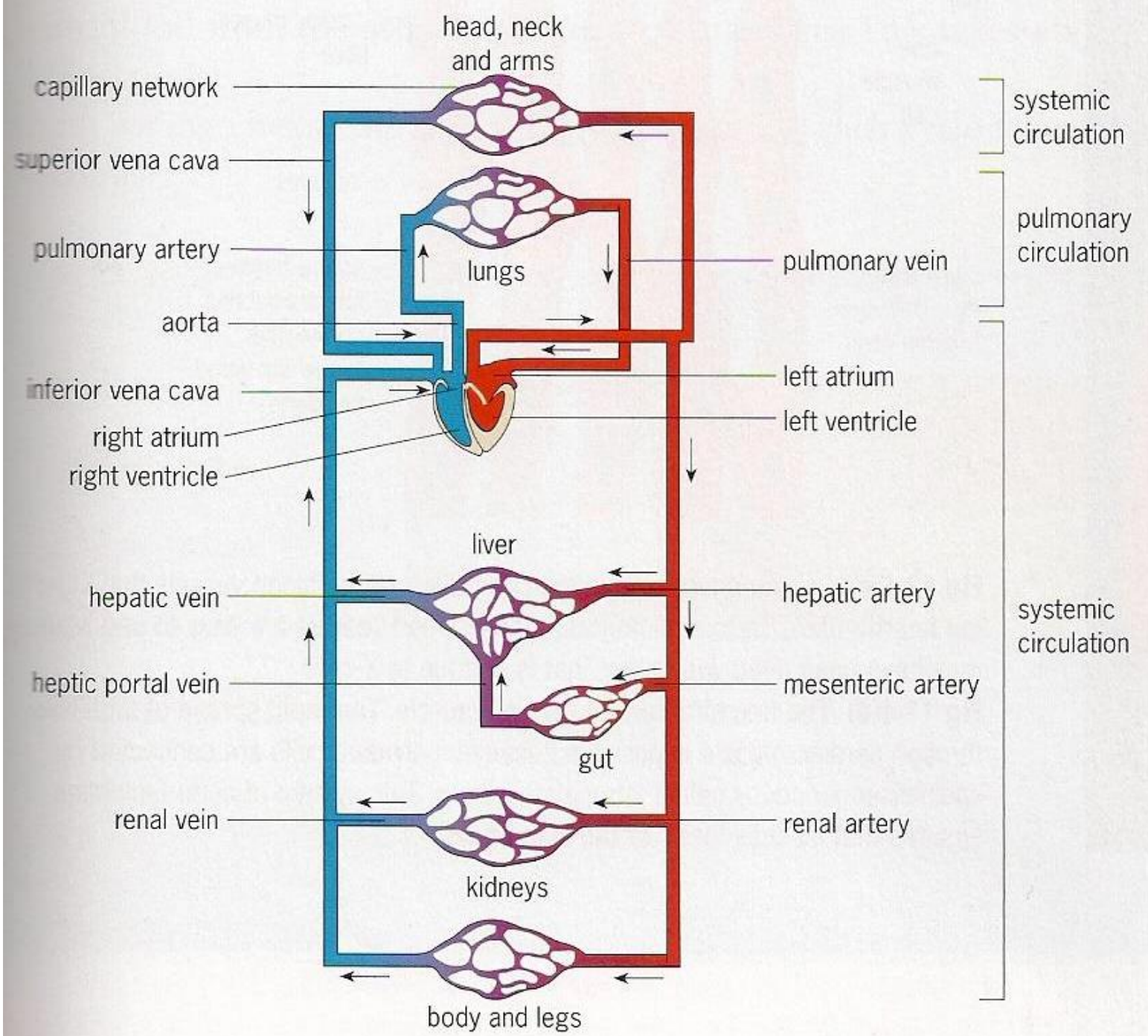


This real hand specimen, injected with a dyed plastic, gives a rare glimpse at our amazing network of blood vessels.

The double circulatory system and the main blood vessels associated with it…


head, neck and arms
superior vena cava
lungs
pulmonary artery
pulmonary vein
aorta
right atrium
left atrium
inferior vena cava
right ventricle
left ventricle
hepatic vein
liver
hepatic artery
hepatic portal vein
gut
mesenteric artery
renal vein
kidneys
renal artery
body and legs


Lungs
Pulmonary vein
Pulmonary artery
Pulmonary circulation
Head and arms
Aorta
Vena cava
Systemic circulation
Hepatic vein
Hepatic artery
Liver
Hepatic portal vein
Intestines
Renal vein
Renal artery
Kidneys


head, neck
and arms
capillary network
superior vena cava
pulmonary artery
aorta
inferior vena cava
right atrium
right ventricle
lungs
pulmonary vein
left atrium
left ventricle
liver
hepatic vein
hepatic artery
heptic portal vein
mesenteric artery
gut
renal vein
renal artery
kidneys
body and legs
systemic
circulation
pulmonary
circulation
systemic
circulation

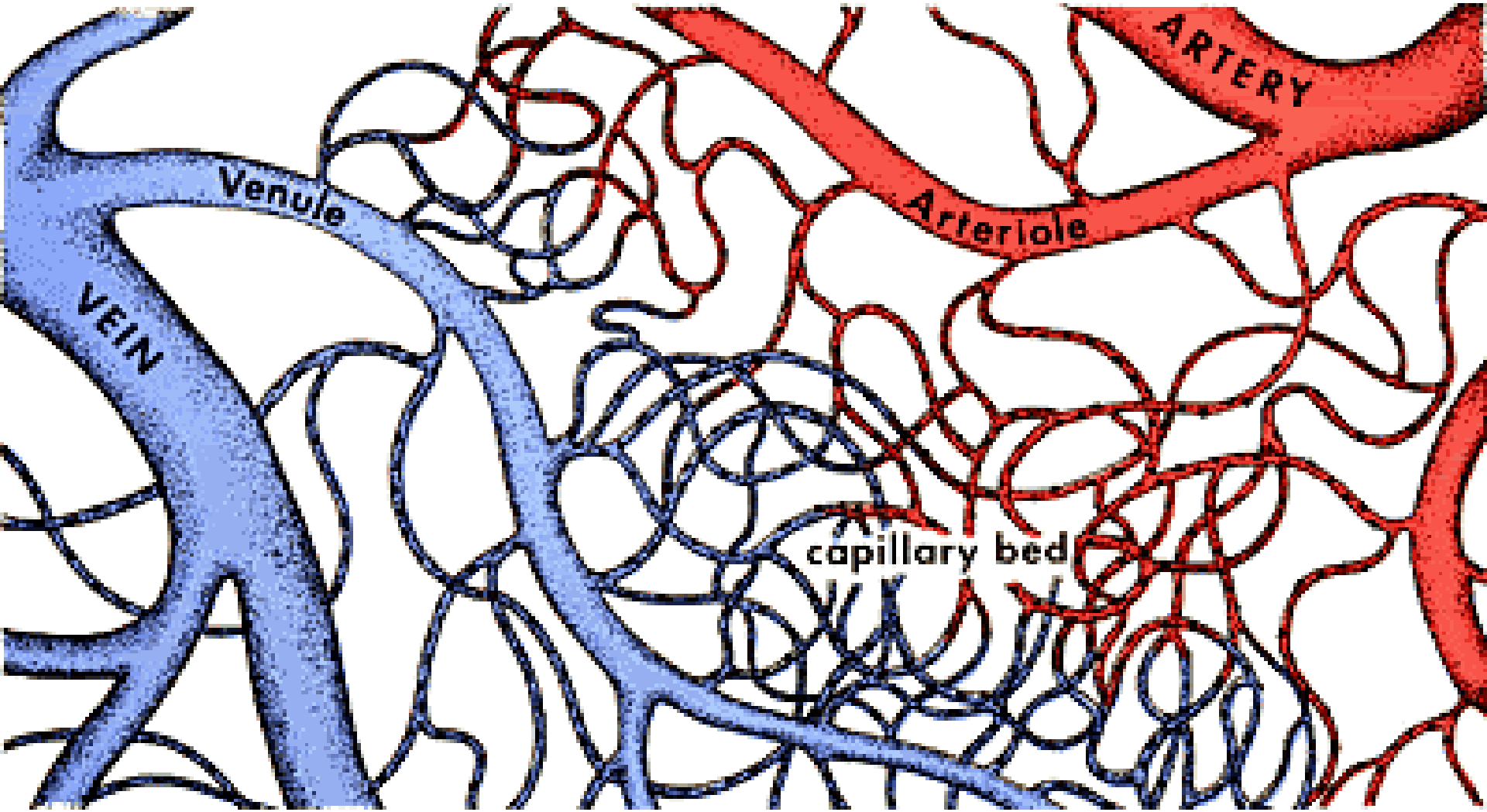
BLOOD VESSELS

Entire human circulatory system from the "bodies revealed exhibition":

Blood vessels

- Three types; arteries, veins and capillaries
- Arteries carry blood away from the heart under high pressure. They branch to form smaller arterioles. Arterioles sub divide into capillaries. Capillaries join up to form venules. Venules join up to form veins

Veins←Venules←Capillaries←Arterioles←Arteries



Capillary bed:

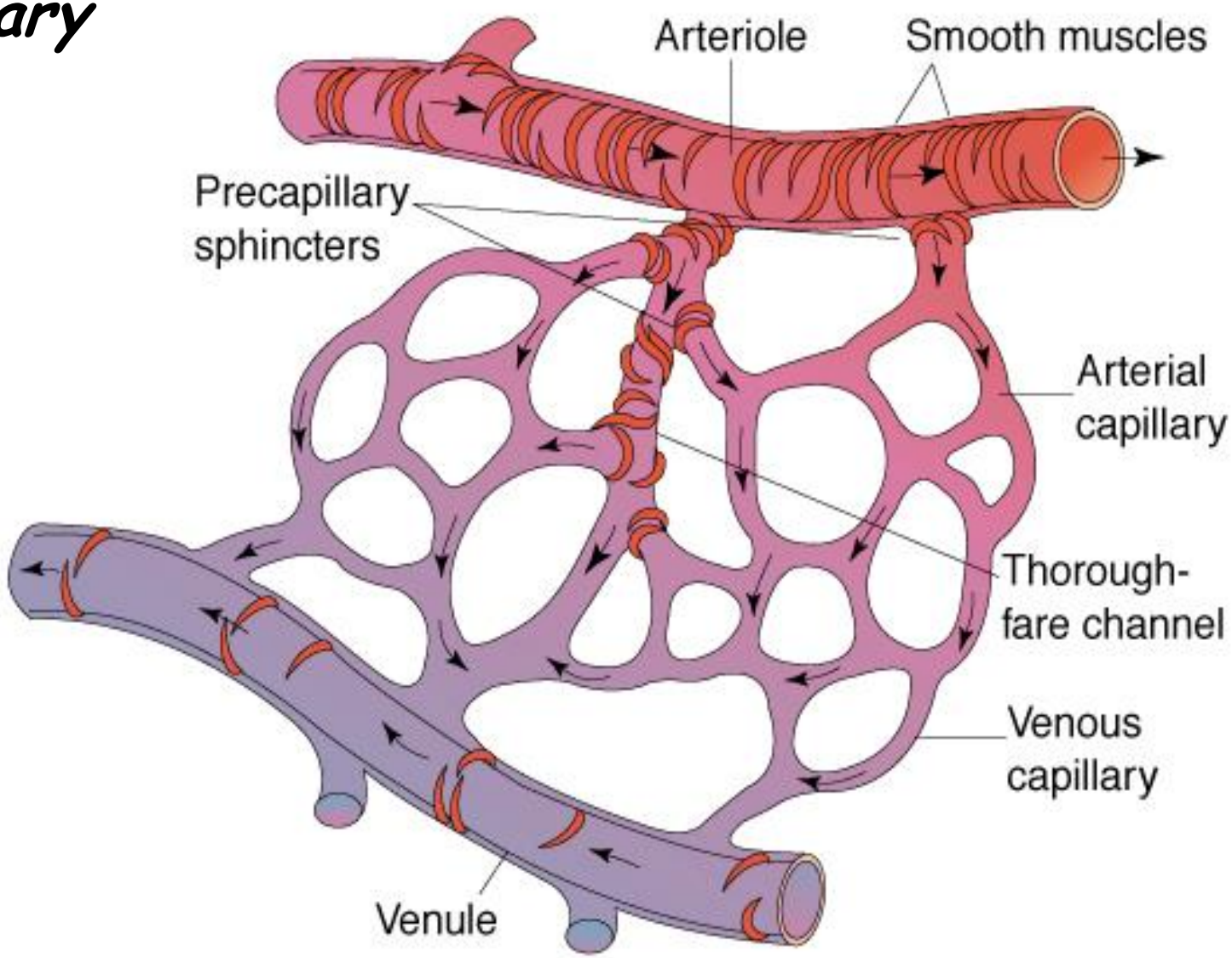
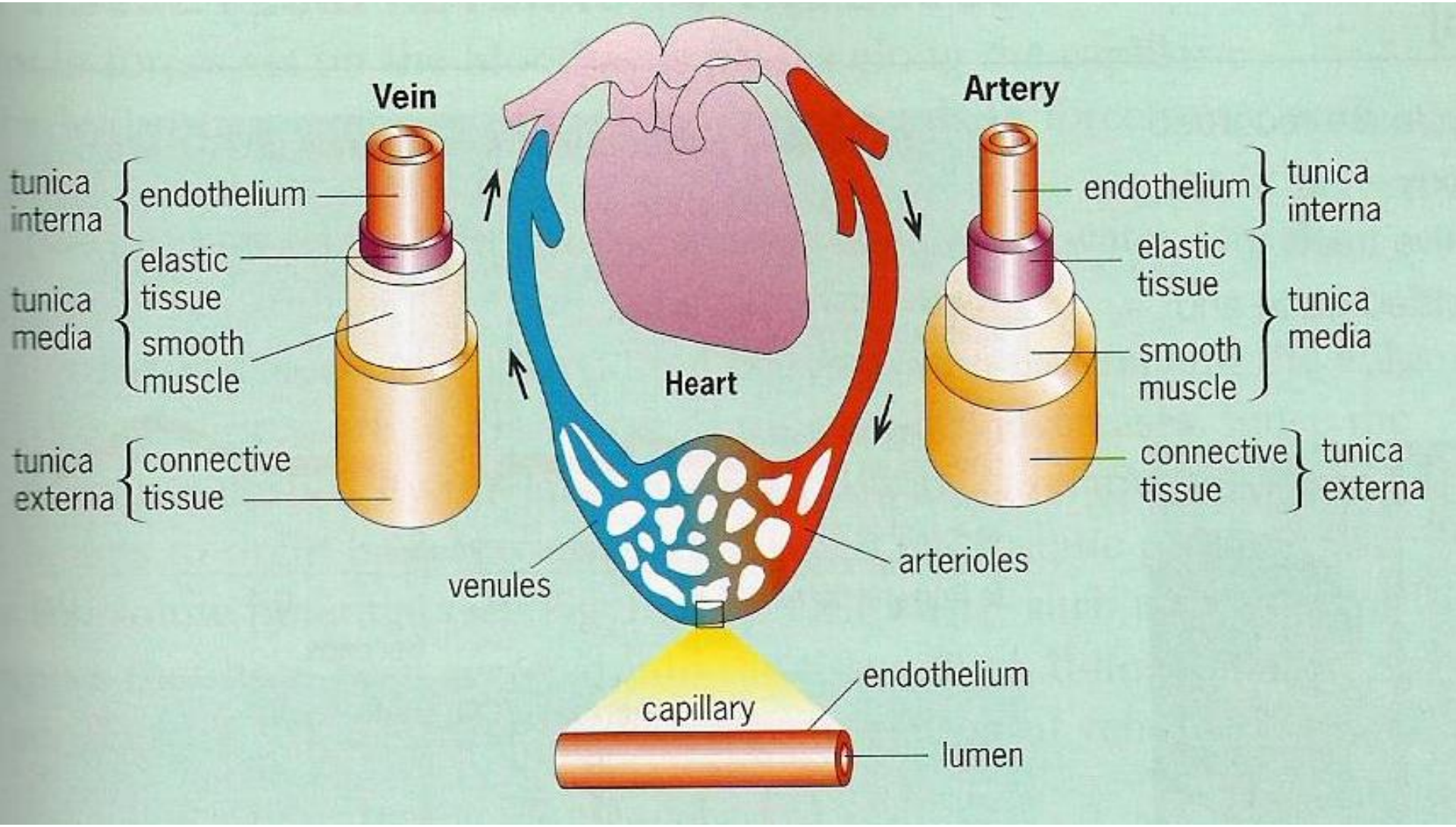


Figure 23-23 Capillary bed. Precapillary sphincters control the flow of blood through the capillary network. Thoroughfare channels (*i.e.*, arteriovenous shunts) allow blood to move directly from the arteriole into the venule without moving through nutrient channels of the capillary.

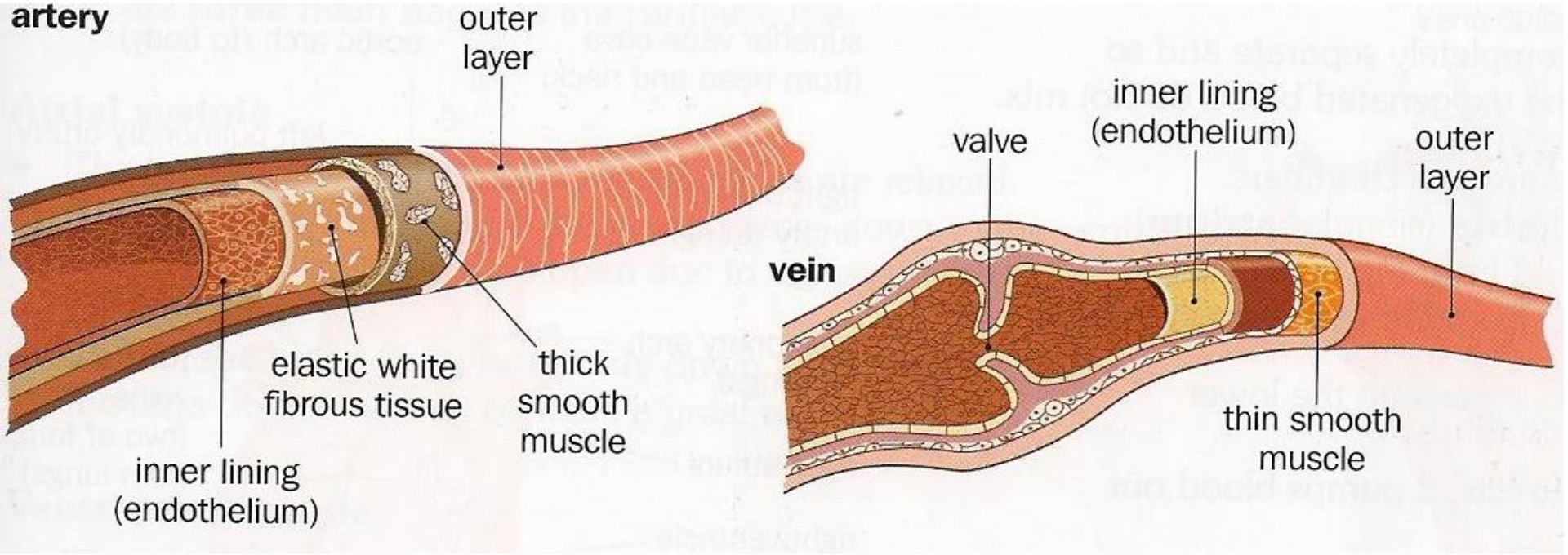
From the lumen out, arteries and veins are made up of 3 layers:

- Outer layer- tough **fibrous layer** (made of collagen and elastic tissue)-protects against the pressure from other organs rubbing against it
- Middle layer has elastic fibres for stretching and recoiling and muscle tissue (more in arteries than veins)
- Inner layer has thin endothelium - smooth to reduce friction

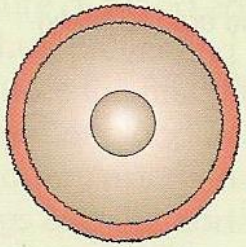
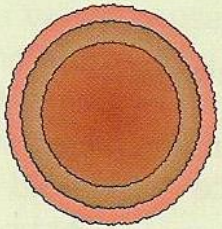
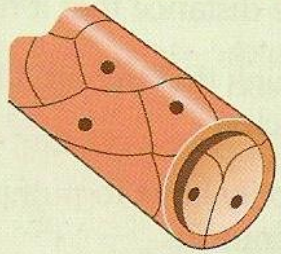
*Remember that **capillaries have only one layer! – just squamous endothelium***

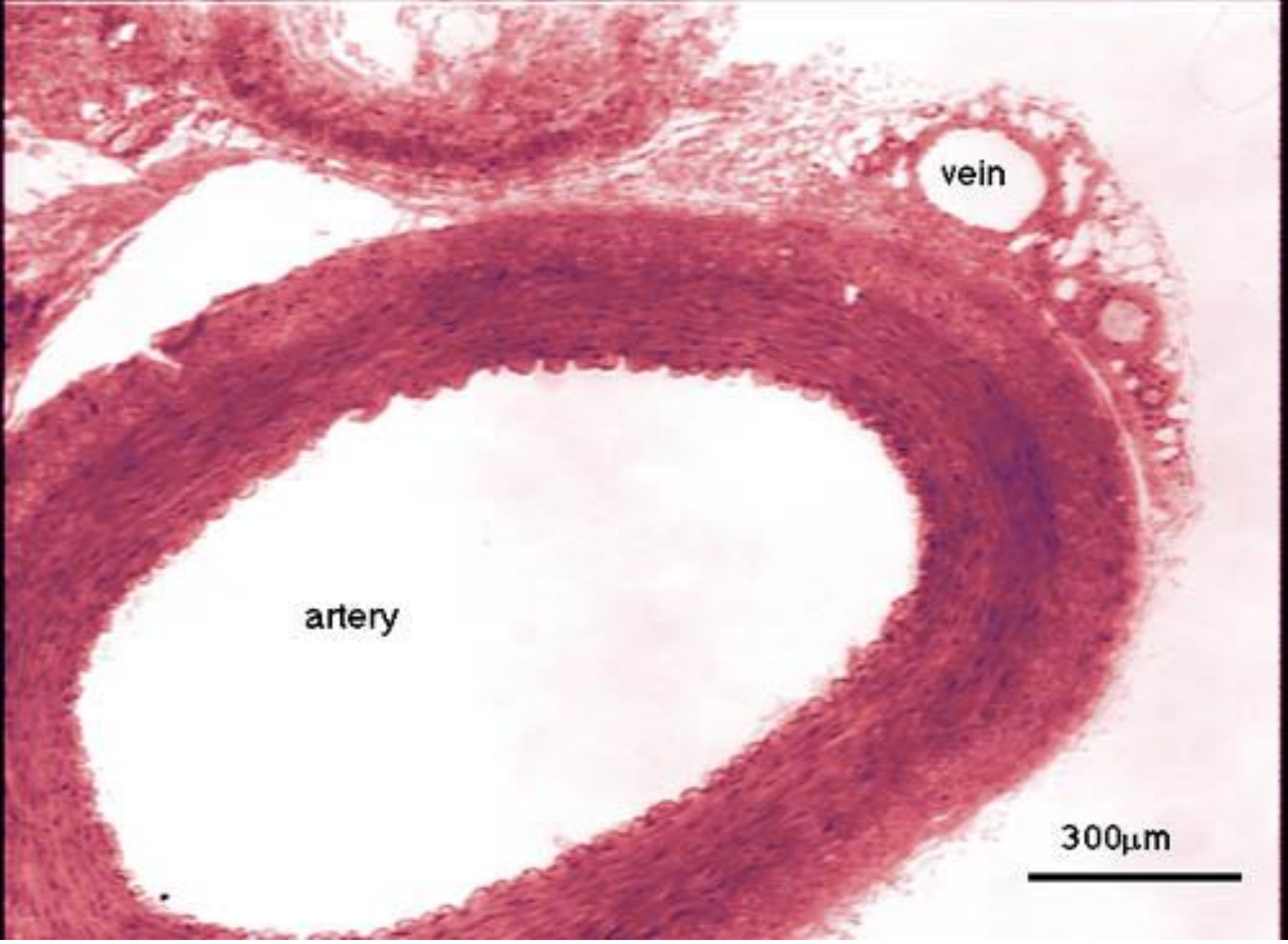

Vein
Artery
Heart
tunica interna
endothelium
tunica media
elastic tissue
smooth muscle
tunica externa
connective tissue
endothelium
tunica interna
elastic tissue
smooth muscle
tunica media
connective tissue
tunica externa
venules
arterioles
capillary
endothelium
lumen

Structure of an artery and vein:



Comparison of blood vessel structure

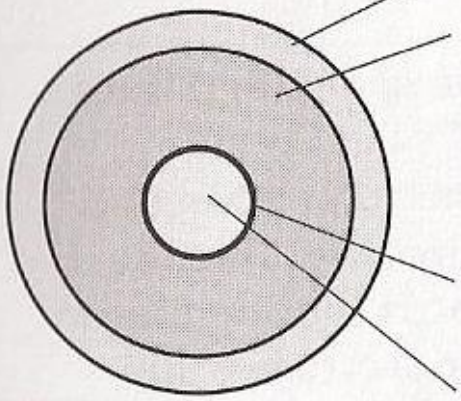
Arteries	Veins	Capillaries
a) 	b) 	c) 
carry blood away from the heart thick muscular walls lots of elastic tissue in wall relatively small lumen blood under high pressure blood flow is rapid blood flows in pulses no valves	carry blood back to the heart thin muscular walls little elastic tissue in wall relatively large lumen blood under low pressure blood flow is slow no pulse valves prevent backflow of blood	link up arteries and veins in the tissues no muscle: wall made up of one cell thick **endothelium** no elastic tissue present small lumen — just large enough for a red blood cell to squeeze through pressure falls as blood passes along capillary blood flow is slowing down no pulse no valves


vein
artery
300µm

Arteries

- They carry blood under high pressure away from the heart, to the organs
- The smaller lumen helps maintain pressure, though can be constricted or dilated depending on smooth muscle
- Therefore arteries contain elastic tissue which allows the vessel to stretch as blood surges through during heart contraction (systole) - this smoothes out the pulse wave
- The elastic fibres also allow the artery to recoil when the heart relaxes (diastole) and thus continue to push blood through the vessel

- The arteries have smooth muscle and can contract (vasoconstriction) to close off the capillary beds to which they lead; or relax (vasodilation) to open up the capillary bed. This controls blood supply to organs and the skeletal muscle
- The large muscle and elastic fibre layers mean they have a thick wall (tunica media)



Outer layer of fibrous tissue — protection

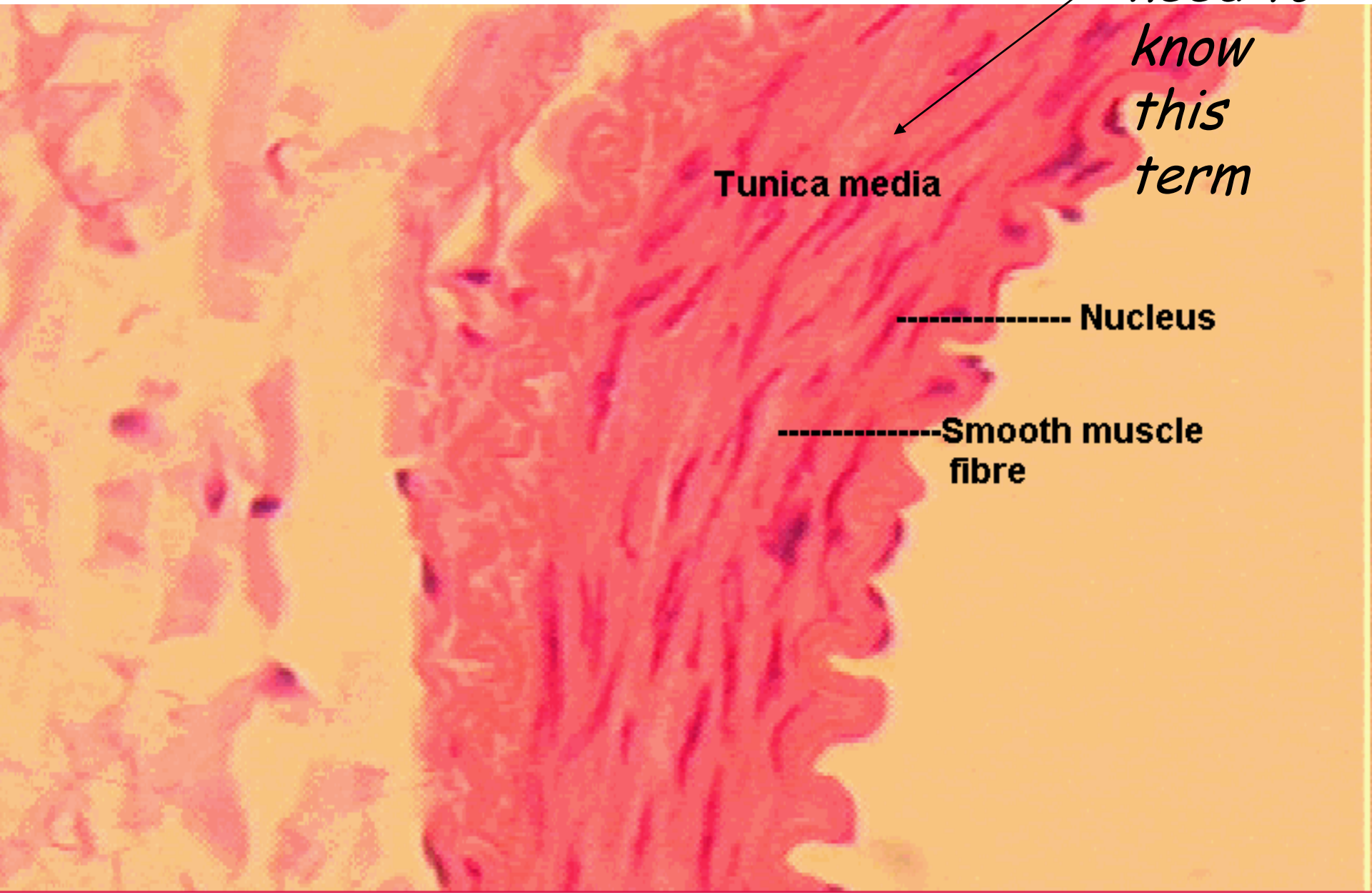
Thick middle layer containing elastic tissue — allows stretching when blood surges (during systole) and recoils to continue pushing blood along (during diastole) — and **muscle tissue** — may contract to narrow the lumen (vasoconstriction) so reducing blood supply to an organ, or relax to increase supply (vasodilation)

Endothelium — provides a smooth inner surface which reduces the friction caused by blood flow through the lumen

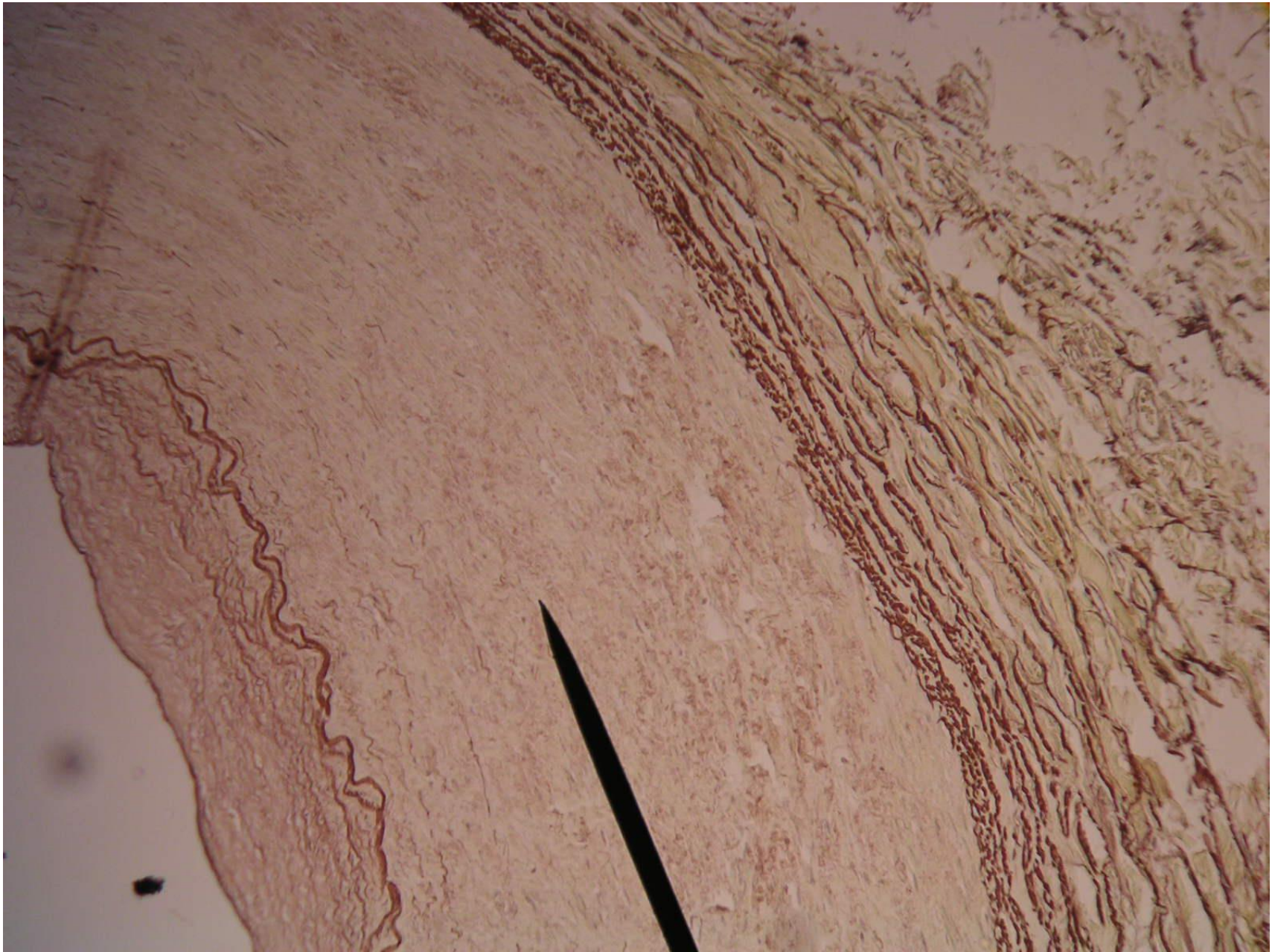
Lumen — small, maintaining a high blood pressure, and may be constricted or dilated

Figure 21 The wall of an artery

Smooth muscle in arteries



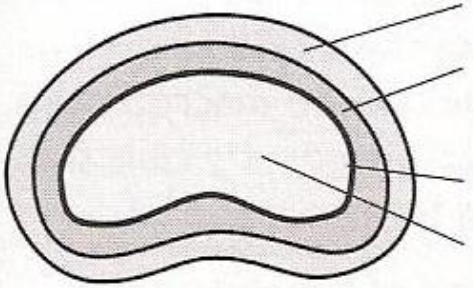
Elastic tissue in arteries



Veins

- Carry blood back to the heart under low pressure (non-pulsatile)
- Contains fibrous tissue for protection (though less than arteries)
- Little elastic tissue as blood is under low pressure, so wall is thin compared to arteries
- Also contain less smooth muscle than arteries
- Have a large lumen to facilitate blood entering from the capillaries, and also lessen the resistance to blood flowing back to the heart WHICH ENSURES THE BLOOD FLOW VELOCITY CAN BE HIGH DESPITE THERE BEING LOW PRESSURE

- They have semilunar valves to prevent backflow of blood, and the surrounding muscle pump system (as skeletal muscle contracts) aids blood flow (especially in the legs)



Outer layer of fibrous tissue — protection

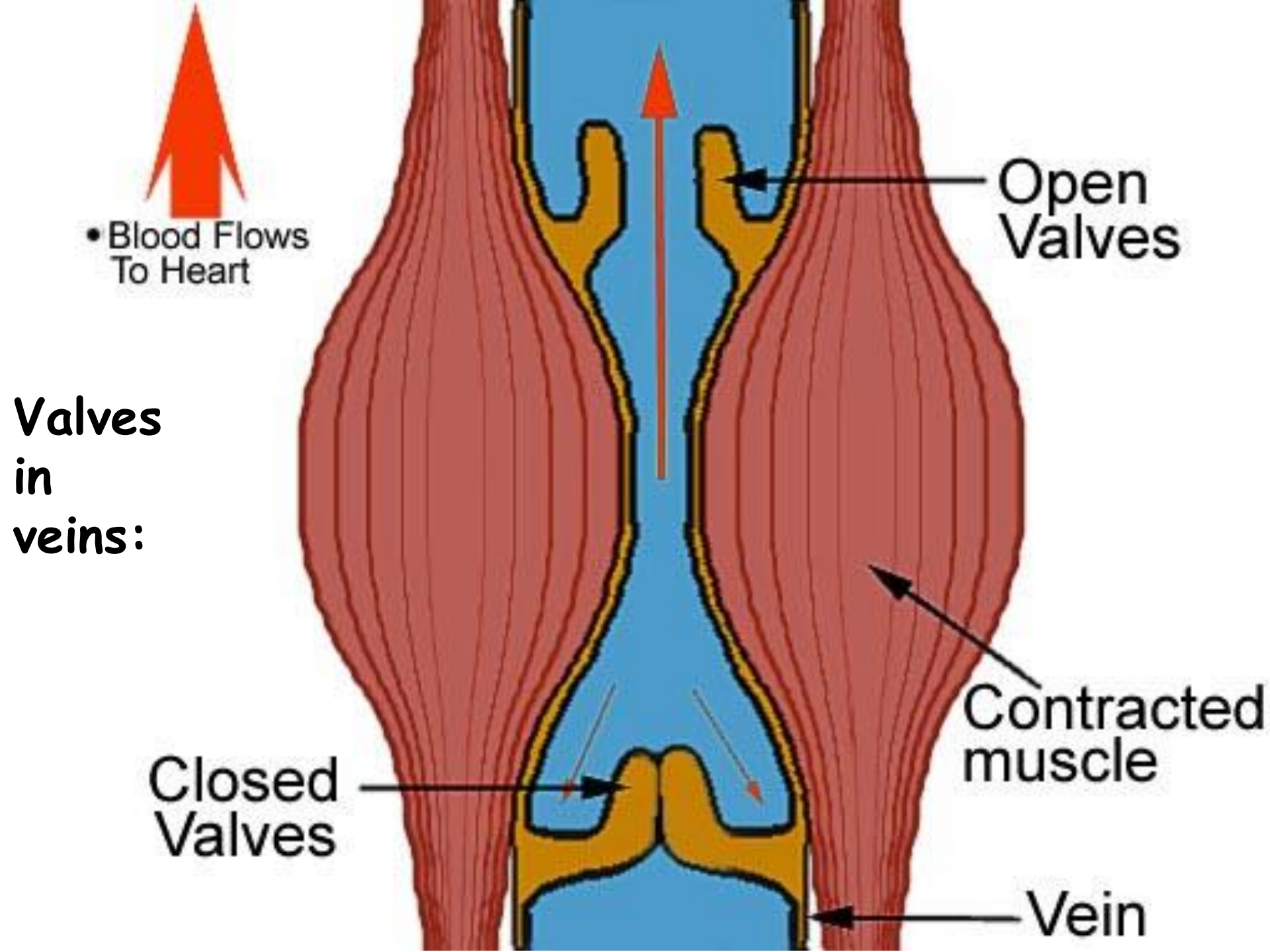
Thin middle layer containing some smooth muscle and few elastic fibres — small layer since blood is under low pressure

Endothelium — provides a smooth inner surface

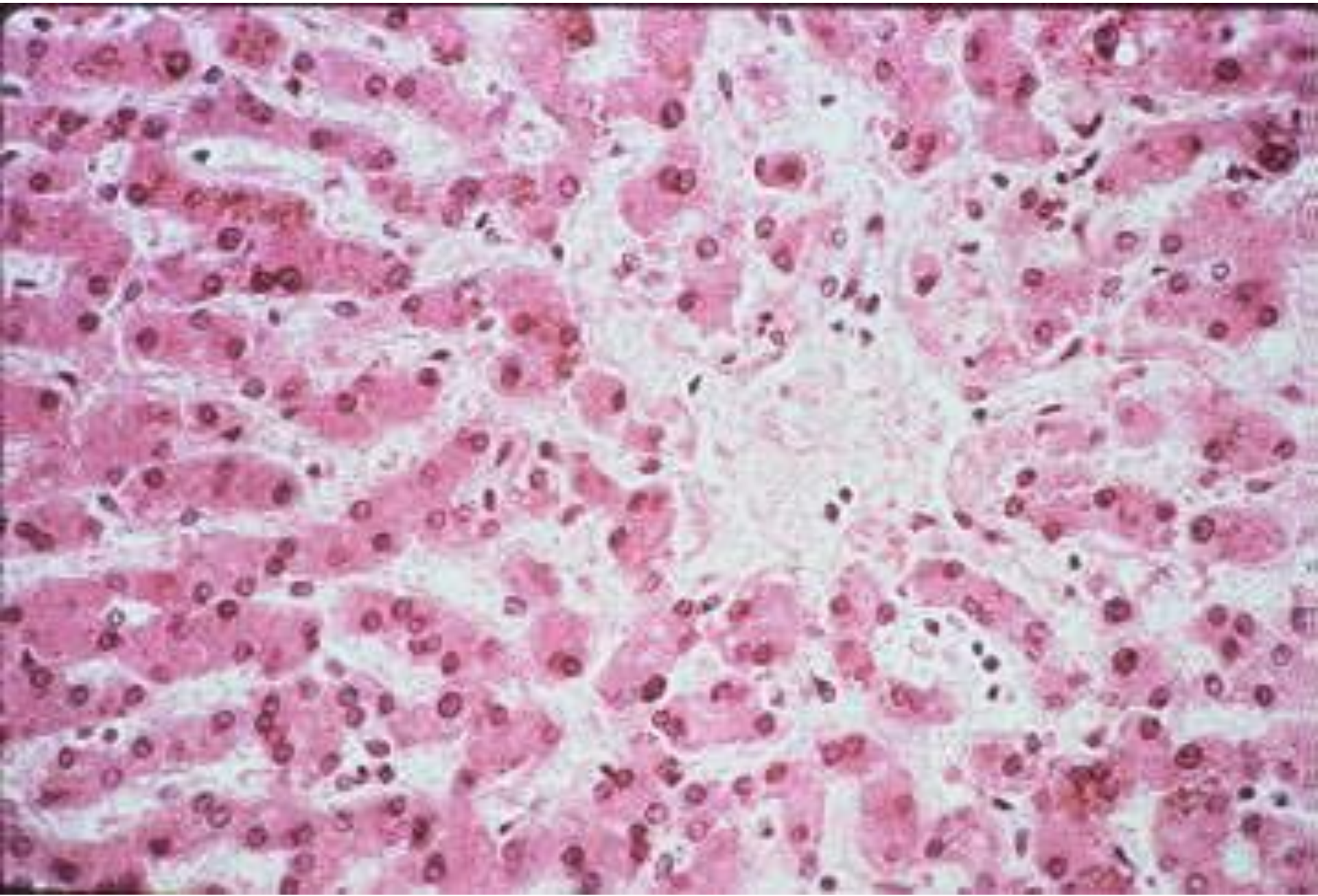
Lumen — large space making it easier for blood to enter from the capillaries while friction is reduced as blood flows back to the heart

Figure 23 The wall of a vein

Valves in veins:



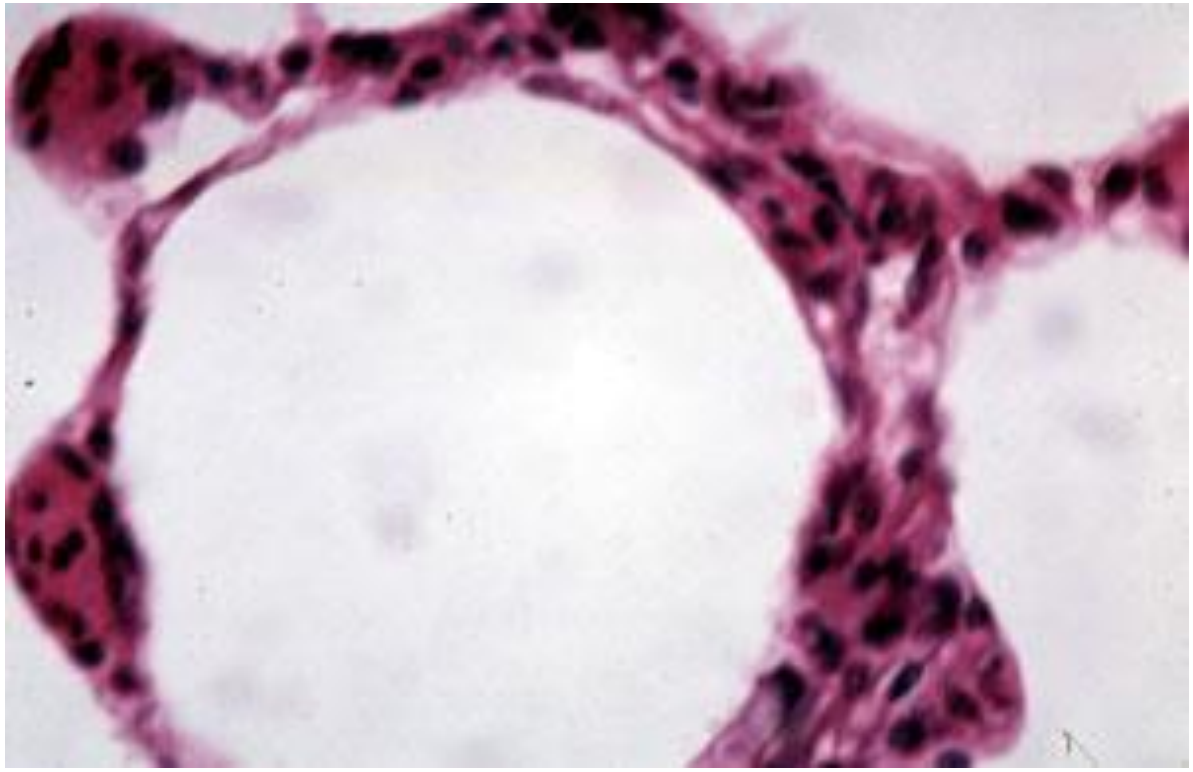
Outer layer of fibrous tissue in veins:



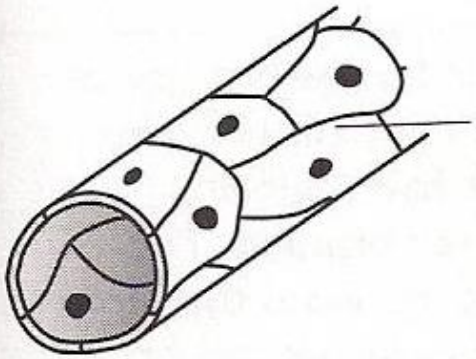
Capillaries:

- Wall made of squamous (pavement) endothelium - a thin wall, only 1 cell thick permeable to water, solutes and dissolved gases
- This reduces diffusion distance to supply oxygen, glucose and metabolites to the tissues
- The total of the capillaries represents a huge surface area AND THIS REDUCES THE PRESSURE AND VELOCITY OF THE BLOOD SIGNIFICANTLY
- The very small lumen aids diffusion by slowing the blood flow and distorting the RBCs to increase their surface area and improve contact with tissue cells

Squamous endothelium in capillaries lining alveoli:



- Contains no elastic or muscle tissue
- Tissue fluid forms at arterial end and is reabsorbed at the venule end of the capillary network surrounding a tissue or organ



Squamous (pavement) endothelium — thin wall, permeable to water and solutes, so providing a short diffusion distance and facilitating the exchange of substances between the blood and tissue cells

Figure 22 A capillary

Decrease at venule end

✓ ✗

High

Blood to tissue

Close to cells rapid exchange

Blood from tissue

Low

Feature	Artery	Vein	Capillary
Outer layer			
Middle layer			
Inner layer			
Function			
Pressure			

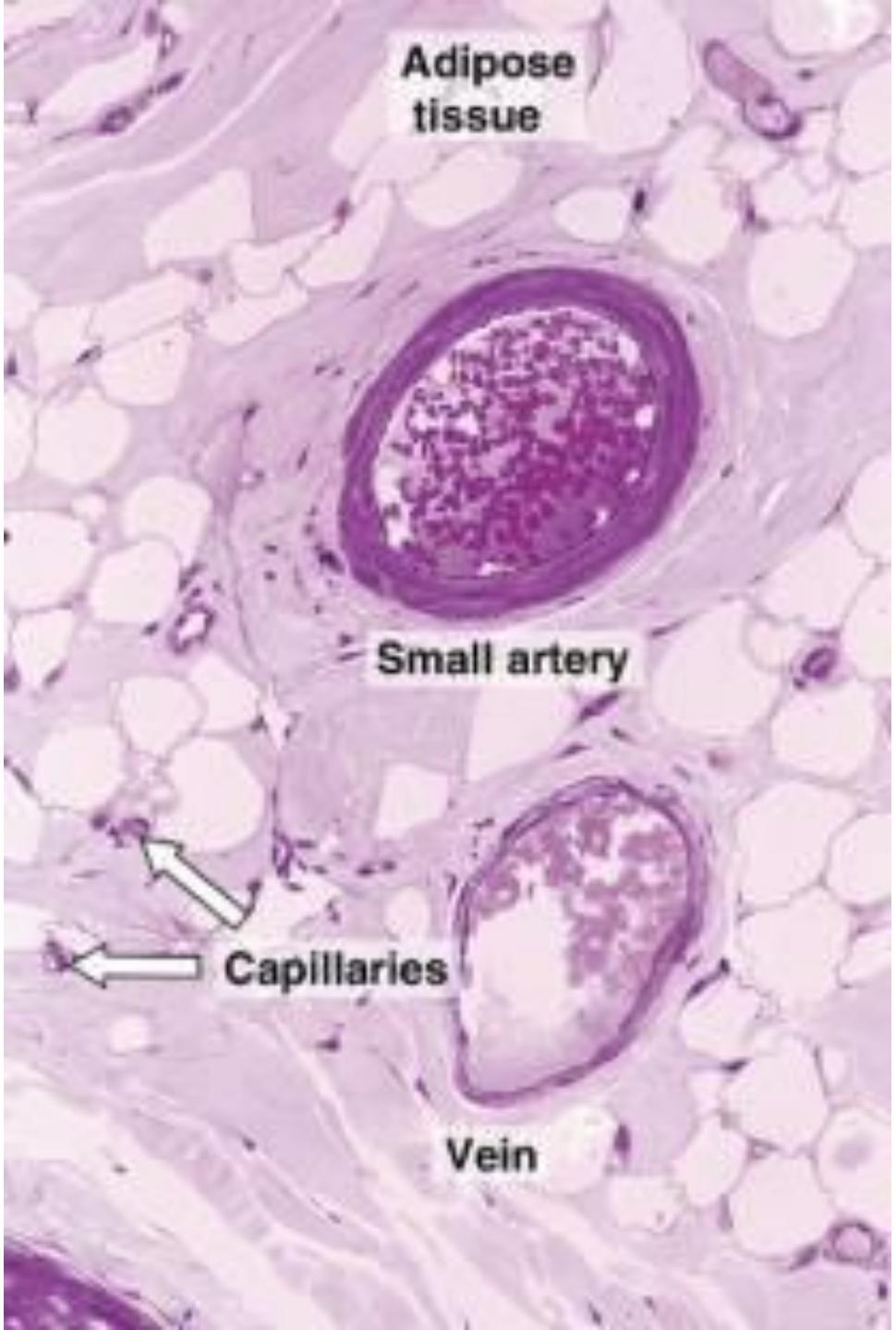
Comparison of Artery, vein and Capillary

Feature	Artery	Vein	Capillary
Outer layer	✓	✓	X
Middle layer	✓	✓	X
Inner layer	✓	✓	✓
Function	Blood to tissue	Blood from tissue	Close to cells rapid exchange
Pressure	High	Low	Decrease at venule end

Practical – examining blood vessel microscope slides

Examine prepared slides and/or photographs of blood vessels (in section) and mammalian heart (dissected and in section):

- *distinguish between arteries, veins and capillaries;*
- *identification of heart chambers, AV-valves, semilunar valves, chordae tendinae, papillary muscles, interventricular septum, major blood vessels (vena cavae, pulmonary artery and aorta).*

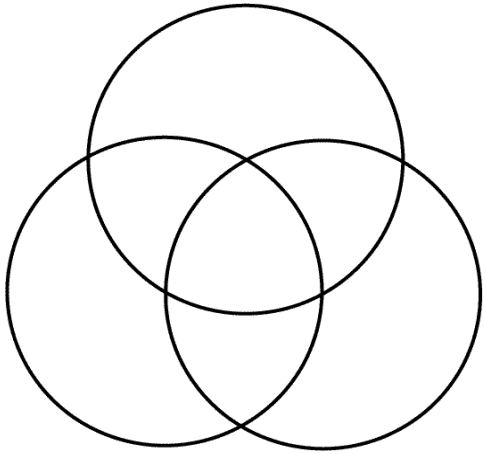

Adipose tissue
Small artery
Capillaries
Vein

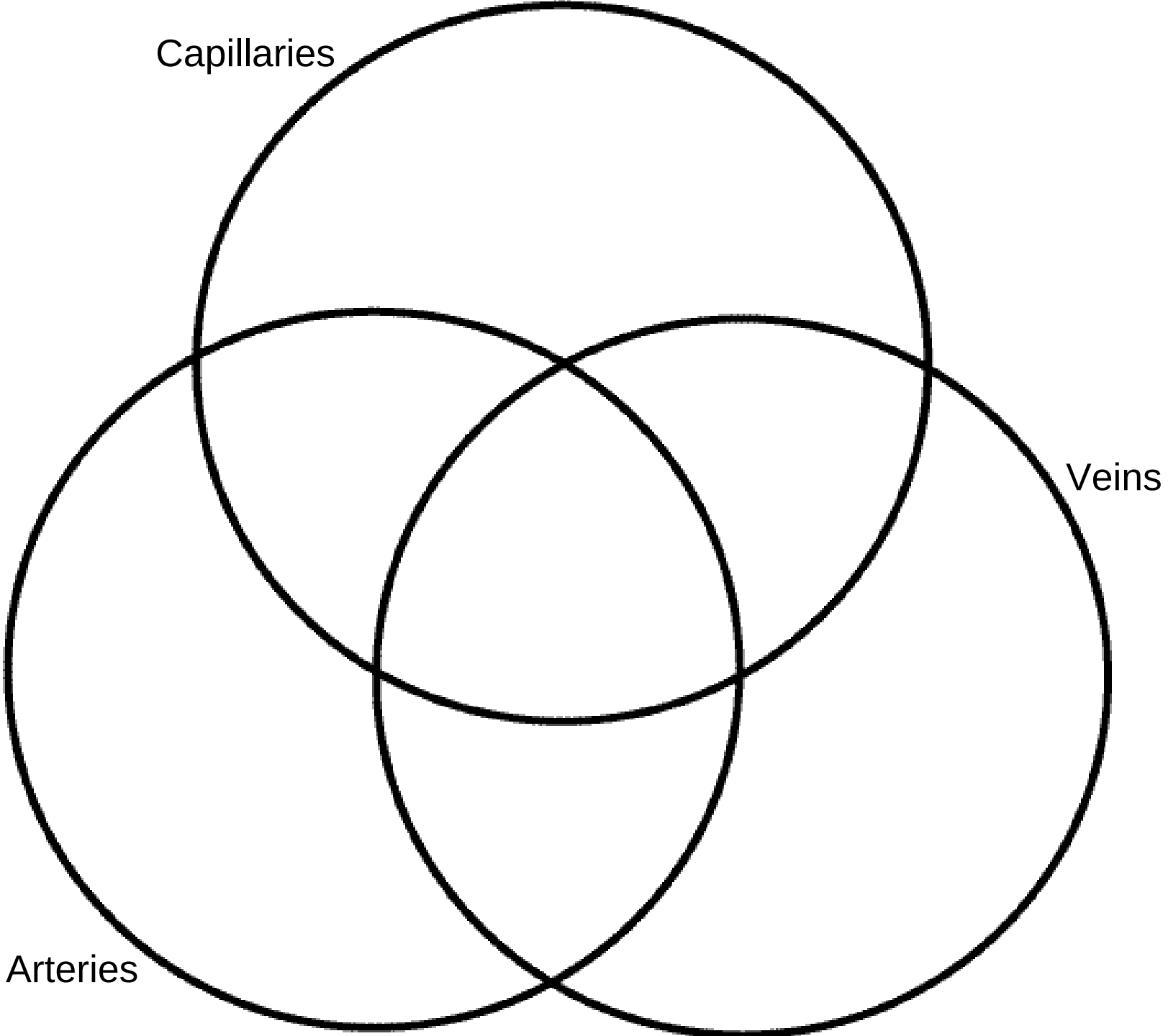
Homework for Monday:

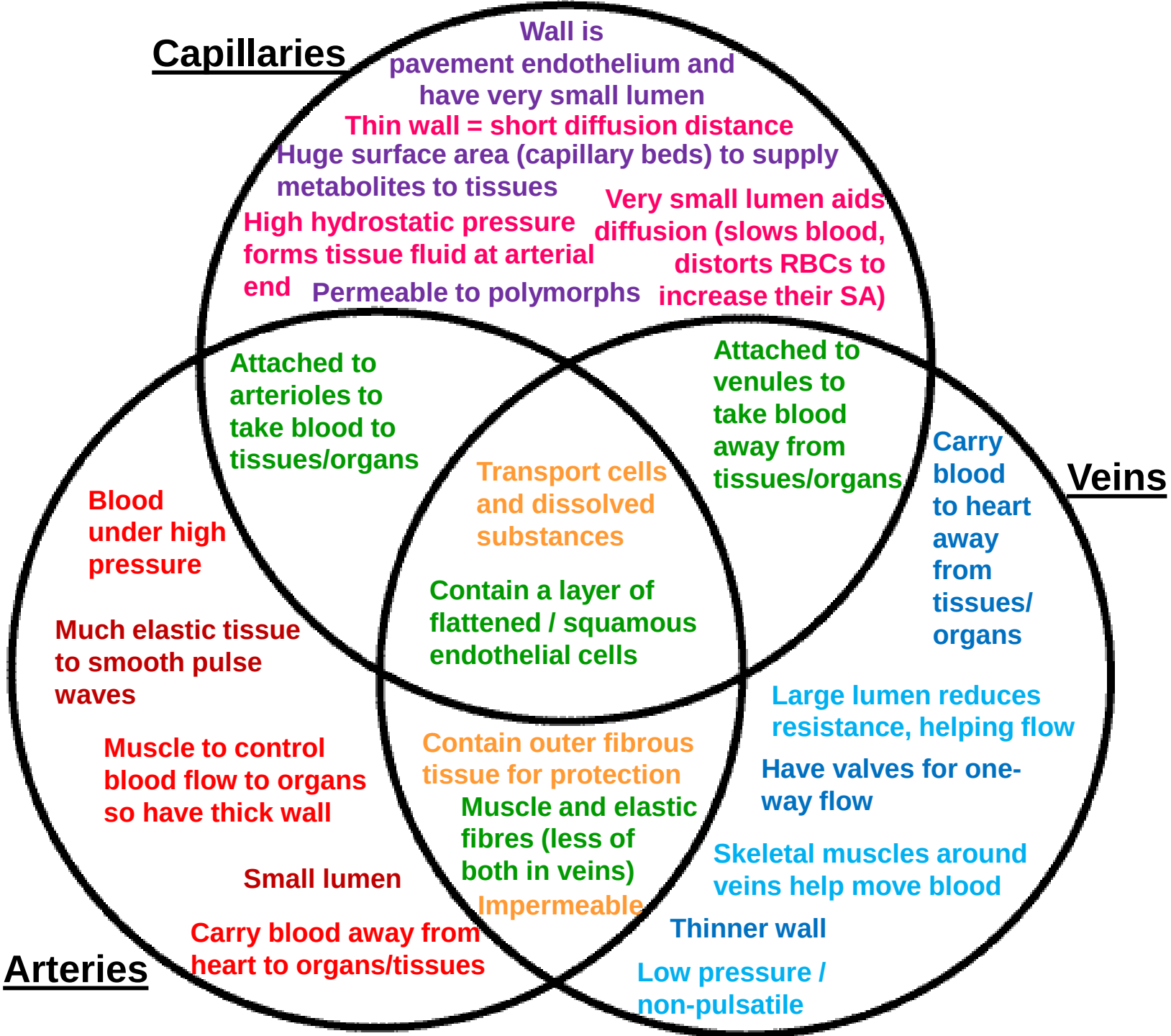
CHD sheet read and do question (Weebly)
(Photo on Monday / no sickness)

REVIEW CHALLENGE…

Create a Venn diagram to compare and contrast the structures and functions of the 3 types of blood vessel




Capillaries
Veins
Arteries


Capillaries
Wall is pavement endothelium and have very small lumen
Thin wall = short diffusion distance
Huge surface area (capillary beds) to supply metabolites to tissues
Very small lumen aids diffusion (slows blood, distorts RBCs to increase their SA)
High hydrostatic pressure forms tissue fluid at arterial end
Permeable to polymorphs
Attached to arterioles to take blood to tissues/organs
Attached to venules to take blood away from tissues/organs
Veins
Carry blood to heart away from tissues/ organs
Transport cells and dissolved substances
Contain a layer of flattened / squamous endothelial cells
Blood under high pressure
Much elastic tissue to smooth pulse waves
Muscle to control blood flow to organs so have thick wall
Small lumen
Carry blood away from heart to organs/tissues
Arteries
Contain outer fibrous tissue for protection
Muscle and elastic fibres (less of both in veins)
Impermeable
Large lumen reduces resistance, helping flow
Have valves for one-way flow
Skeletal muscles around veins help move blood
Thinner wall
Low pressure / non-pulsatile

Essay question

Give an account of the adaptations and roles of the following blood vessels in the mammalian circulatory system.

- Arteries
- Capillaries
- Veins

[12] with [2] awarded for the quality of written communication

Section B

Jan 07

8 Ten points (with at least three from each section)

Arteries:

- three layers
- carry blood under high pressure
- have much elastic tissue to withstand pressure/smooth out pulse waves
- carry blood to organs/away from the heart
- contain much muscle tissue
- to control blood flow to organs/skeletal muscle (vasoconstriction)
- as a result have a thick wall/tunica media
- small lumen helps maintain pressure

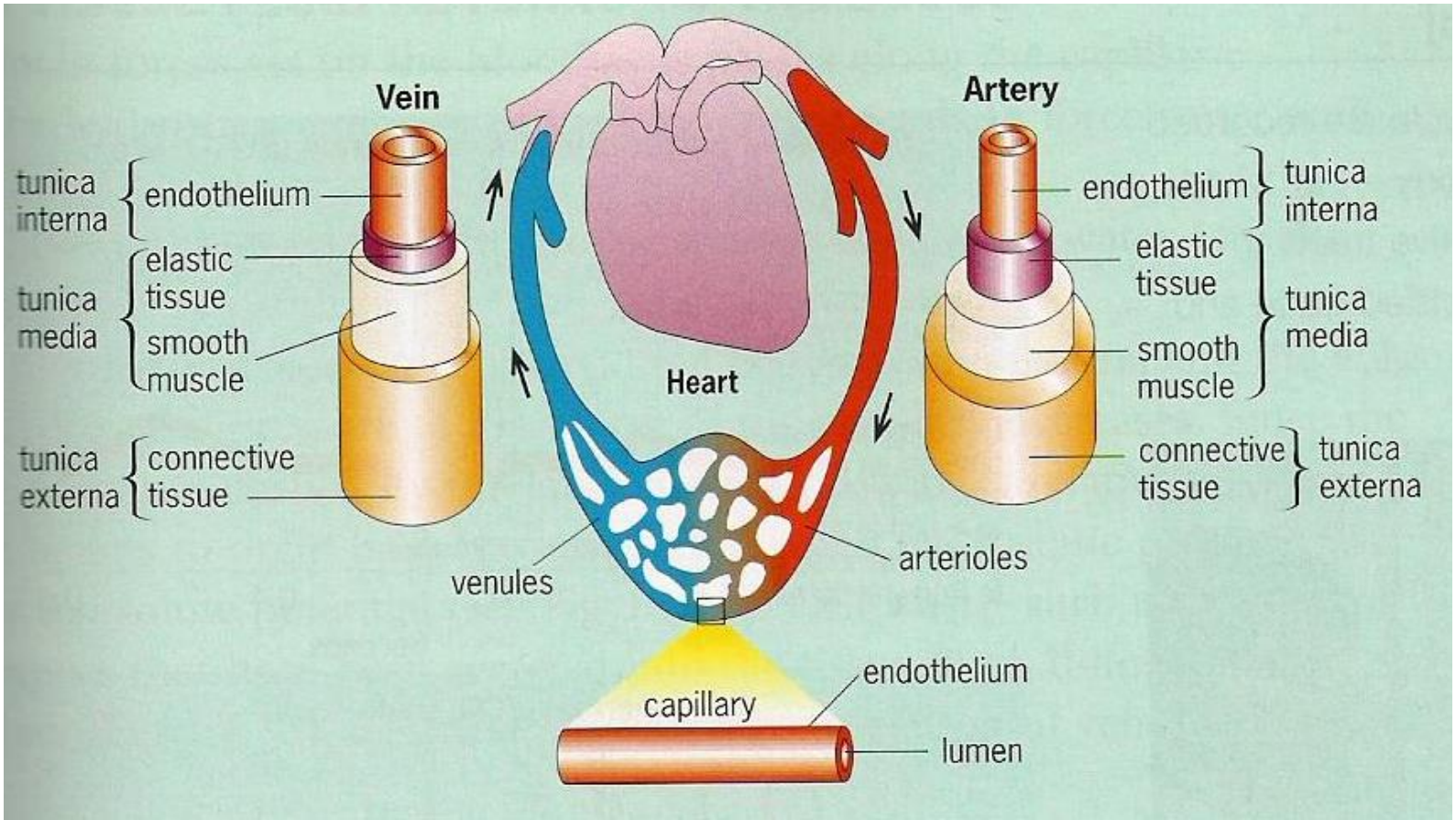
Capillaries:

- wall consists of a pavement/thin endothelium only
- thin wall reduces diffusion distance
- represent a huge surface area
- tissue fluid formed at arterial end
- due to high (hydrostatic) pressure
- supply oxygen/glucose/metabolites to the tissues
- proteins too large to leave the blood stream/fluid reabsorbed at the venule end
- permeable to polymorphs
- very small lumen assists diffusion (slows blood flow, distorts red blood cells increasing their surface area)

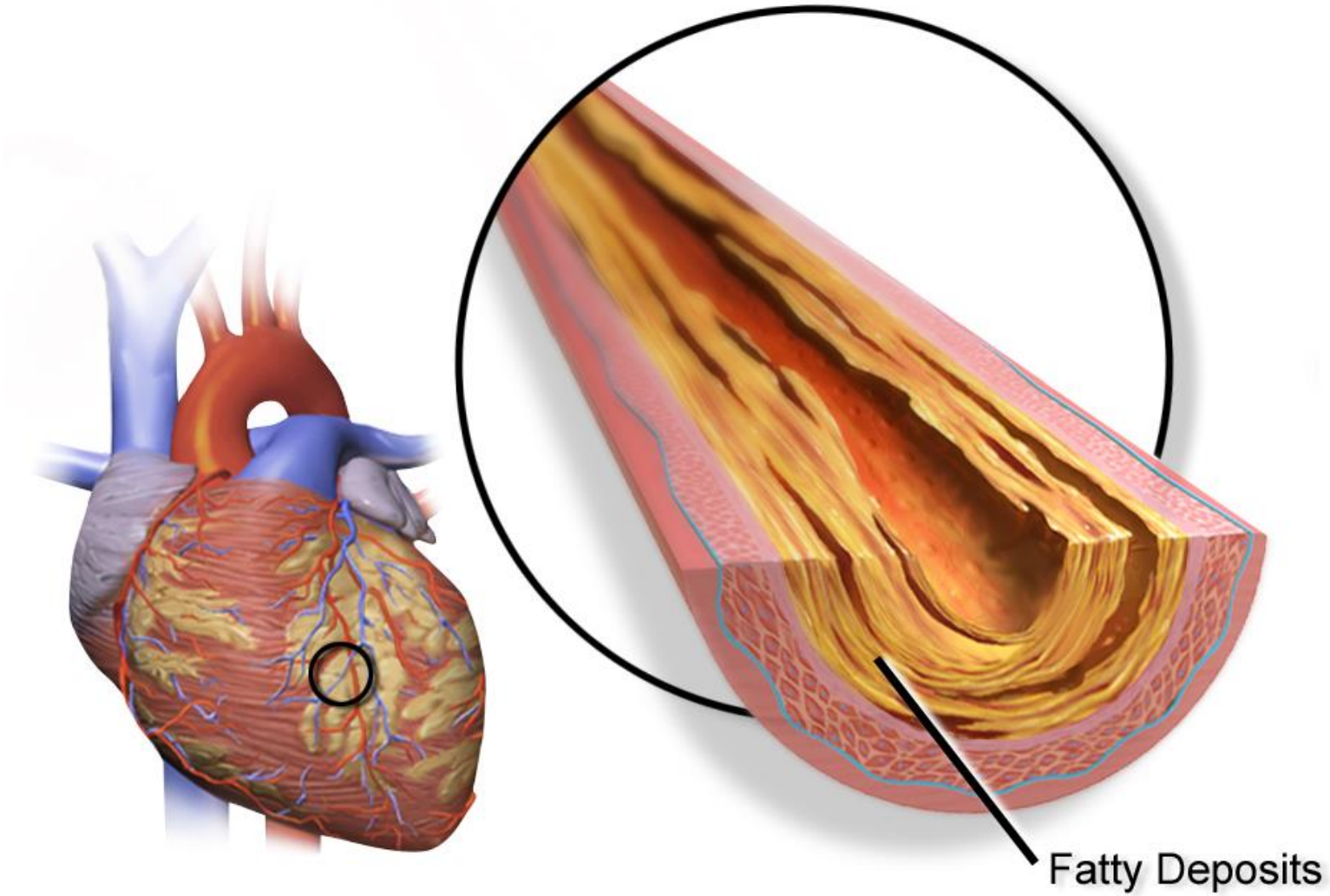
Veins:

- three layers
- carry blood back to the heart
- under low pressure/non-pulsatile
- have a large lumen (less resistance to blood flow)
- and valves (to ensure one-way flow)
- surrounding muscle pump system aids blood flow
- thin wall
- tunica media contains less fibrous tissue [10]

•veins contain abundant fibrous tissue for protection

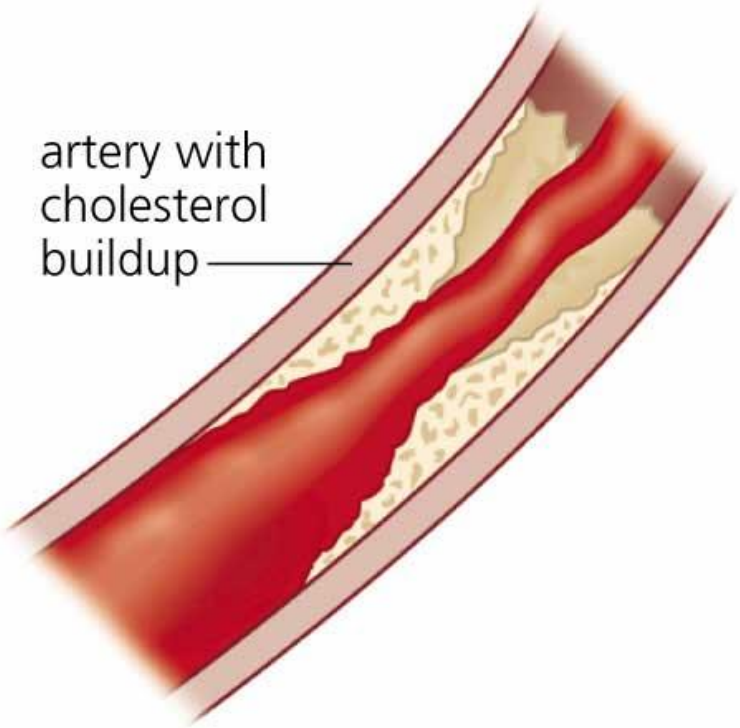


CHD – Coronary Heart Disease (damage to the coronary arteries)



http://www.nhs.uk/conditions/coronary-heart-disease/Pages/Introduction.aspx

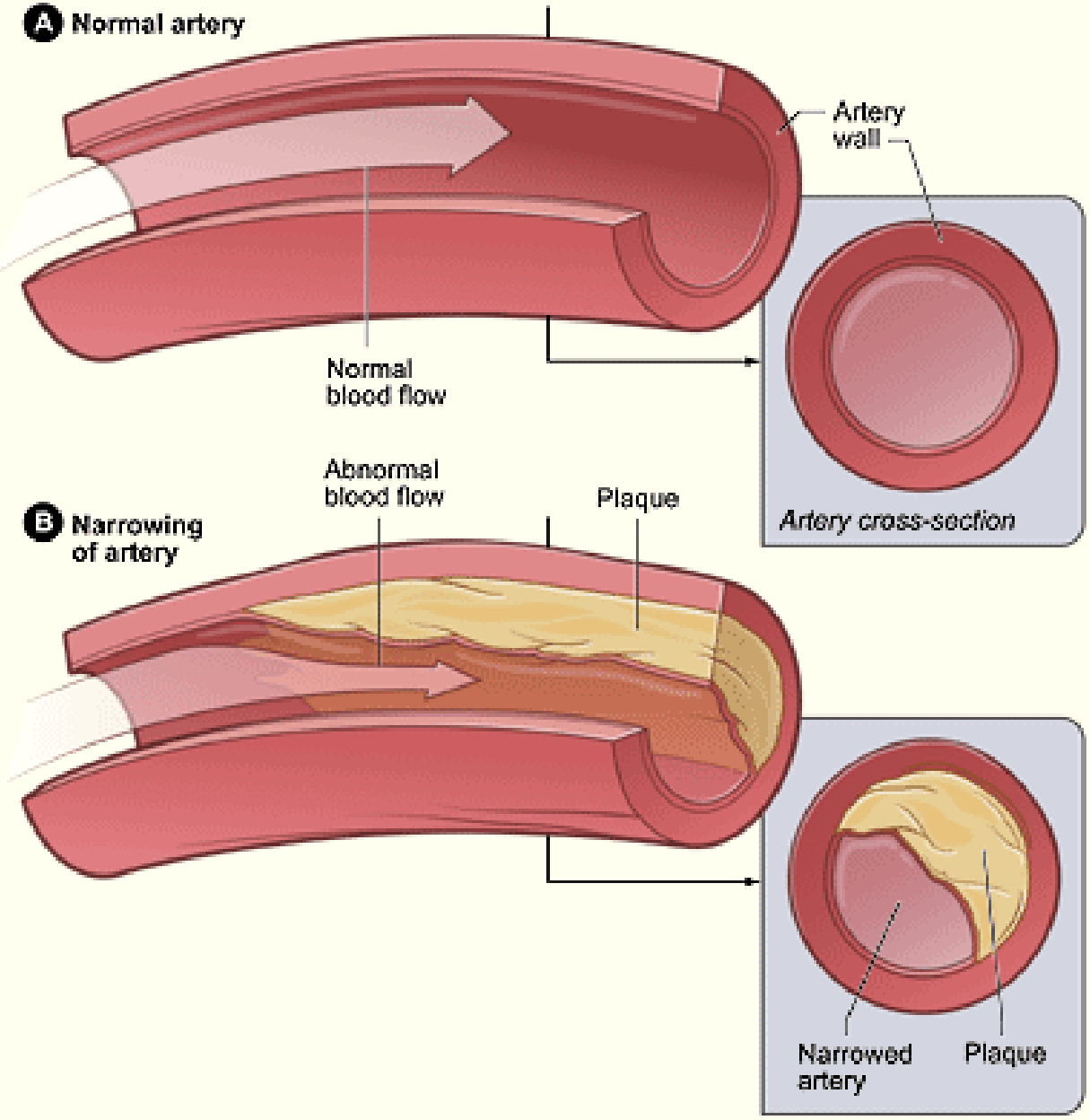
- **Atherosclerosis** is a disease in which an artery wall thickens THROUGH THE DEVELOPMENT OF ATHEROMAS OR FATTY PLAQUES



- *Risk factors include:* smoking, inactivity, stress, high salt intake, high blood cholesterol
- THE ARTERY WALL BECOMES LESS ELASTIC, THE LUMEN NARROWS AND BLOOD PRESSURE INCREASES

DID YOU KNOW?

Comes from the Greek words athero meaning gruel and sclerosis meaning hardness


A Normal artery
Artery wall
Normal blood flow
Artery cross-section
B Narrowing of artery
Abnormal blood flow
Plaque
Narrowed artery
Plaque

A cholesterol-filled atherosclerotic coronary artery from a human body

(Image Courtesy: University of Pennsylvania School of Medicine)

THE FORMATION OF AN ATEROMA USUALLY *follows this sequence of events...*

1. Damage to the **SQUAMOUS ENDOTHELIAL CELLS** (endothelium) lining the artery e.g. from high blood pressure which puts an extra strain on the layer of cells **OR** damage from the toxins from tobacco smoke in the blood stream

2. An inflammatory response occurs once the endothelium has been breached/damaged AND THE ATHEROMA STARTS TO BUILD UP IN THE WALL OF THE ARTERY, BENEATH THE ENDOTHELIUM.

Macrophages (white blood cells DEVELOPED from monocytes) leave the blood vessel and move into the artery wall. They accumulate chemicals from the blood, particularly cholesterol BUT ALSO DEAD MUSCLE CELLS AND SALTS (e.g. CALCIUM). FIBROUS TISSUE WILL BUILD UP TOO AS THE ARTERY ATTEMPTS TO REPAIR DAMAGE. THIS DEPOSIT IS CALLED THE ATHEROMA, WHICH WILL BEGIN TO BUILD UP INTO HARDENED PLAQUES

3. THE ATHEROMAS (PLAQUES) INCREASE IN SIZE AND TOUGHNESS AND BULGE INTO THE ARTERY LUMEN. THIS NARROWING RESTRICTS BLOOD FLOW AND INCREASES BLOOD PRESSURE AND WILL LIKELY LEAD TO FURTHER ATHEROMAS FORMING (ENDOTHELIAL DAMAGE)

IMPORTANTLY, THE HARDENING OF THE ARTERIES WITH FIBROUS MATERIAL CAUSES THE ARTERY TO BE LESS ELASTIC AND LESS ABLE TO REGULATE BLOOD FLOW THROUGH VASOCONSTRICTION AND VASODILATION.

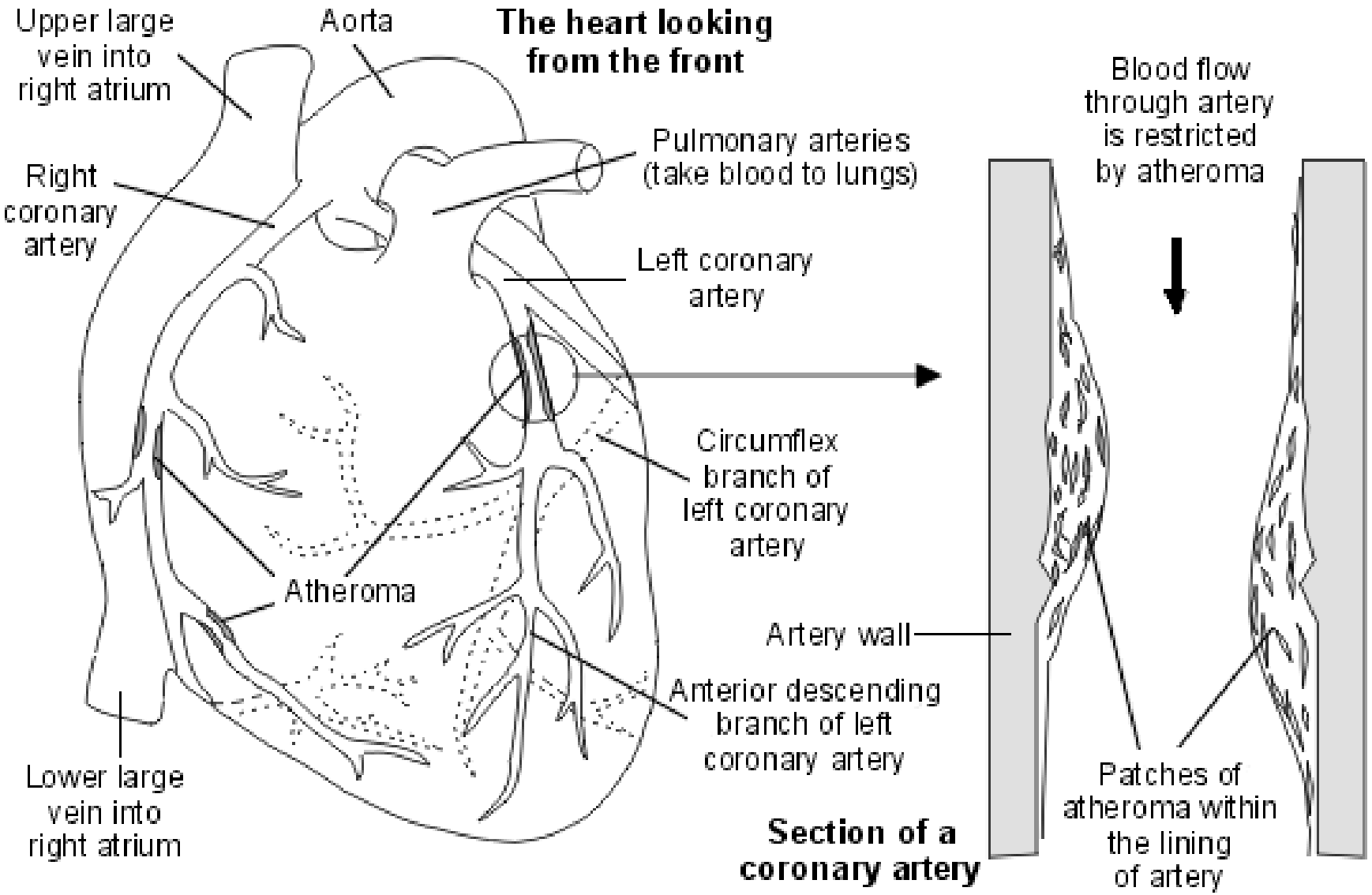
REMEMBER!

If the arteries become very narrow or blocked then they cannot supply enough blood to their tissues or organs and those cells will die WHY?

THROMBOSIS is the formation of blood clots within a blood vessel. They are a particular problem in narrow arteries e.g. coronary arteries or ones narrowed by heart disease (atherosclerosis) but they can occur anywhere.

A thrombosis in a coronary artery is called a **coronary thromobosis** and is more likely to happen if the artery wall has been damaged e.g. due to the presence of an atheroma. The affected area of the heart doesn't receive blood carrying glucose and oxygen and therefore those cells could die from **lack of respiration** if the blockage persists. If a large area of the heart is affected e.g. blockage near the start/origin of the artery rather than at the end, a heart attack results. This is called a **myocardial infarction.**

Angina caused by atherosclerosis in the coronary arteries:



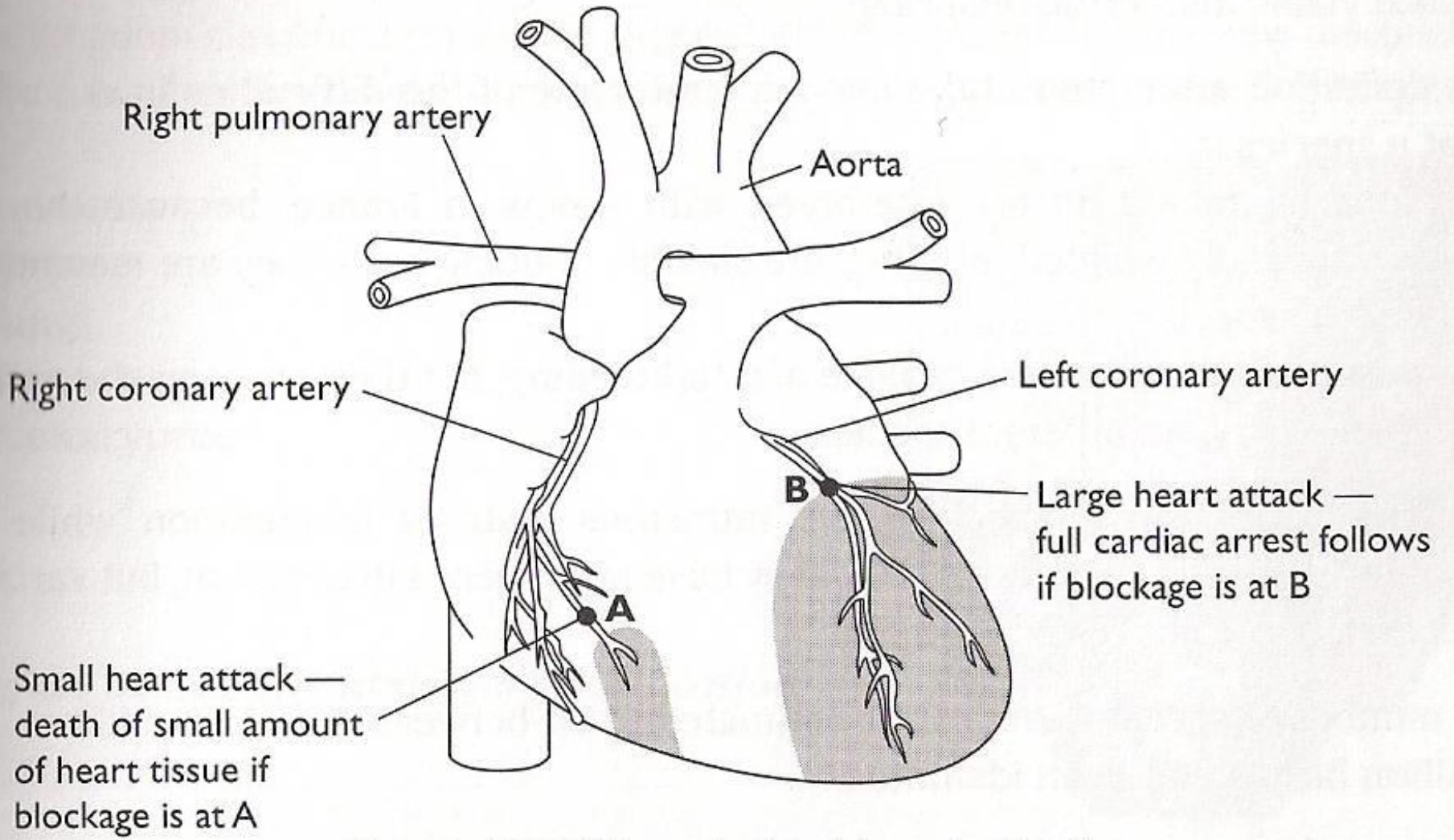


Figure 30 Different-sized heart attacks

(c) Distinguish between the terms “atheroma” and “atherosclerosis” and explain how they may lead to a coronary thrombosis (heart attack).

[5]

January 2011

(c) An atheroma is an accumulation (of macrophages/cholesterol)/ swelling in artery walls;
in atherosclerosis the artery wall loses its elasticity/artery lumen becomes narrower; [2]

Any three from

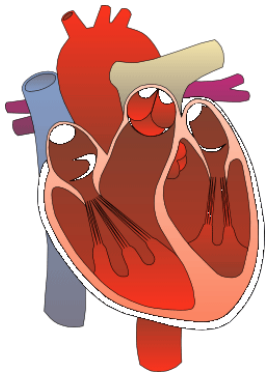
- atherosclerosis leads to an increase in blood pressure
- surface of the atheroma/plaque to become damaged/ atheromatous plaque forms
- change in blood flow/damaged surface may trigger the production of a clot or thrombus
- clot/thrombus may block the coronary artery
- starving the cardiac muscle of oxygen (metabolites)/leading to death of the cardiac muscle tissue [3]

Homework for Wednesday:

Complete blood vessels essay

Label heart diagram

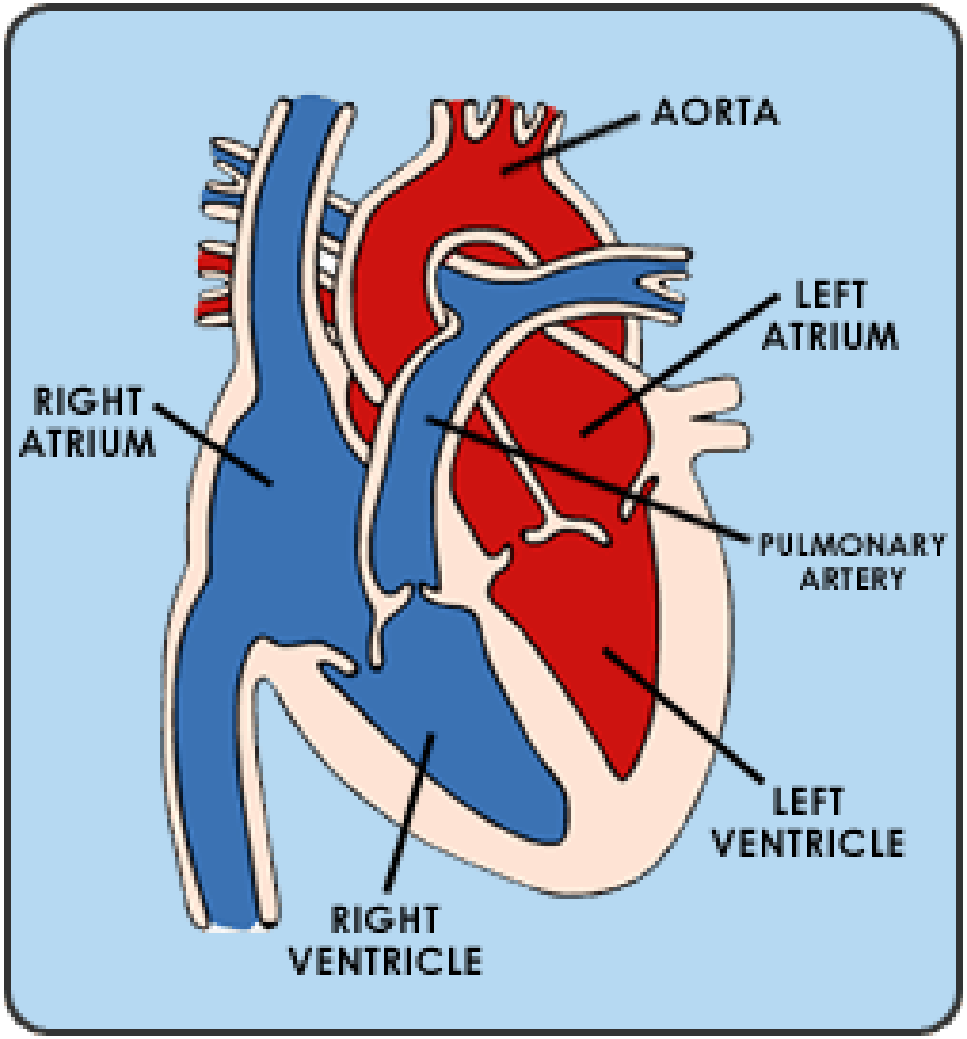
Practical – **heart dissection**



- You do not have to take part but can read instead
- Wear safety glasses and gloves if you want
- Be very careful with the very sharp scalpels
- Return all equipment to correct place when finished after they have been cleaned
- Place all biological material in the one tray when finished

Method:

- Make a cut on one side from the base of the atria towards beside the apex (bottom tip of the heart)
- Use the heart diagram to try and identify the structures (atria and ventricles) and blood vessels



- *Also look out for:*

chordae tendinae that attach to the papillary muscles and control the valves opening); fat on the heart, and any blood clots in the vessels

CHALLENGE – You must show me **7** of the following…

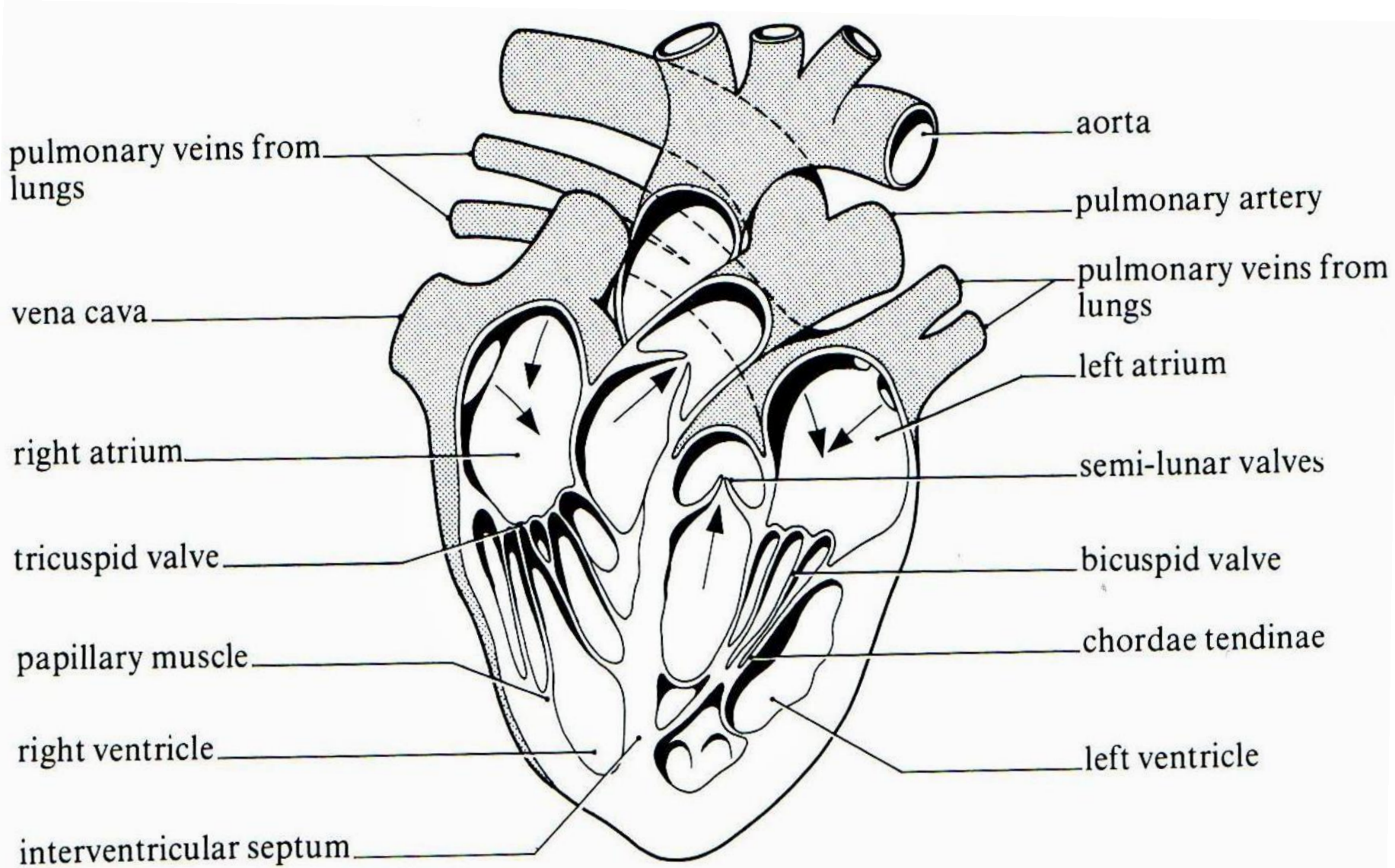


Fig 14.50 *Section through mammalian heart*

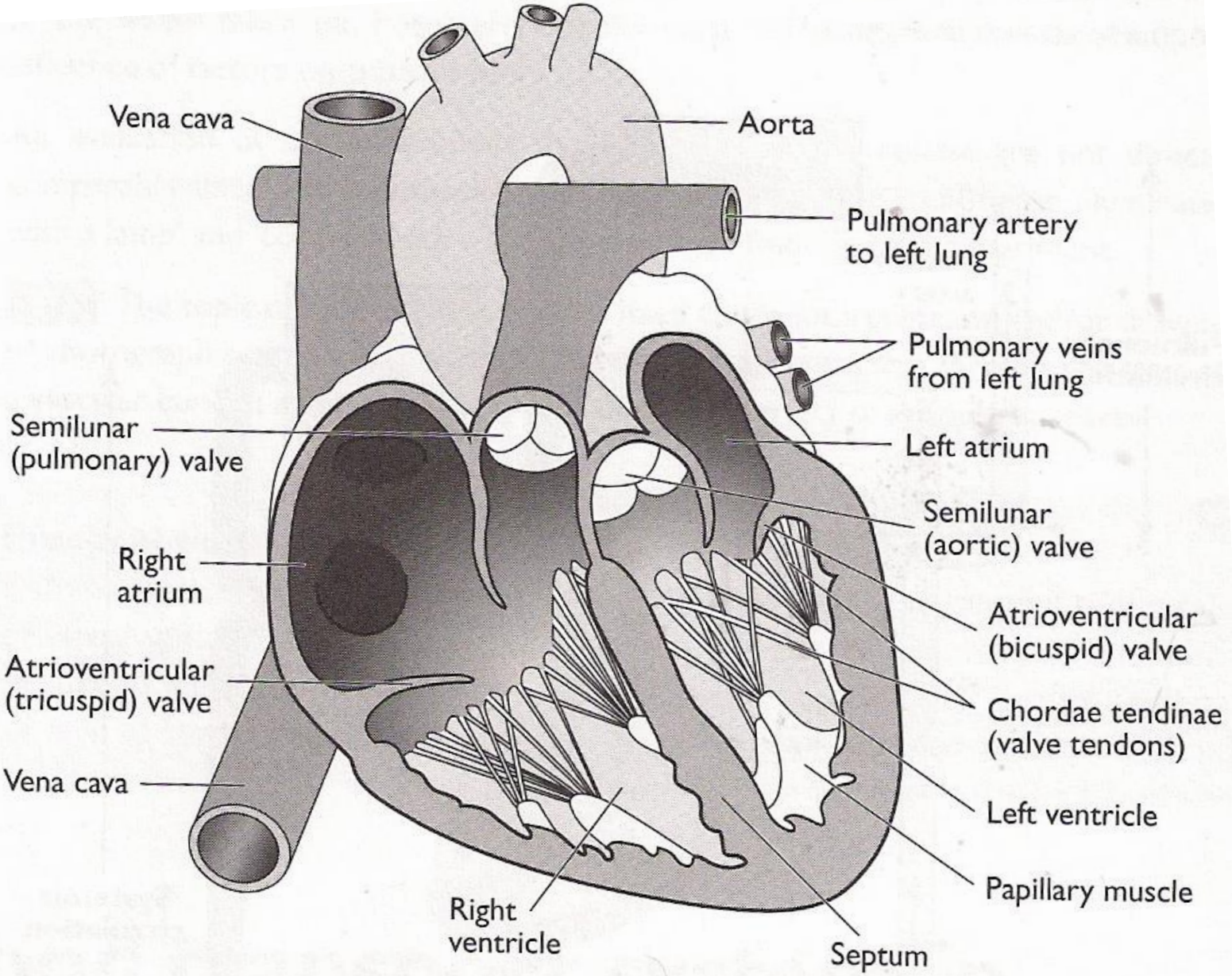
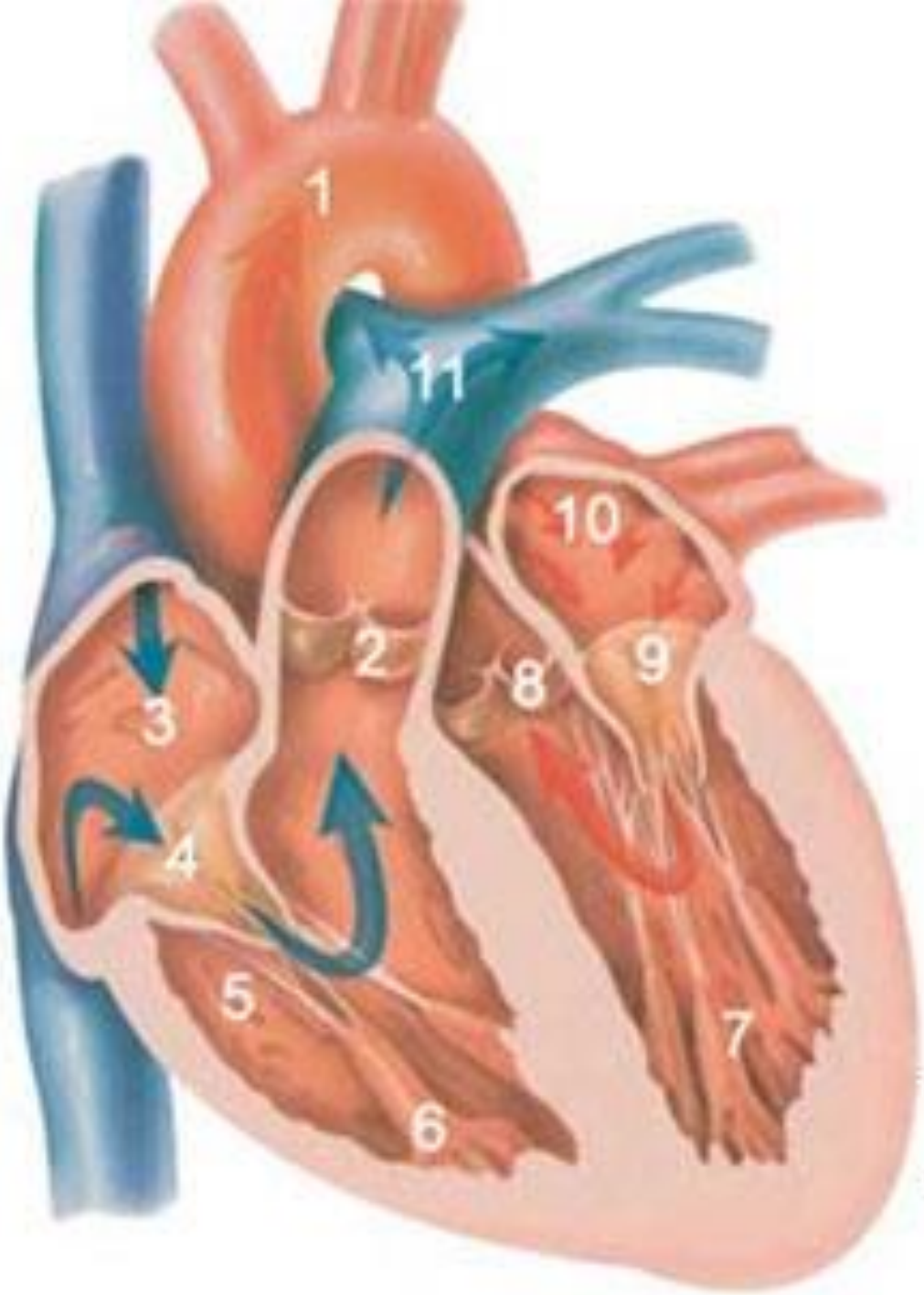


Figure 18 The structure of the heart

THE STRUCTURE AND FUNCTION OF THE HEART...

Circulation rap



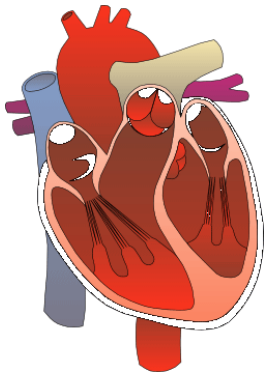
1. Aorta
2. Pulmonic Valve
3. Right Atrium
4. Tricuspid Valve
5. Right Ventricle
6. Supportive Structures
7. Left Ventricle
8. Aortic Valve
9. Mitral Valve
10. Left Atrium
11. Pulmonary Artery

Valves – Semilunar and Atrioventricular

All the valves work so as to prevent backflow and keep the blood flowing in one direction. **Their opening and closing is controlled by the pressure of blood (they are forced open or closed)**

Atrioventricular valves – the bi-cuspid valve has two cusps/flaps and the tri-cuspid (on the right side) has three

Semilinar valves – each has 3 semilunar (halfmoon shaped) cusps/**pockets**



- When the ventricles contract, the AV valves bulge into the atria. They don't turn inside out however as they are held by the **strong chordae tendinae fibres**
- The semi-lunar valves have no chordae tendinae and are not linked to papillary muscles. When the blood pressure forces them open, they **lie flat** against the walls of the aorta or pulmonary artery and they close again when the pressure in the arteries exceeds that in the ventricles and their **"pockets" fill with blood**

Papillary muscles are on the walls of the ventricles – these contract and relax to control the tension of the **chordae tendinae** which are attached to the AV valves. These are very strong fibrous chords linking the papillary muscles in the ventricular wall to the AV valves (stop valves opening into atria)

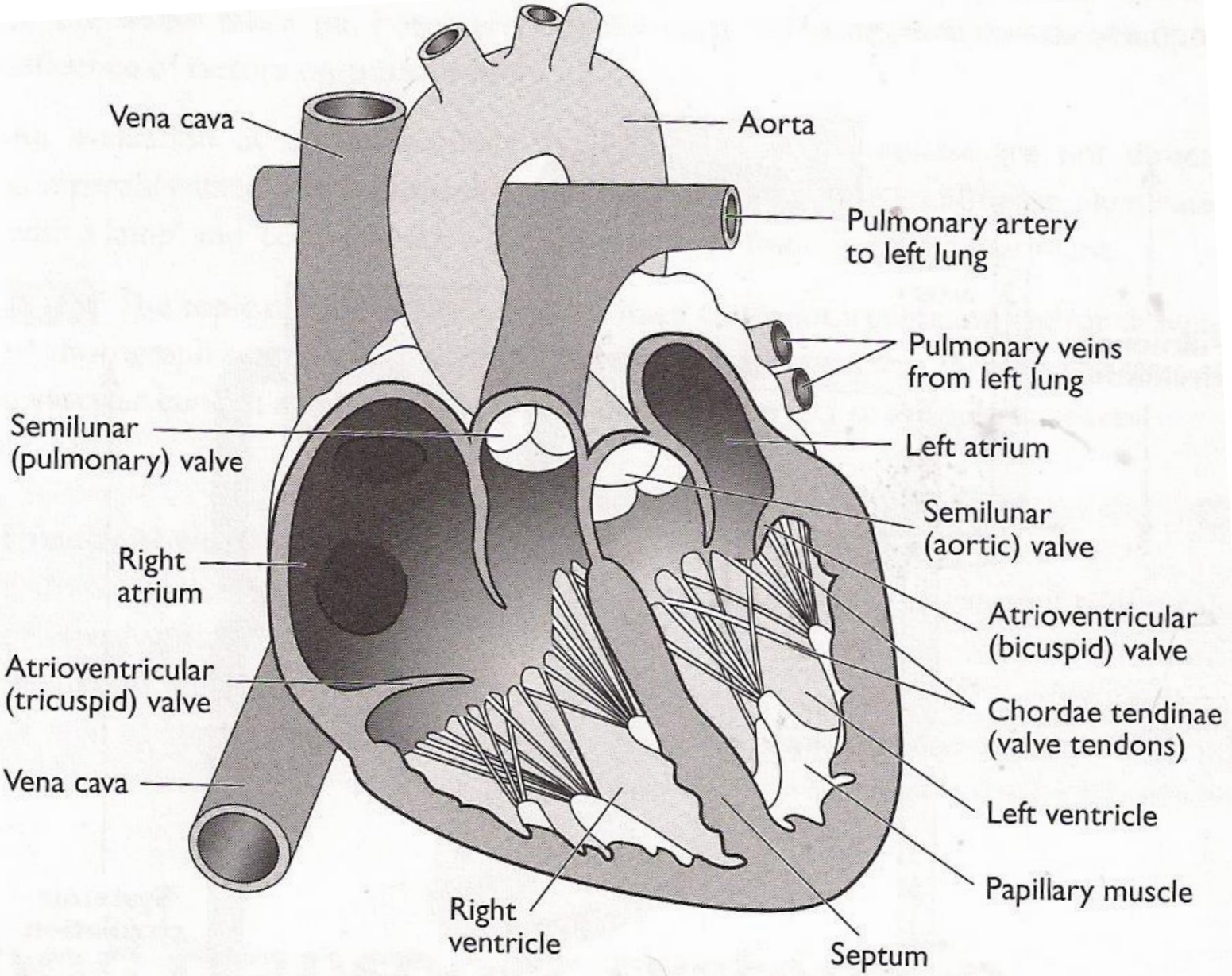
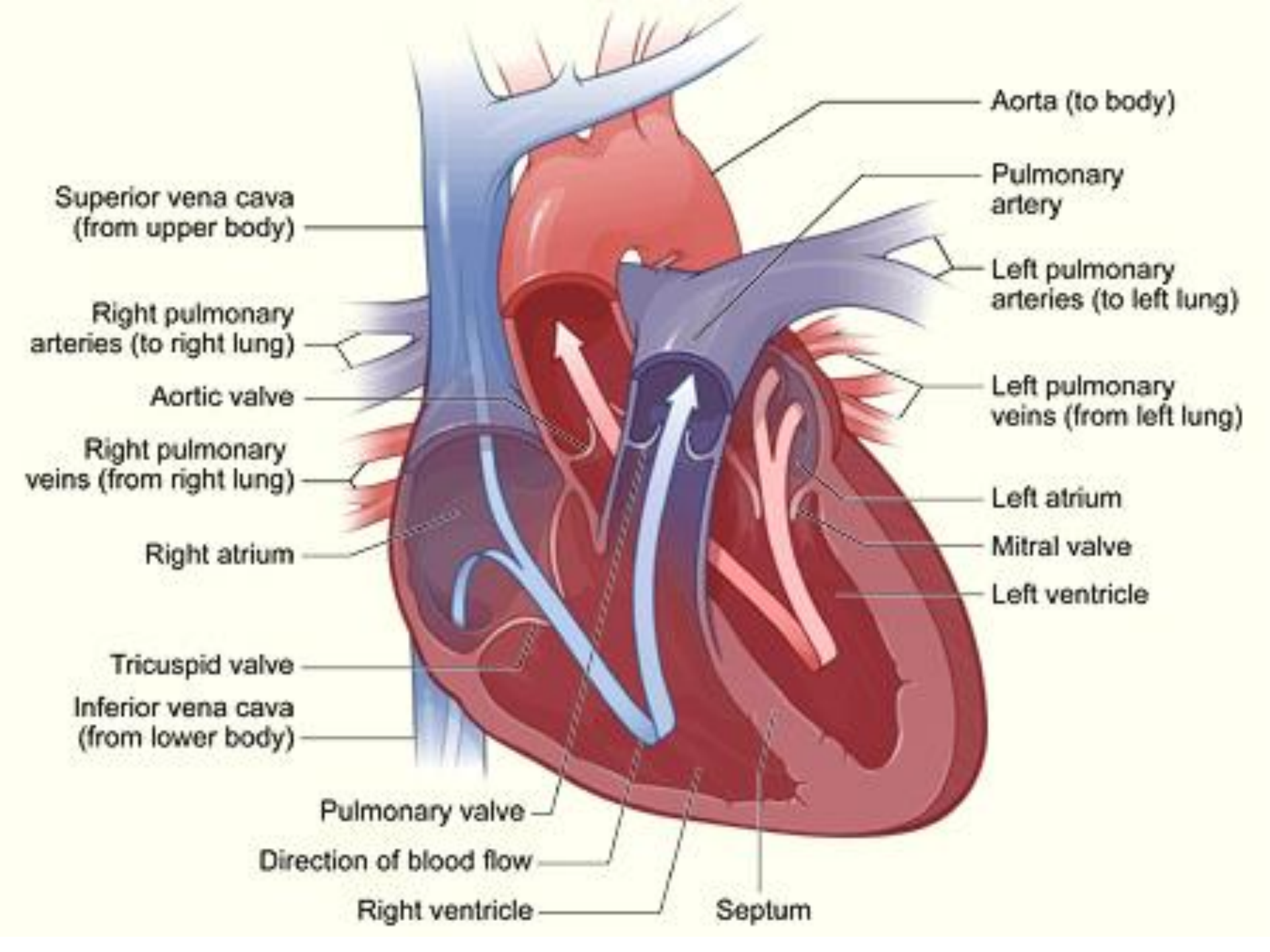
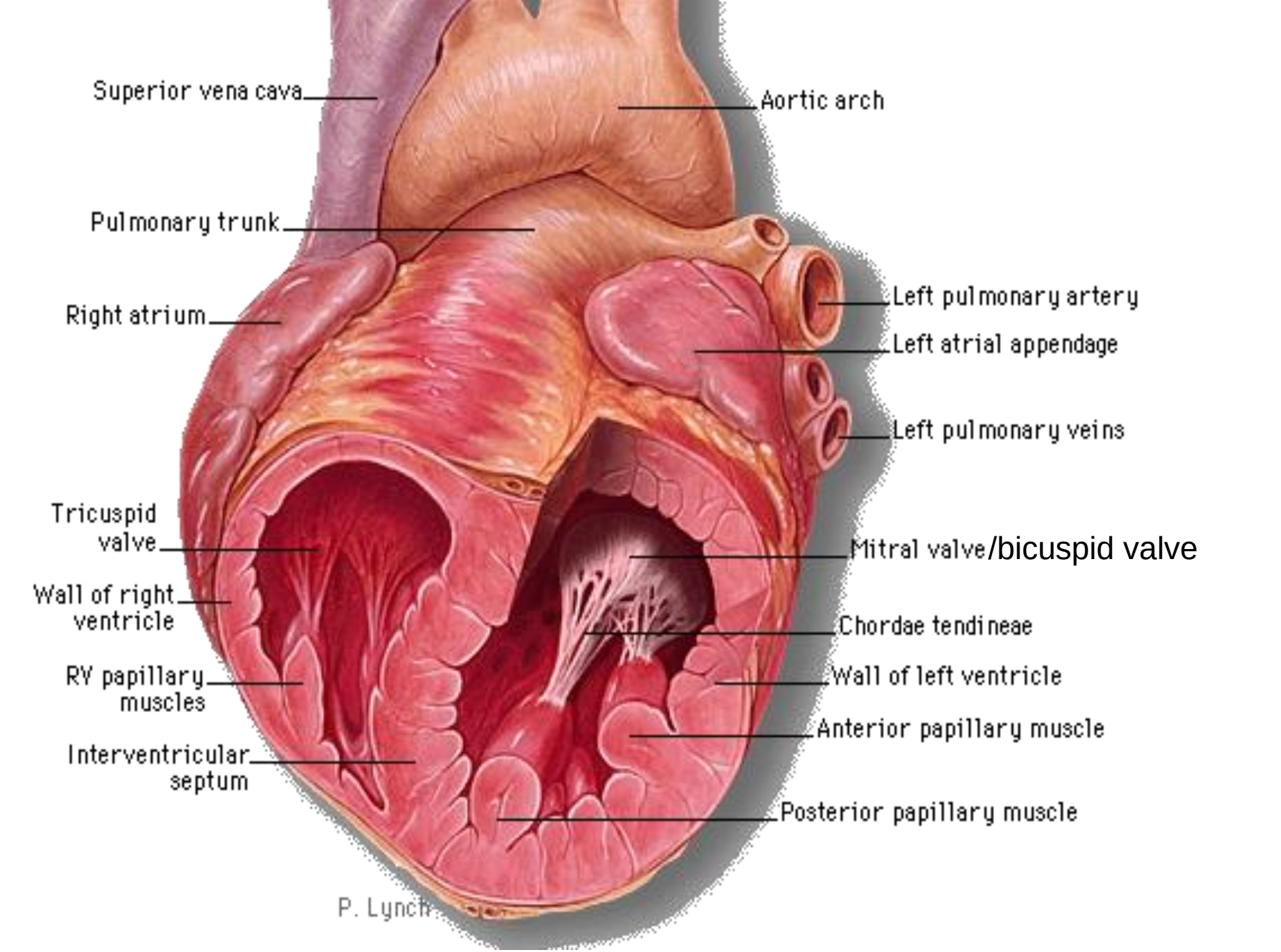


Figure 18 The structure of the heart


Aorta (to body)
Pulmonary artery
Superior vena cava (from upper body)
Left pulmonary arteries (to left lung)
Right pulmonary arteries (to right lung)
Aortic valve
Left pulmonary veins (from left lung)
Right pulmonary veins (from right lung)
Left atrium
Right atrium
Mitral valve
Left ventricle
Tricuspid valve
Inferior vena cava (from lower body)
Pulmonary valve
Direction of blood flow
Right ventricle
Septum


Superior vena cava
Aortic arch
Pulmonary trunk
Right atrium
Left pulmonary artery
Left atrial appendage
Left pulmonary veins
Tricuspid valve
Mitral valve/bicuspid valve
Wall of right ventricle
Chordae tendineae
RV papillary muscles
Wall of left ventricle
Anterior papillary muscle
Interventricular septum
Posterior papillary muscle
P. Lynch

Anticucho de corazon (stewed heart meat on skewers), Peru

Structure of the heart

http://www.gwc.maricopa.edu/class/bio202/cyberheart/hartint0.htm

Practical – mammalian heart dissection to observe structures

- *identification of heart chambers, AV-valves, semilunar valves, chordae tendinae, papillary muscles, interventricular septum, major blood vessels (vena cavae, pulmonary artery and aorta).*

Homework for tomorrow:

Read the **cardiac cycle** sections:

http://www.s-cool.co.uk/a-level/biology/transport/revise-it/the-heart

http://www.biologymad.com/master.html?http://www.biologymad.com/ASBiology.htm

Cardiac Cycle

Blood flow through the heart animation:

http://www.kett6.net/adulteducation/heartanimations.html

- **The cardiac cycle** represents one heartbeat in which the heart fills and empties
- The beating of the two sides is synchronised (both sides beat together)
- The valves in the heart respond to pressure changes during a cardiac cycle – **the blood flows along pressure gradients** (from high pressure areas to lower pressure areas, forcing valves to open and close)
- The closing of the valves gives the characteristic "lup dup" sound of the heart beat

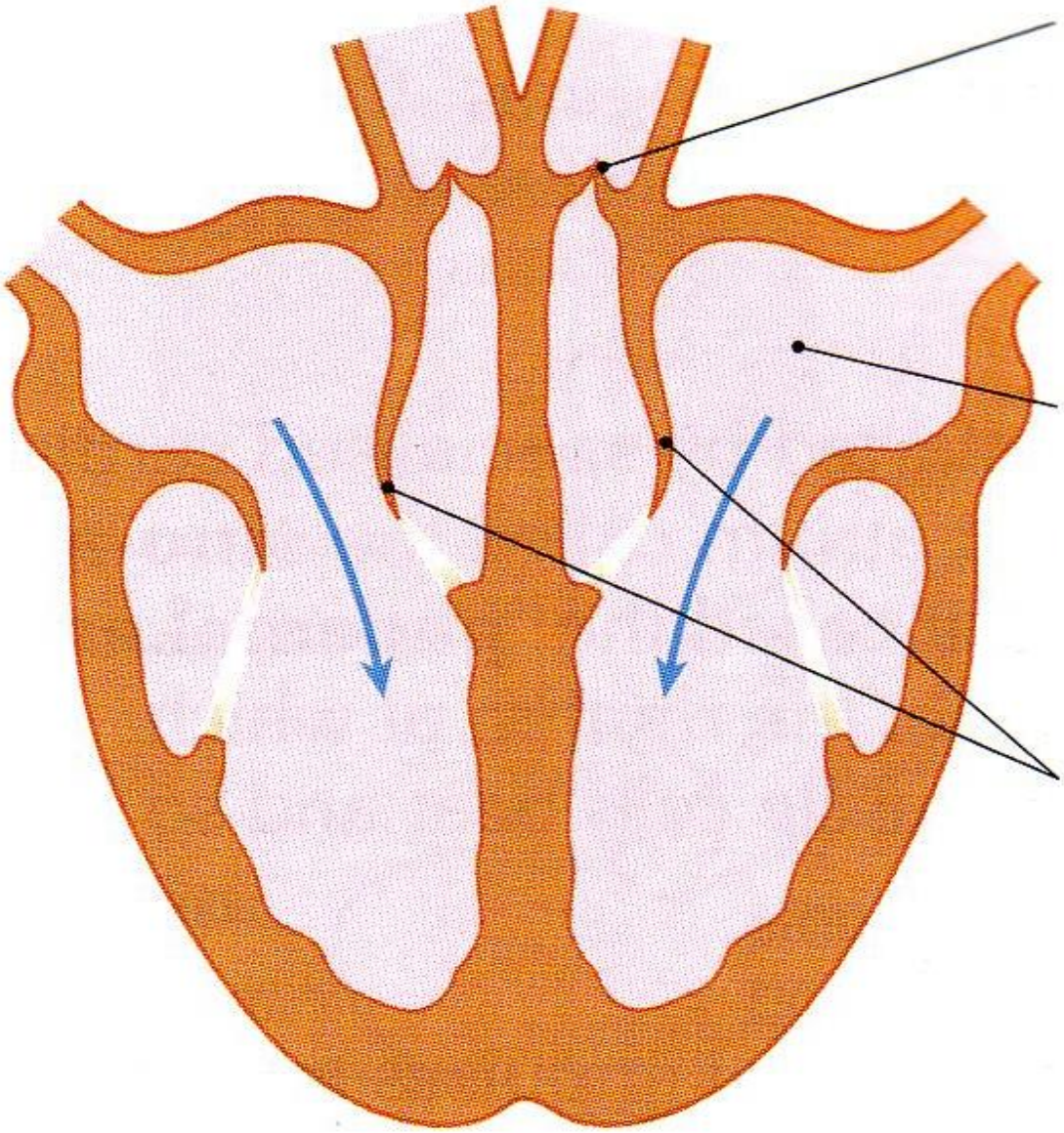
There are 3 stages in each cardiac cycle:

1. **Atrial systole** – atria contract (ventricles are releaxed)
2. **Ventricular systole** – ventricles contract (atria are relaxed)
3. **Diastole** – both atria and ventricles are relaxed

Atrial Systole – atria contract (ventricles are relaxed)

- 70% of blood flows passively from the atria to the ventricles during diastole when the AV valves are open
- Both atria contract (ventricles are relaxed)
- Leads to increased pressure in atria and the rest of the blood is forced into ventricles
- Atrioventricular (AV) valves are kept open due to pressure of blood against them
- The atrial systole "tops up" the ventricle with the blood remaining in the atria

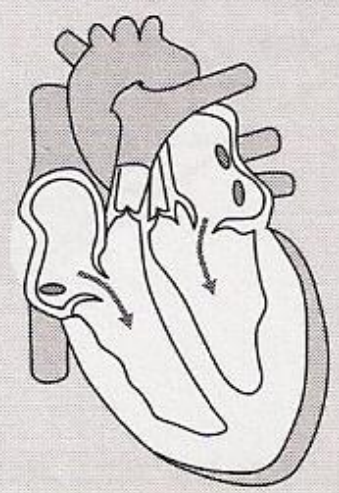
Atrial systole



semi-lunar valves closed

atria contract to push remaining blood into ventricles

bicuspid and tricuspid valves open

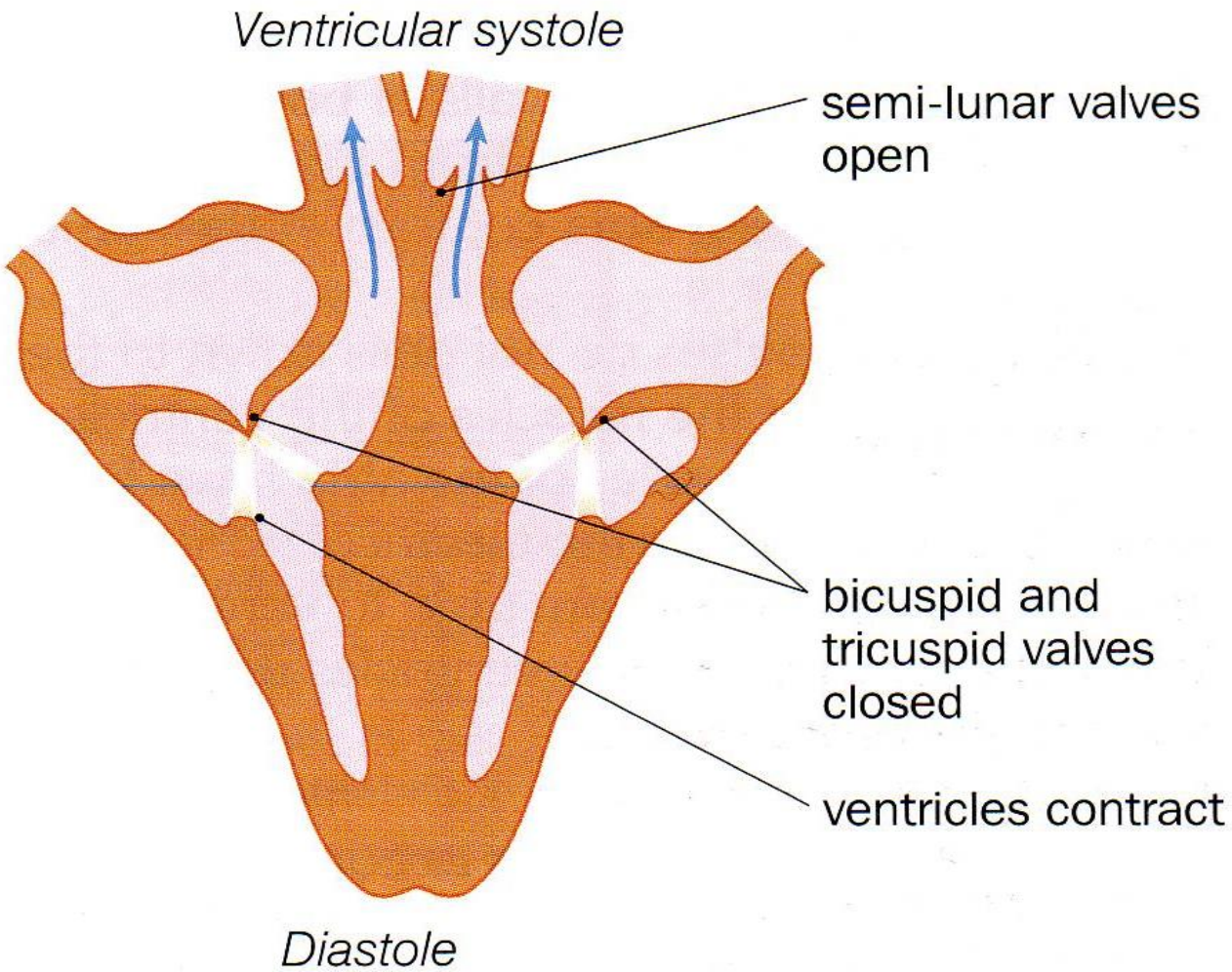
Stage	Description of events
(1) Atrial systole 	Atria contract (ventricles are relaxed) pushing more blood into the ventricles. This is essentially topping up the ventricles (since blood has already entered the ventricles during diastole when the atrioventricular valves are open).

Ventricular Systole – ventricles contract (atria are relaxed)

- Atria relax and the ventricles contract to increase pressure of blood inside the ventricles
- The AV valves shut due to the pressure of the blood against them (to prevent the blood going back to atria; this is the 1st heart sound "lub")
- Two phases:

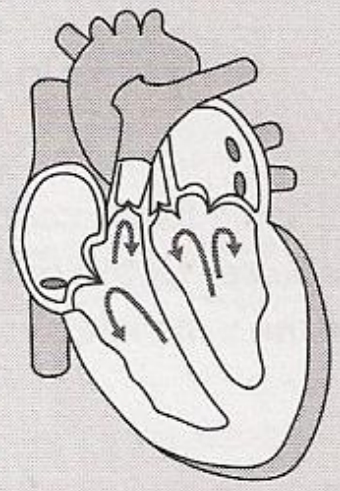
a) Ventricular pressure causes the AV valves to bulge into the atria, causing pressure to increase there slightly. The flaps of the AV valves don't turn inside out due to being held by the chordae tendinae aided by contraction of the papillary muscles

b) Ventricular pressure increases to more than in the major arteries. This pushes the semi-lunar valves open and blood leaves the heart. Blood returns to the heart/atria from the major veins and the atrial pressure gradually increases

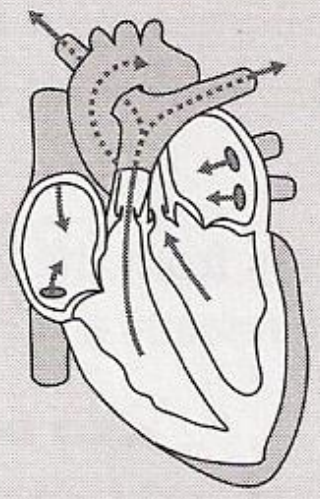


(2) Ventricular systole

(a)



(b)



Ventricles contract (atria are relaxed) causing the pressure of the blood inside the ventricles to become greater and forcing the atrioventricular valves shut.

Two phases are evident (see Figure 19):

(a) Ventricular pressure causes the atrioventricular valves to bulge into the atria increasing pressure there, while not being great enough to cause blood to exit the major arteries; the flaps of the atrioventricular valves are prevented from turning inside out by the chordae tendinae aided by contraction of the papillary muscles (see Figure 18)

(b) Ventricular pressure increases to exceed that in the major arteries, pushing the semi-lunar valves open and causing the ejection of blood from the heart; blood is returned to the atria from the major veins and so atrial pressure gradually increases

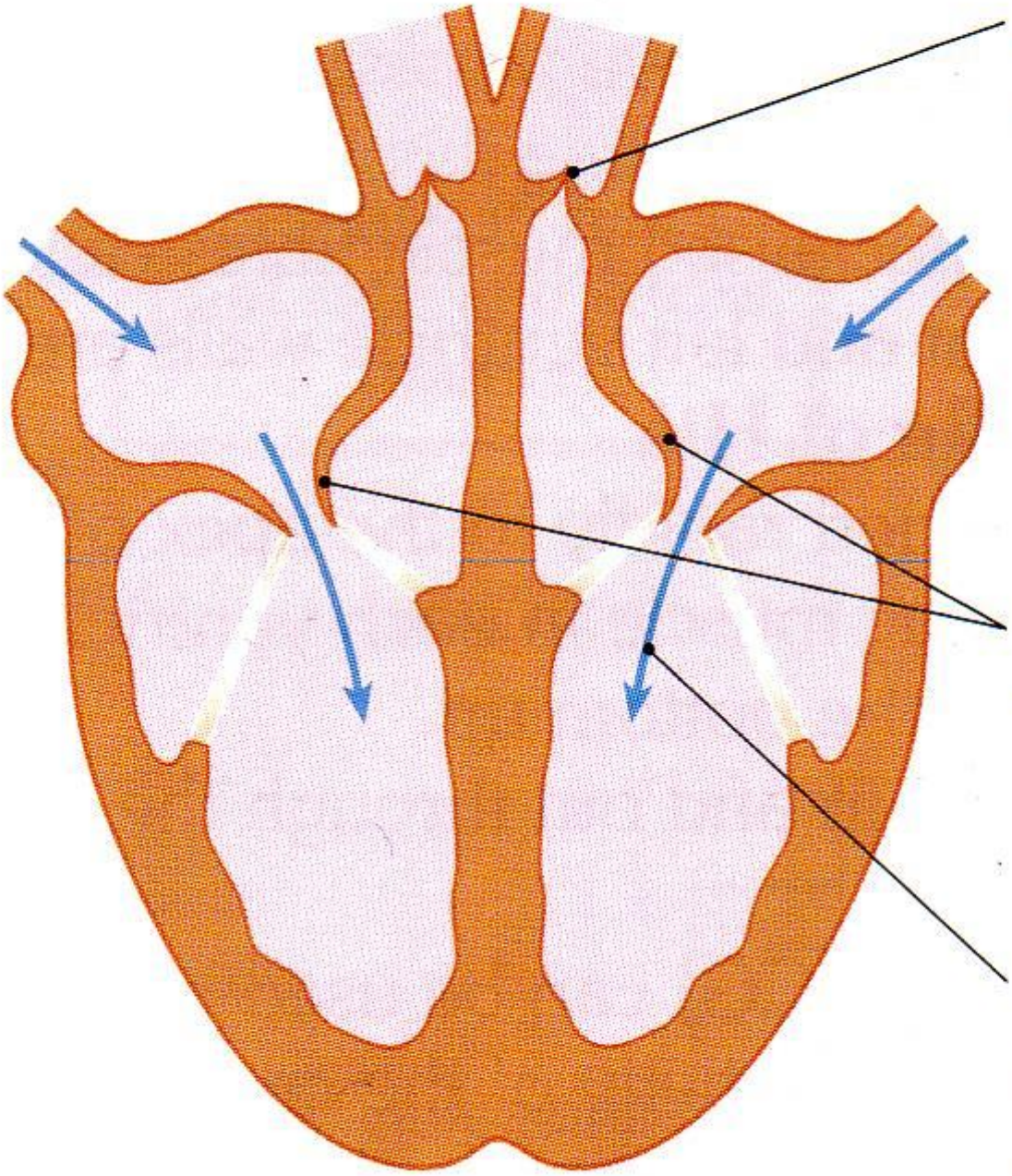
Diastole – both atria and ventricles are relaxed

- The cardiac muscle throughout the atria and ventricles relax
- 2 phases:

a) Pressure in the ventricles drops below that of the main arteries so the Semi-lunar valves are forced shut (2nd heart sound "dub"). Blood continues to return to the atria but doesn't enter ventricles yet as ventricular pressure is still higher than atrial pressure, and AV valves remain closed

b) Ventricular pressure then drops to the point where it is less than atrial pressure so AV valves are forced open and blood enters the ventricles passively from the atria

Diastole



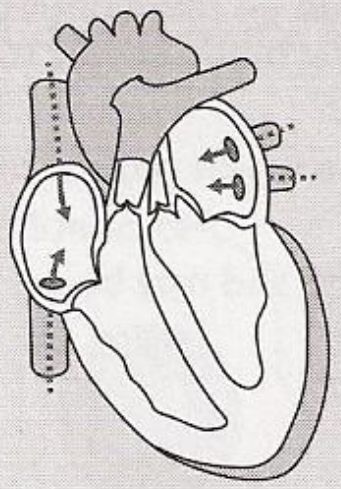
semi-lunar valves closed

bicuspid and tricuspid valves open

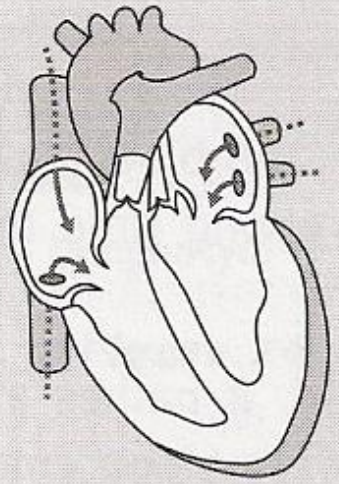
relaxation of ventricles draws blood from atria

(3) Diastole

(a)



(b)



Cardiac muscle throughout the atria and ventricles relaxes. Two phases are evident (see Figure 19):

(a) Ventricular pressure drops to become lower than that in the main arteries so the semilunar valves are forced shut. Blood continues to be returned to the atria though it cannot enter the ventricles since the ventricular pressure is still greater than that in the atria, so atrioventricular valves remain closed.

(b) Ventricular pressure drops to a point where it becomes lower than that in the atria. Therefore, the atrioventricular valves are forced open and blood enters the ventricles from the atria.

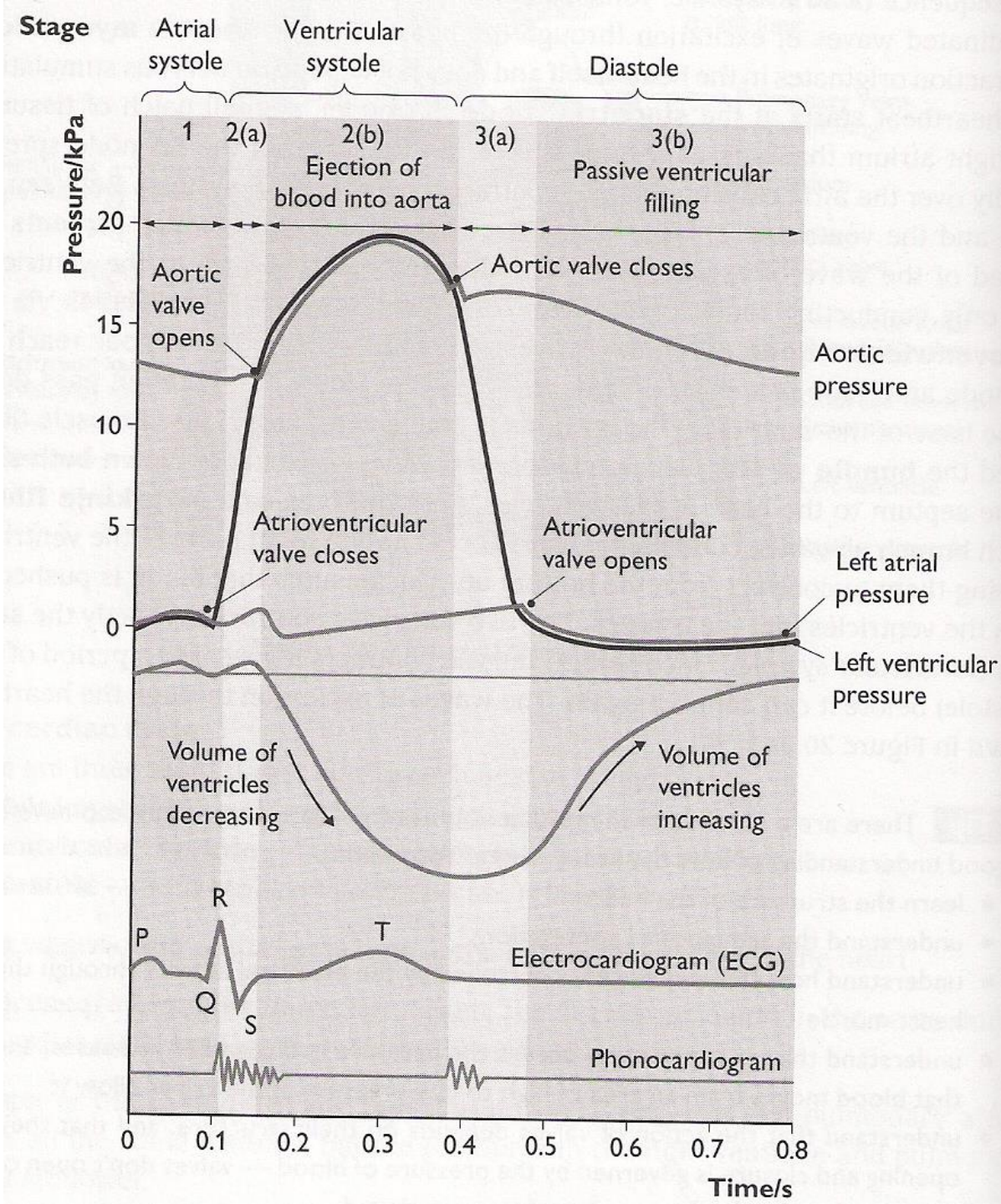
Pressure changes in the heart...

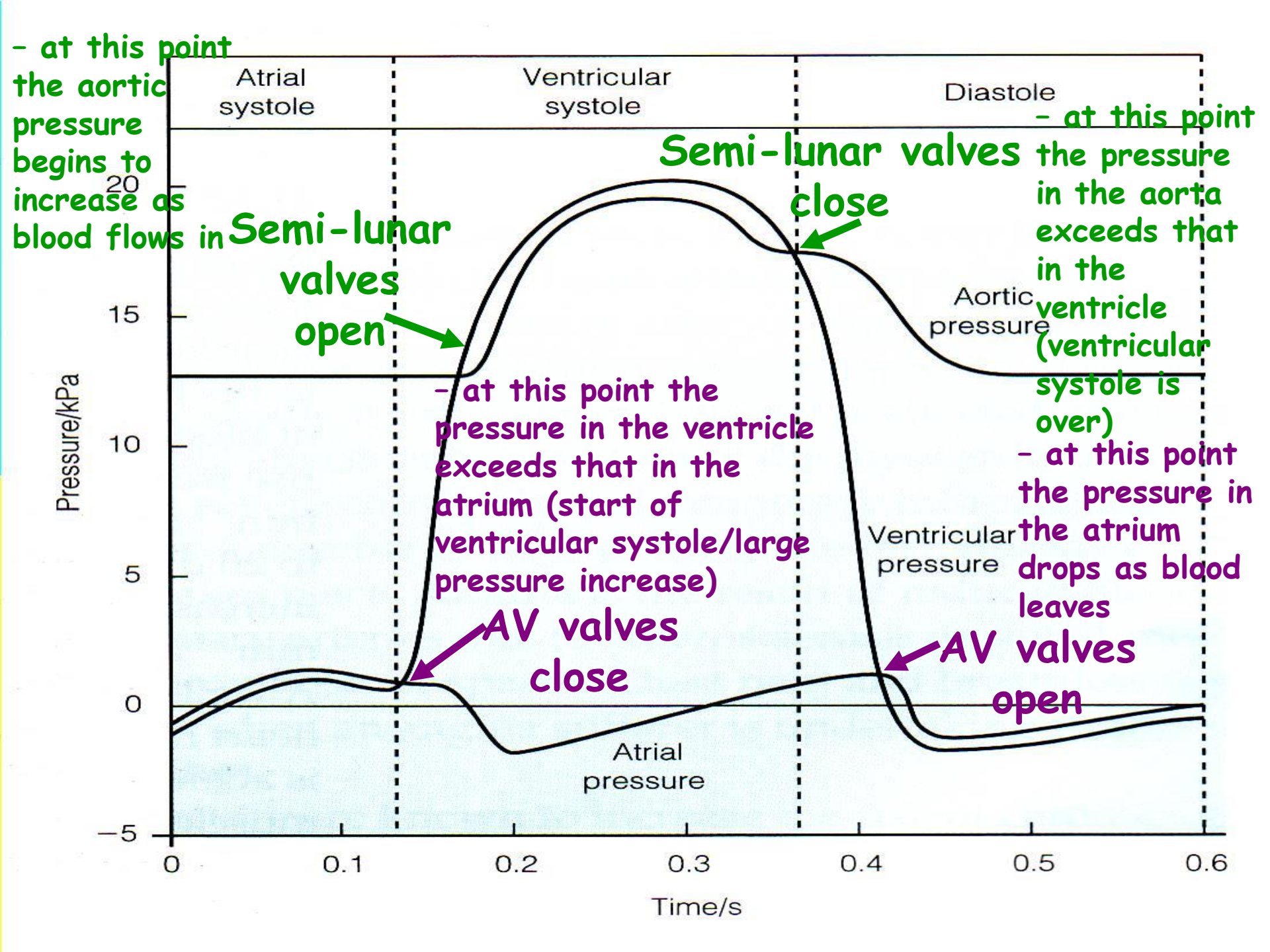
POINTS TO REMEMBER...

- Blood flows along a pressure gradient (from high to low pressure) and valves open and close in response to changes in pressure
- Atrial systole occurs just before the AV valves close, to push **any remaining blood** into the ventricles before ventricular systole
- During ventricular systole the pressure in the **atria** increases slightly as the AV valves bulge into the atrium. Remember that they don't open however as they are held by the chordae tendinae fibres
- As blood leaves the ventricles, pressure drops in the atria and then begins to increase gradually as they fill again

You should be able to interpret data showing pressure changes in the heart chambers and major arteries, such as those in Figure 19. You need to work through this graph and recognise the events of the cardiac cycle. Note that blood flows from a region of high pressure to a region of lower pressure, unless prevented from doing so by the forced closure of a valve. When valve flaps snap together a heart sound is made. Figure 19 also shows a heartbeat of duration 0.8 seconds. This equates to a heart rate of 75 beats in 1 minute (60×0.8). A very fit person may have a heart rate of 60 beats per minute. Work out the duration of one beat.

Pressure changes in left atrium, left ventricle and aorta during one cardiac cycle (with ventricular volume changes, electrocardiogram and phonocardiogram):



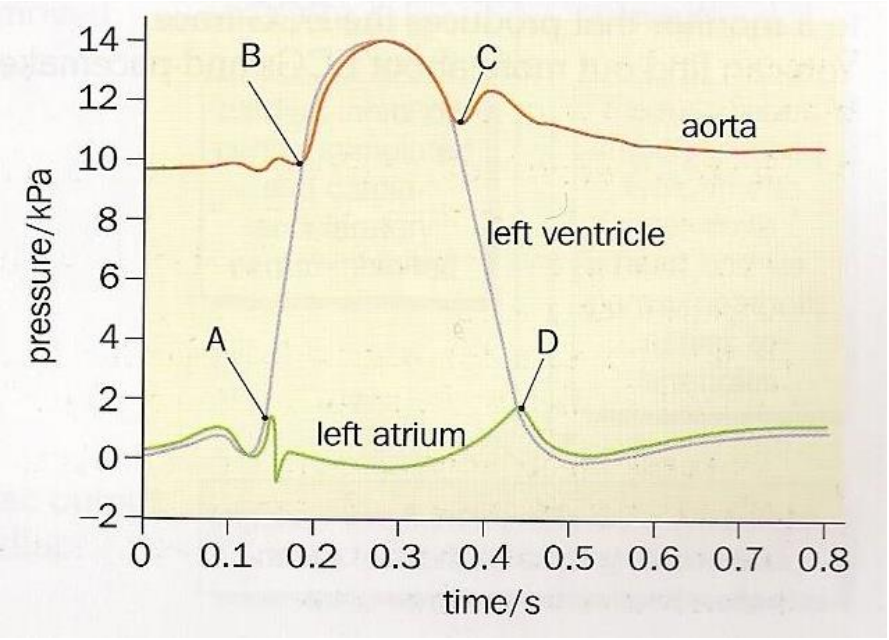

- at this point the aortic pressure begins to increase as blood flows in
Atrial systole
Ventricular systole
Diastole
Semi-lunar valves close
- at this point the pressure in the aorta exceeds that in the ventricle (ventricular systole is over)
Semi-lunar valves open
Aortic pressure
- at this point the pressure in the ventricle exceeds that in the atrium (start of ventricular systole/large pressure increase)
Ventricular pressure
- at this point the pressure in the atrium drops as blood leaves
AV valves close
AV valves open
Atrial pressure
Pressure/kPa
20
15
10
5
0
−5
0
0.1
0.2
0.3
0.4
0.5
0.6
Time/s

That graph displayed the pressure changes for the left side of the heart; how would a graph for the right side of the heart be different?

The pressure changes would be smaller as the muscular wall is thinner

Have a go at the next question – remember to think of the cardiac cycle as the 3 parts (atrial systole, ventrical systole and diastole)...

Pressure changes in the LHS of the heart during a cardiac cycle



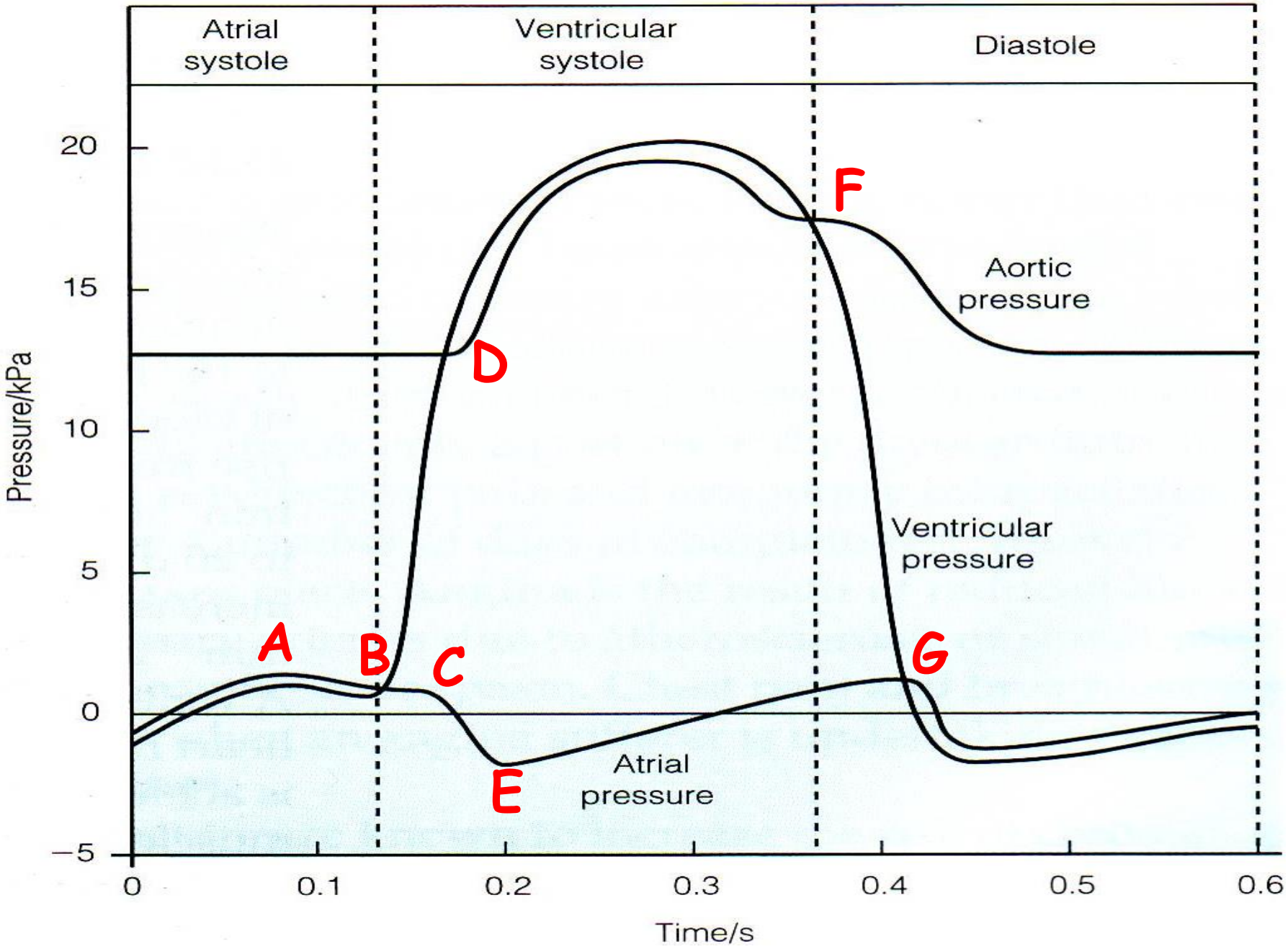
Match the letter with the following events:

- Semi-lunar valves open **B**
- Atrio-ventricular valves close **A**
- Semi-lunar valves close **C**
- Atrio-ventricular valves open **D**

How many complete cardiac cycles would there be per minute? **60/0.8 = 75**

Homework:

For each letter on the graph, relate each change in pressure to the event that is taking place


Atrial systole
Ventricular systole
Diastole
20
15
10
5
0
−5
Pressure/kPa
A
B
C
D
E
F
G
Aortic pressure
Ventricular pressure
Atrial pressure
0
0.1
0.2
0.3
0.4
0.5
0.6
Time/s

Answers:

A. Atria contract to push last of blood into the ventricles
B. The ventricles contract and pressure increases in ventricles to above atrial pressure so AV valves close
C. Atrial pressure increases slightly as AV valves bulge into them. As blood leaves ventricles there is less pressure on the atria and it's pressure drops again
D. Pressure in ventricles becomes greater than that in the arteries leaving them e.g. aorta and pulmonary artery, so semi lunar valves open
E. Blood starts to flow into the atria again from the veins e.g. vena cava and pulmonary vein – atrial pressure gradually increases
F. Pressure in arteries becomes higher than ventricles so semi lunar valves close
G. Pressure from blood in atria force AV valves open as it is higher than in the ventricles (remember it is not atrial systole yet)

Homework for tomorrow:

Cardiac cycle PPQ

(AS2 January 06 question 7)

7 **(a)** **(i)** A valve is closing (valve flaps colliding are the cause of the sound); [1]

(ii) Closure of the aortic/semilunar valve (since at that time the pressure in the aorta exceeds that in the ventricle); [1]

(b) Between 0.15 (or 0.16) s and 0.4 (or 0.39) s;
during this period the ventricular pressure exceeds that in the aorta/ aortic (semilunar) valve is open; [2]

(c) **Any two from**

- the atrioventricular (mitral) valve is closed
- since the pressure in the ventricle exceeds that in the atrium
- the valve flaps are prevented from turning inside out by chordae tendinae – papillary muscle system [2]

(d) Within the first 0.1 second;
it is during this period that the atrium is contracting/atrial pressure is greater than pressure in ventricle; [2]

COORDINATION OF THE CARDIAC CYCLE

17 March 2012
Last updated at 21:33

Share

Bolton's Fabrice Muamba collapses during Spurs-Bolton match

Bolton Wanderers midfielder Fabrice Muamba was left critically ill after collapsing during an FA Cup quarter-final tie against Tottenham.

The 23-year-old was rushed to the intensive care unit of the heart attack centre at the London Chest Hospital.

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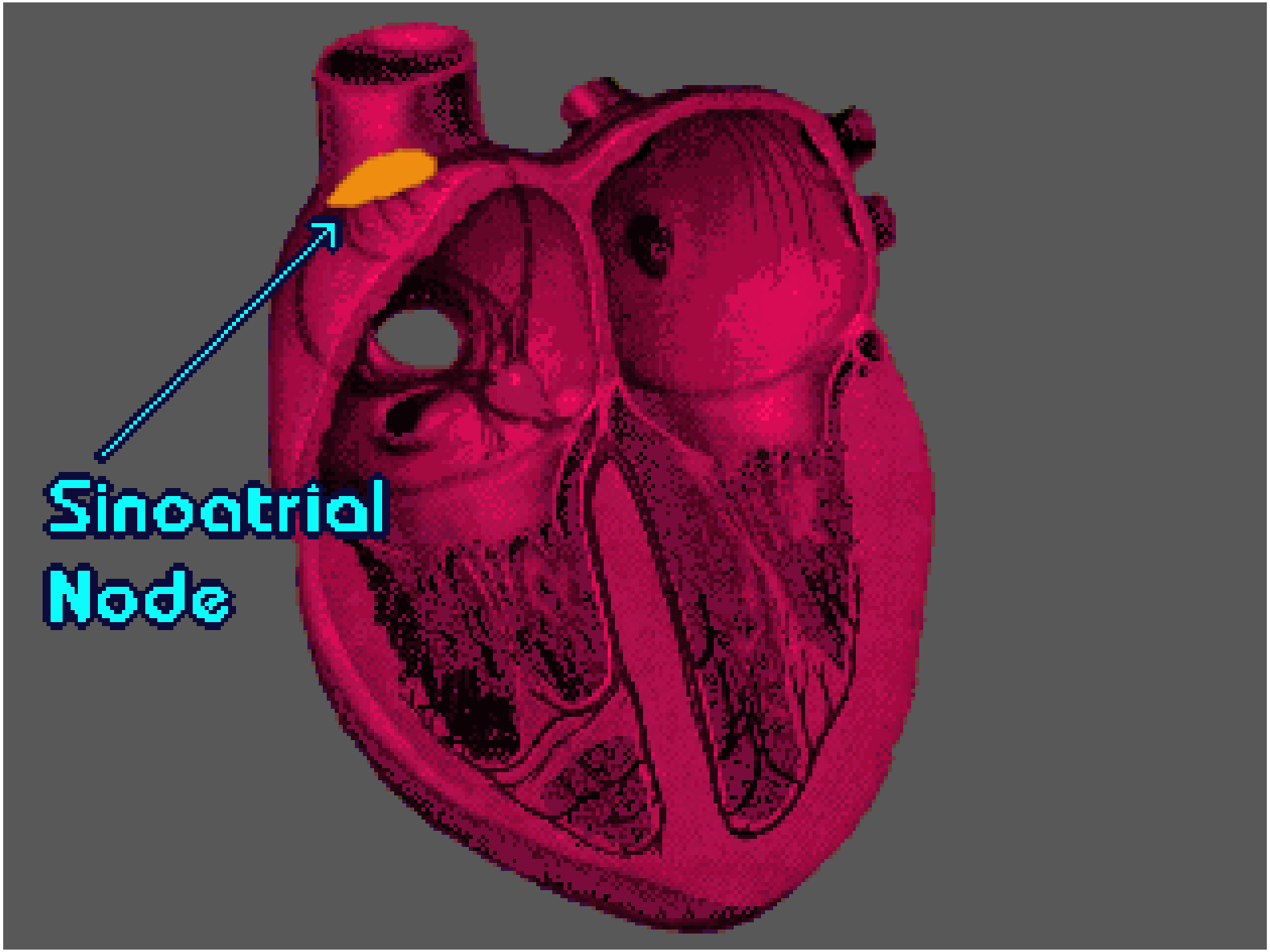
- The cardiac cycle (systole and diastole) is the result of coordinated waves of excitation/electrical activity in the heart
- Cardiac muscle is myogenic i.e. it contracts automatically without receiving impulses form the nervous system (the contraction is initiated in the heart muscle itself by the SAN)
- The heartbeat starts with an electrical signal from an area of the right atrial wall known as the Sino Atrial Node (SAN) (the "pacemaker")

Did you know?

The SAN tissue acts like a clock, contracting spontaneously and rhythmically about once a second, even when surgically removed from the heart


Sinoatrial
Node

Atrial Contraction (systole)

- Impulses initiated at SA node and the excitation wave spreads in a wave over the atrial walls
- This triggers atrial systole (both contract at the same time)
- Electrical impulses cannot pass to the ventricle muscle directly
- A sheet of non-conductive, fibrous connective tissue prevents this (collagen fibres)
- It is located between the atria and ventricles and ensures that ventricular systole follows atrial systole
- The only conductive route is through the Atrioventricular node (AV node)

Answers:

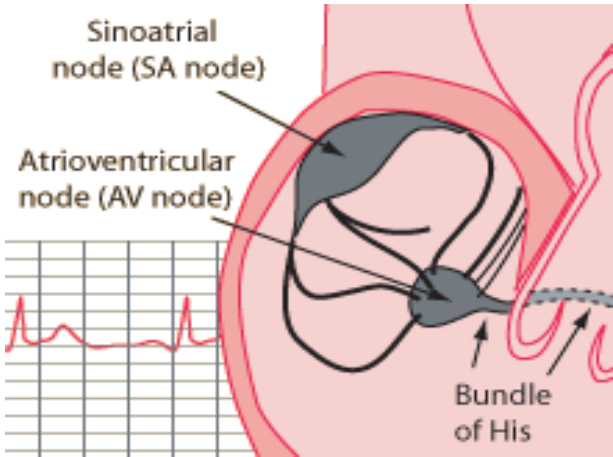
Atria must contract before the ventricles, this ensures the ventricles are filled with blood.

It is blocked by the non-conductive sheet of tissue between the atria and ventricles

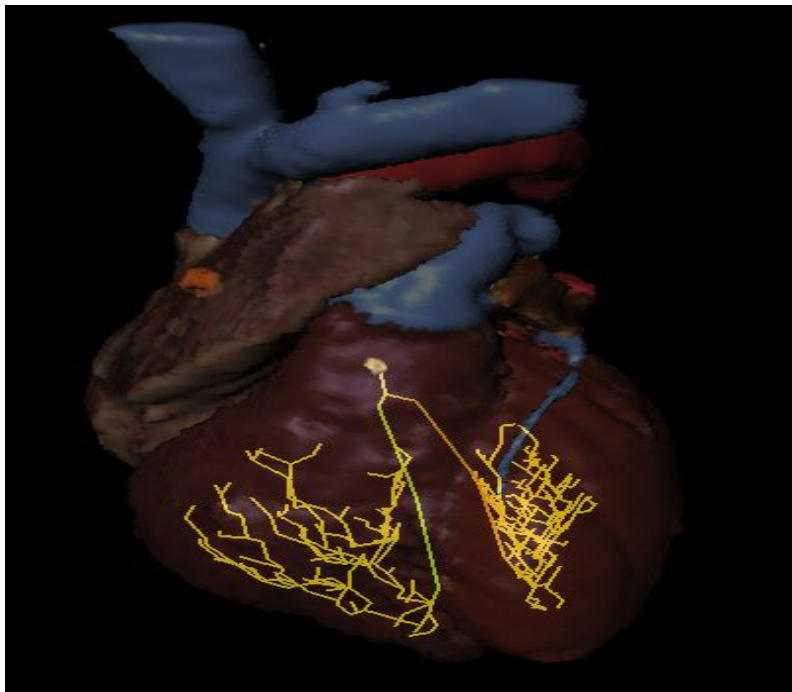
Through the AVN

Ventricular systole

- The wave of electrical impulses from the SAN activates a 2nd node, the AV node, which picks up the impulses
- There is a short time delay before the waves pass down to the base of the ventricles
- The impulses travel from the AV node, down both sides of the septum, in the bundle of His (**a bundle of specialised muscle fibres**)
- The impulses travel to the base/apex of the ventricles



- Special muscle fibres called Purkinje fibres **branch upwards** and carry the wave of excitation through the walls of the ventricles to all parts (specialised muscle fibres)
- This causes the cardiac muscle in the ventricles to contract from the bottom up so that blood is pushed up and out of the arteries
- The two ventricles contract at exactly the same time (ventricular systole)



Diastole

- Once cardiac muscle contracts it goes into a period of rest (diastole) before it can contract again

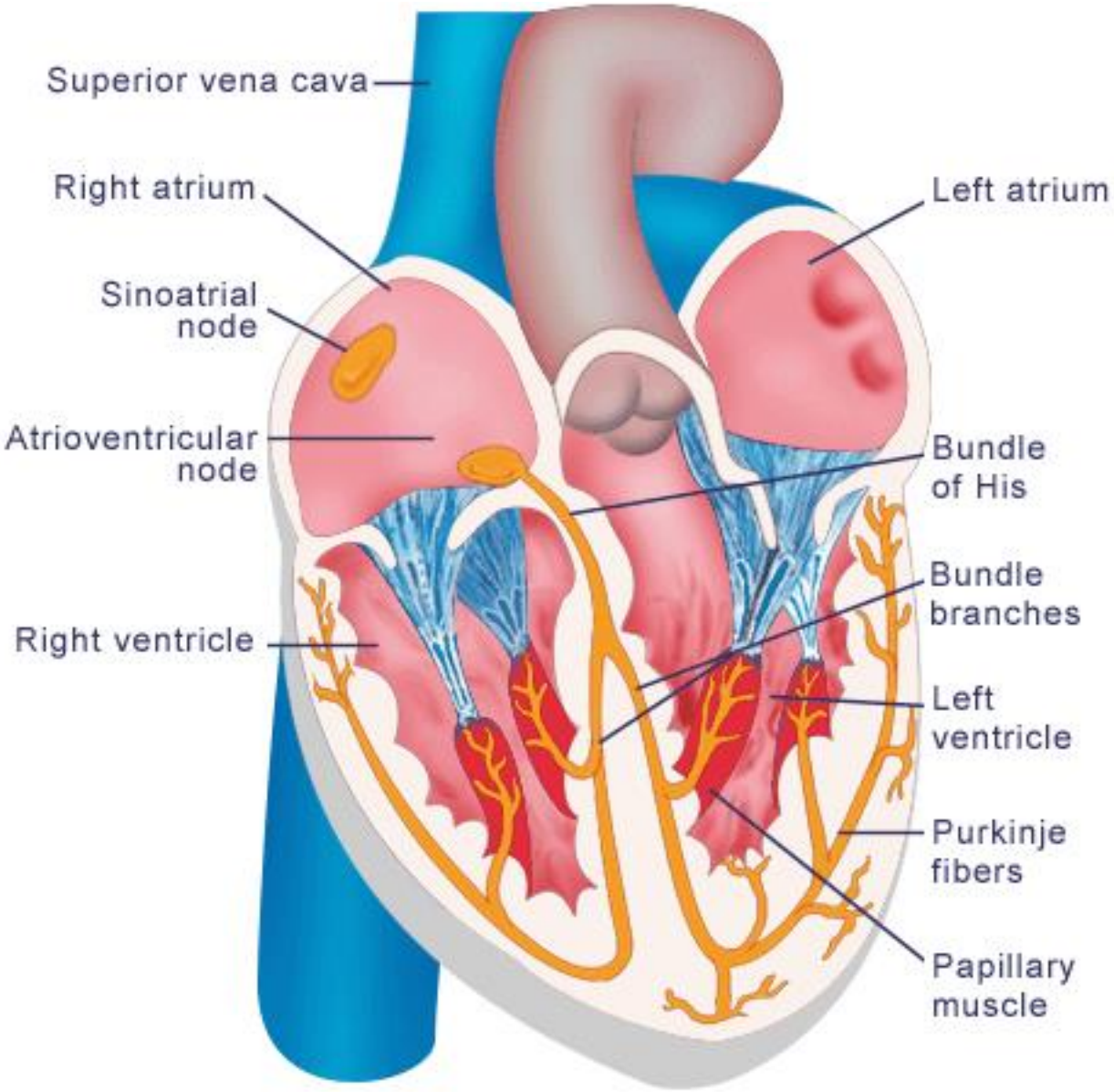
Answers:

To allow the ventricles to be filled with blood

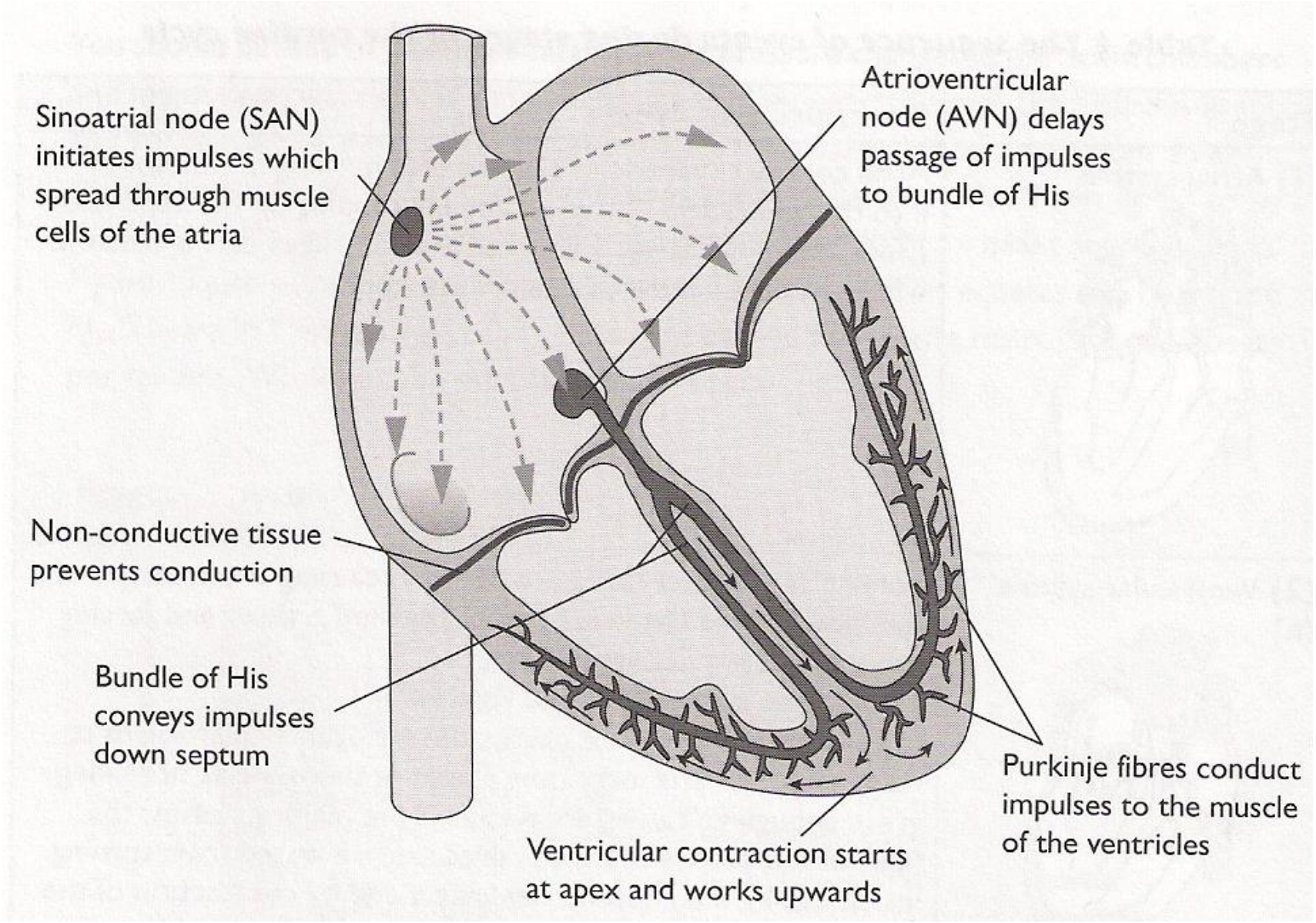
Bundle of His

Upwards, so that the ventricles contract from the bottom (apex) up to push blood out of the arteries

Purkinje fibres and Bundle of His

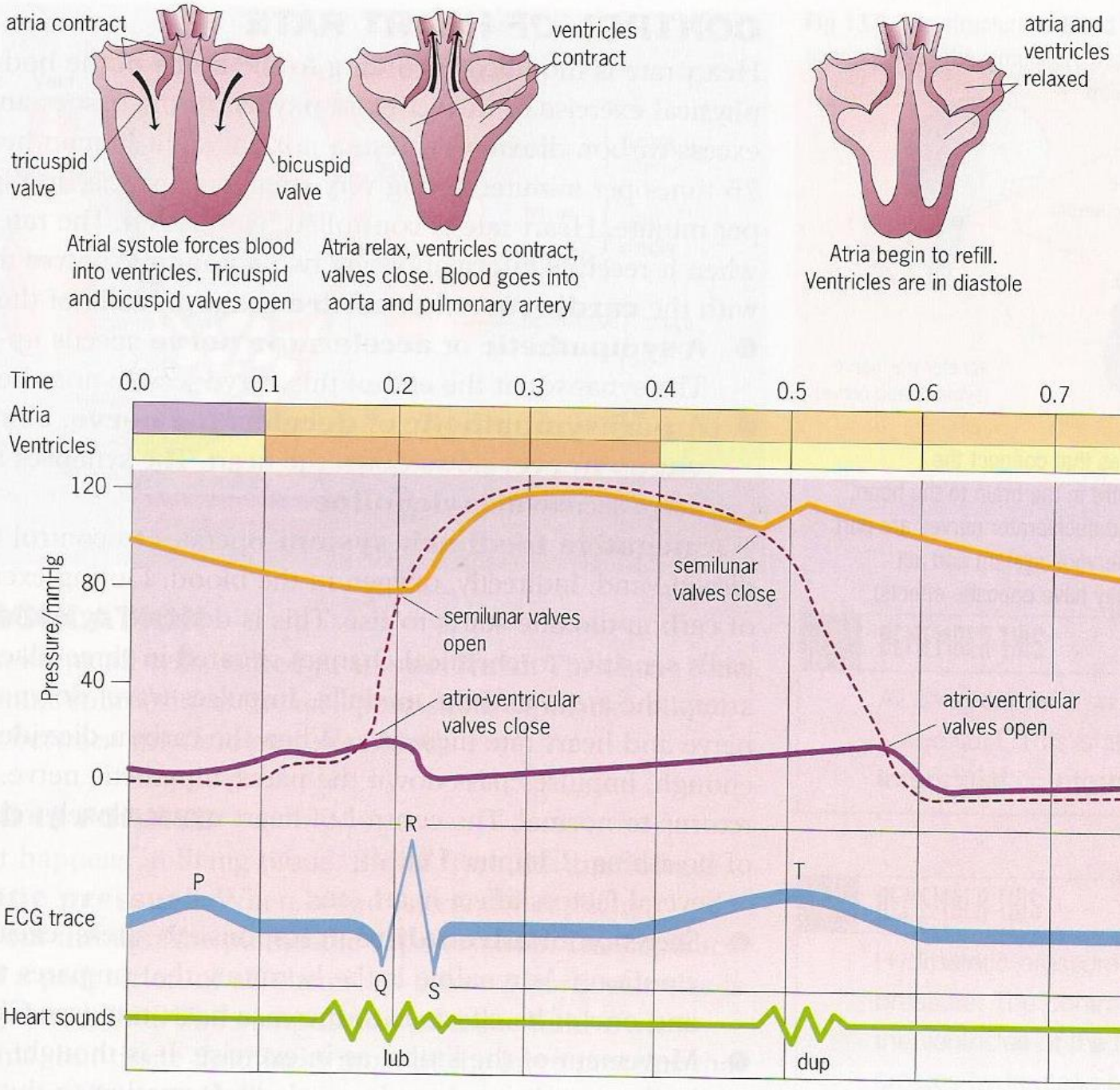


Waves of excitation through the heart – a summary:

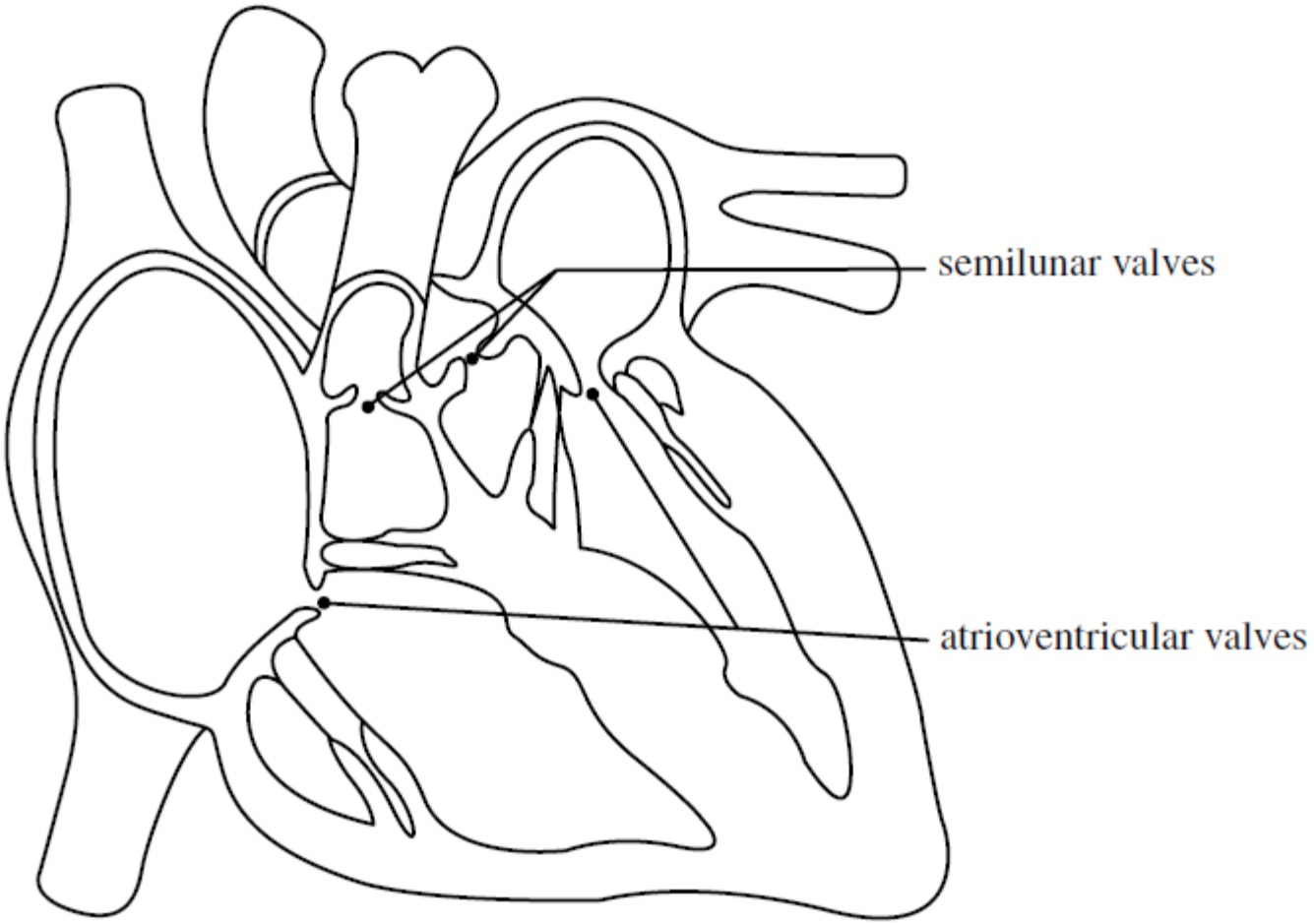


Transmission of heart beat

http://upload.wikimedia.org/wikipedia/commons/0/0b/ECG_Principle_fast.gif


atria contract
tricuspid valve
bicuspid valve
Atrial systole forces blood into ventricles. Tricuspid and bicuspid valves open
ventricles contract
Atria relax, ventricles contract, valves close. Blood goes into aorta and pulmonary artery
atria and ventricles relaxed
Atria begin to refill. Ventricles are in diastole
Key:
atrial systole
atrial diastole
ventricular systole
ventricular diastole
arterial pressure
atrial pressure
ventricular pressure
Time
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Atria
Ventricles
120
80
40
0
Pressure/mmHg
semilunar valves open
semilunar valves close
atrio-ventricular valves close
atrio-ventricular valves open
R
P
T
ECG trace
Q
S
Heart sounds
lub
dup

2 The diagram below shows a sectional view of the mammalian heart with the valves labelled.



(a) With reference to blood pressure and heart structure, explain why blood does not flow back into the atria when the ventricles contract.

June 07

2 (a) Any two from

- the atrioventricular valves close
- when the pressure in the ventricles is greater than that in the atria
- chordae tendinae (heart strings) prevent the valve flaps from turning inside out [2]

(b) The atrioventricular valves are part of a sheet of insulating tissue, that prevents the excitation wave passing directly from the atria to the ventricles.

(i) Briefly explain how the excitation wave passes into the ventricles.

_____

_____ [1]

(ii) What is the advantage of the delay caused by this arrangement?

_____

_____ [1]

(b) **(i)** Ventricles are stimulated via the atrio-ventricular node (AVN)/bundle of His/Purkinje (Purkyne) tissue; [1]

(ii) It ensures that blood flows into the ventricles before the ventricles contract/atrial and ventricular systole are not simultaneous; [1]

(c) With reference to blood pressure and structures involved, explain why blood does not flow back into the ventricles when they relax.

_____

_____

_____

_____ [2]

(c) Any two from

- Semilunar valves close
- when the pressure in the arteries is greater than that in the ventricles
- pockets of the semilunar valves fill with blood (to block the artery lumen)

[2]

As a class, represent through the media of dance, speech and motion, how the heart contracts

think about: the structures involved and how the impulse travels

KD: optional!

Homework for Monday:

Give an account of the co-ordinated sequence of events which result in the flow of blood through the heart during one cardiac cycle. [15]

Essay mark scheme:

Any thirteen points

Atrial systole:

- excitation wave is initiated at the SA-node/cardiac muscle myogenic
- electrical impulses discharged across atrial muscle triggers atrial systole
- the remaining blood is forced into the ventricles/atrial systole "tops up" the ventricle
- electrical impulses cannot pass directly to the ventricle muscle (because of a sheet of non-conducting fibrous connective tissue between the atria and the ventricles)
- ensures ventricular systole follows atrial systole

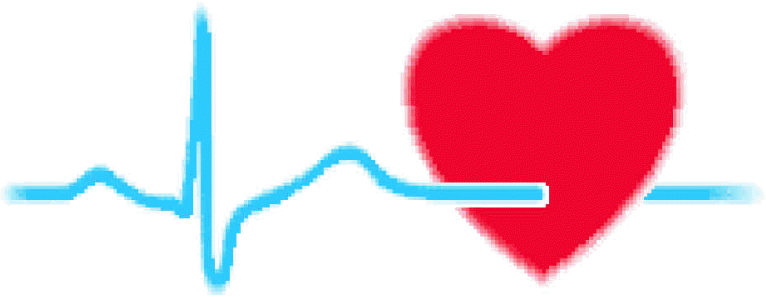
Ventricular systole:

- AV-node “picks-up” the impulses from the atrial muscle
- impulses pass along the Bundle of His and Purkinje fibres to the ventricle wall
- ventricular systole increases pressure within the ventricles
- blood pressure increases from the base of the ventricles
- blood is forced against the AV-valves which close
  (not just closed must relate to above)
- the chordae tendinae prevent the AV-valves blowing inside out (so preventing reflux of blood into the atria)
- closure of the AV-valves causes the first heart sound
- semilunar valves are blown open
- blood exits the ventricles via the pulmonary artery/aorta

Diastole:

- ventricular diastole results in a decrease in pressure within the ventricles
- semilunar valves close as “pockets” fill with blood/ventricular pressure is less than the pressure in the artery
- closure of the semilunar valves causes second heart sound
- reflux of blood into the ventricles is prevented
- blood returns to the atria from the venae cavae or pulmonary veins (also during ventricular systole)
- as atria fill with blood, pressure increases/the AV-valves are pushed open during atrial diastole
- blood moves from atria to ventricles [13]

ECG – Electrocardiogram

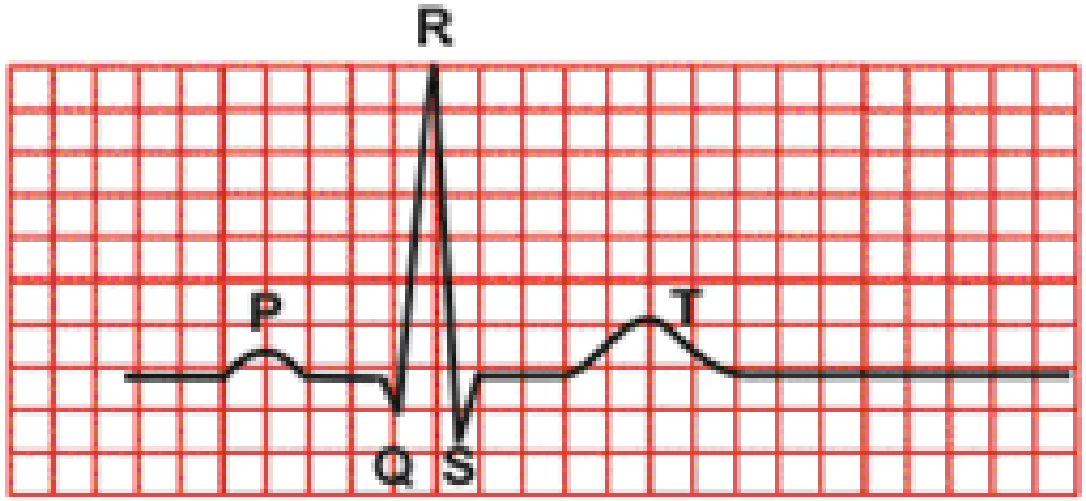


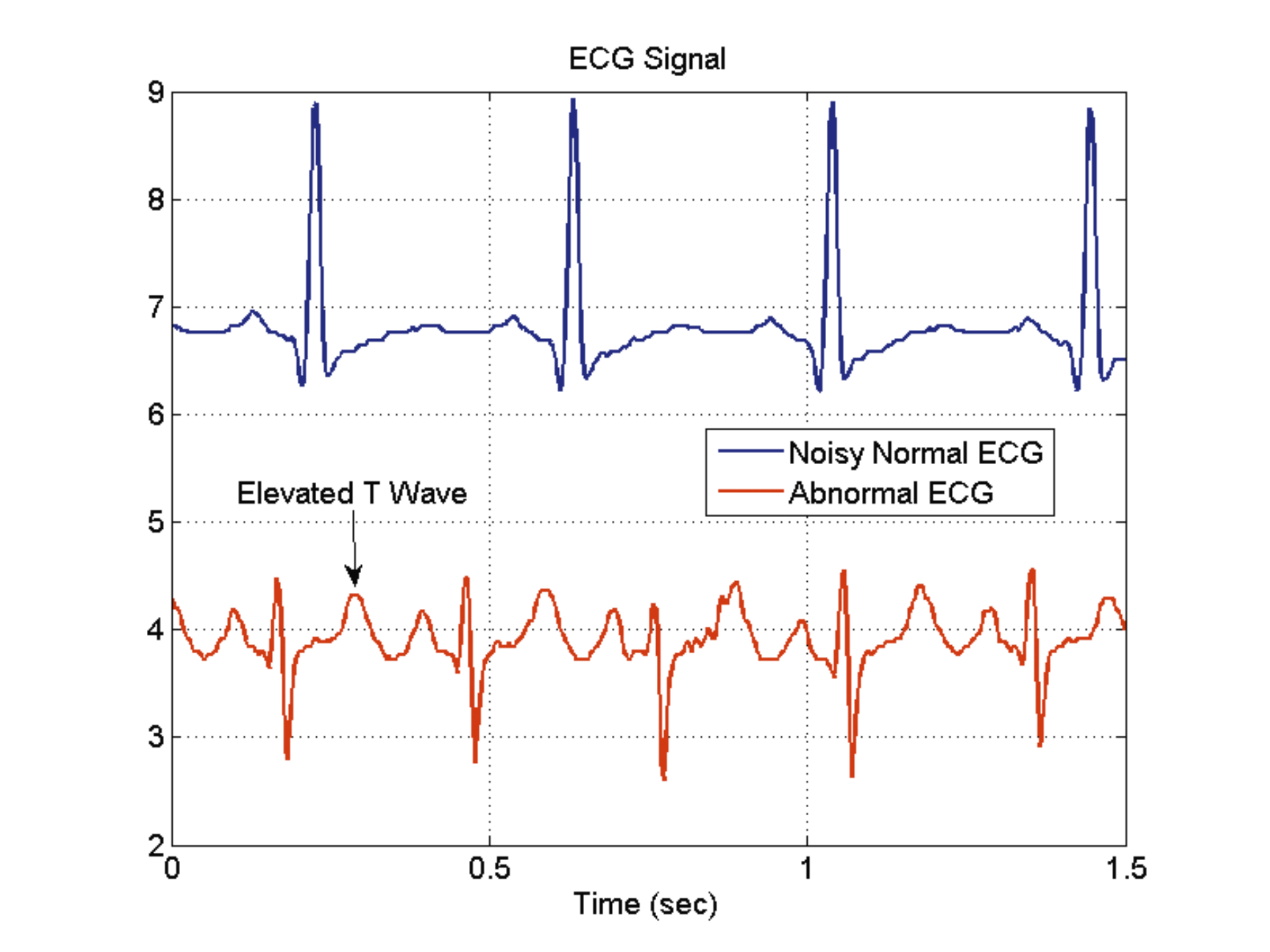
- An ECG shows the excitation wave in the cardiac cycle i.e. **the electrical activity of the heart**
- It can be used to detect irregularity in the electrical activity of a patients heart
- A normal ECG has a characteristic wave pattern of P, QRS and T waves

P - the excitiation of the atria (preceeding atrial systole)

QRS – the excitation of the ventricles (immediately precedes the contraction of the ventricles/ventricular systole)

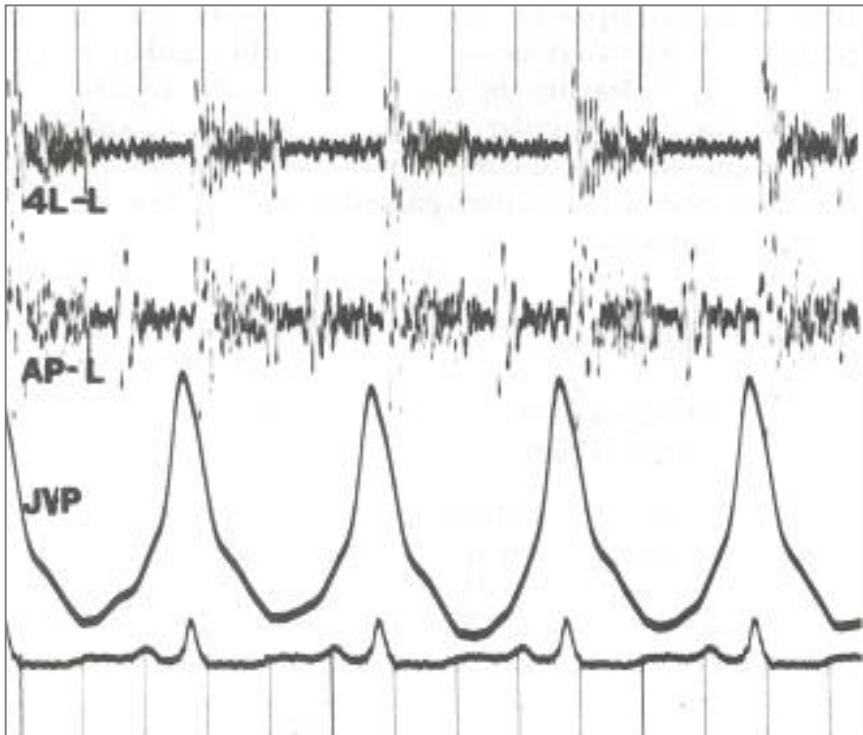
T – diastole (ventricles and atria now both relaxed)

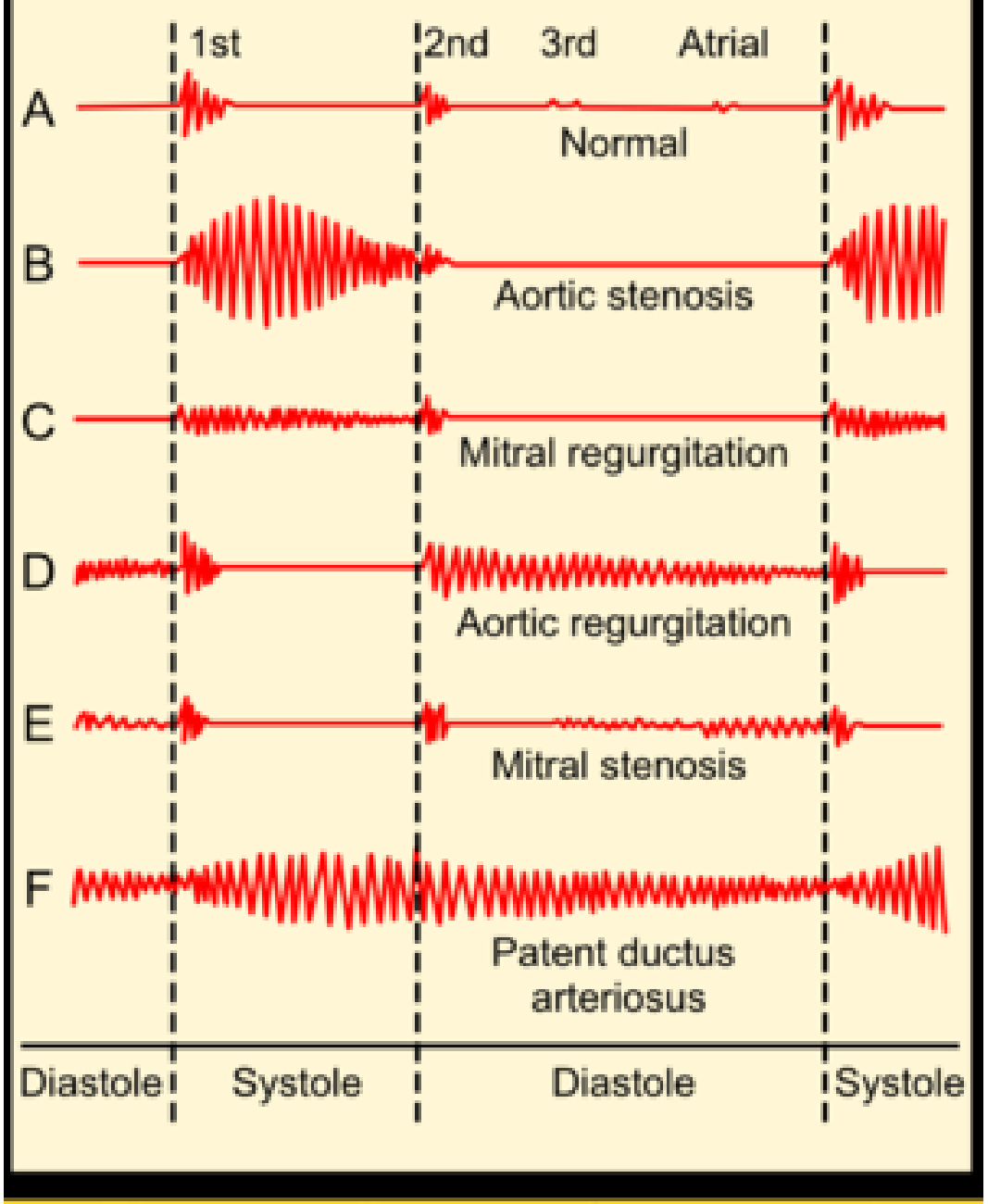



ECG Signal
9
8
7
6
5
4
3
2
0
0.5
1
1.5
Time (sec)
Noisy Normal ECG
Abnormal ECG
Elevated T Wave

The sounds of the heart can be recorded by a phonocardiograph and a phonocardiogram produced

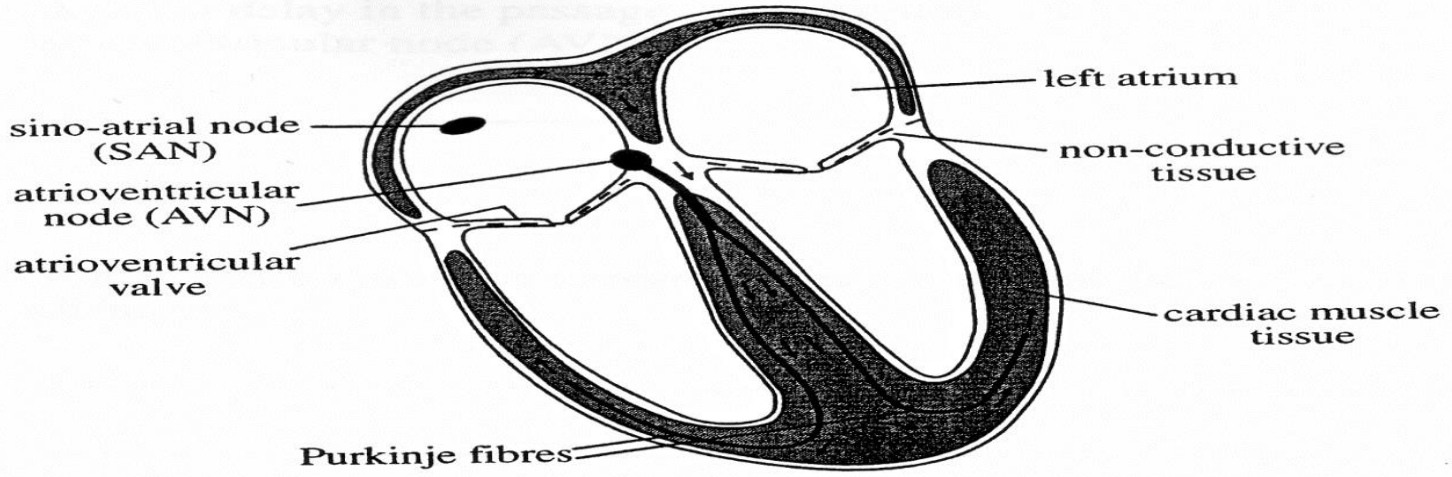
- When the flaps of tissue that are the valves close, subaudible vibrations or murmurs are created which can be detected by a high fidelity microphone
- These sounds are not picked up through a normal stethoscope
- The closing of the semilunar valves is louder than the closing of the atrioventricular valves
- The information yielded can indicate disease and also be used to study effects of drugs on a patient





Phonocardiograms from normal and abnormal heart sounds

The diagram below is a simplified representation of a mammalian heart. Certain regions of the heart are identified.



(a) Using the information in the diagram and your own understanding, describe how the wave of excitation spreads through the heart during a cardiac cycle.

Wave of electrical activity begins in the SAN which stimulates the atrial systole by travelling along the atrial wall to the AV node. After a delay, the AVN generates a stimulus that travels to the apex of the ventricles from the bundle of his along purkinje fibres and stimulates ventricular systole from the base of the ventricles up.

[3]

Jan03

(b) Explain why the wave of excitation through the atria cannot be transmitted directly to the ventricles.

The ventricles are electrically insulated from the impulse from the SAN by collagen fibres. The electrical impulse can only pass through the AVN which causes a delay in the wave until the atria are empty/ventricles are filled

[1]

(c) Suggest why each of the following is important for the efficient pumping of blood through the heart.

(i) A slight delay in the passage of the excitation wave at the atrioventricular node (AVN).

So that the atria and ventricles don't contract together (so the ventricles can fill with blood before ventricular systole)

[1]

(ii) Ventricular contraction (systole) is initiated from the bottom of the chambers.

So that all the blood in the ventricles is forced out through the arteries at the top of the heart

[1]

Jan03

Practicals:

Examine slides of blood vessels and mammalian heart

- *Distinguish between arteries, veins and capillaries*
- *Identification of heart chambers, AV valves, semilunar valves, chordae tendinae, papillary muscles, interventricular septum, major blood vessels (vena cavae, pulmonary artery and aorta)*

"Excuse me, sir, would you mind getting the door for us?"