INTRODUCTION TO THE CARDIOVASCULAR SYSTEM

INTRODUCTION

The first part of this class is an introduction to the cardiovascular system and requires you to complete the following text, by filling in the correct responses. There are then two further exercises that require you to work in groups. In exercise 1, working in pairs, you will learn the technique of indirect arterial blood pressure measurements. In exercise 2 you will work in groups of 4 and dissect a sheep's heart.

The cardiovascular system comprises the heart, which pumps the blood, and the blood vessels through which the blood flows.

Figure 1A is a schematic representation of the mammalian cardiovascular system. Note that there are two circuits: One in which blood is pumped from the right ventricle to the lungs and back to the left atrium. This is the **1**.__***Pulmonary***__________ circulation. In the other circuit, blood is pumped from the **2**.__***left ventricle***__ to the various organs and tissues, (via their individual circulations) and then returns to the **3**. _***right atrium***_ via the venae cavae. This is the **systemic** circulation.

In Figure 1B each individual organ or tissue system is supplied by **4**._***large arteries***_ leaving the aorta. These vessels divide into smaller vessels, the **5**.__***small arteries***_ and these branch into **6**.___***arterioles***_____ and finally **7**.___***capillaries***___. These very small vessels then reform into slightly larger vessels, the **8**.___***venules***____ which join to form **9**.___***small veins***__ and then **10**.___***large veins***_. These vessels empty into the **11**._***superior venae cavae***_ or **12**._***inferior venae cavae***__ which then enter the right atrium of the heart. As vessels divide into successively smaller vessels they become more numerous so that the capillaries, which have the smallest diameter of any of the vessels are also the most common.

THE HEART

The heart is a muscular organ located in the thoracic cavity. It is covered by a fibrous sac, the **pericardium**. The walls are composed of cardiac muscles, the **myocardium** and the inner surface is covered by a thin layer of cells, the **endocardium**. In Figure 2A note that the heart has a number of chambers or cavities. How many chambers are there and what are they called? **13**. __***4 chambers, L & R atrium and L & R ventricles***__.

There is no direct communication between the left and right sides of the heart in adult mammals. Note that there are valves between the atria and the ventricles and between the ventricles and the vessels. The valves between the atria and the ventricles are the **atrio-ventricular (A-V) valves**. These permit flow from the atria to the ventricles but not in the reverse direction. The valve between the left atrium and the left ventricle has two cusps and is called the **14**.__***bicuspid***___ or **15**.___***mitral***__ **valve**. The A-V valve between the right atrium and the right ventricle has three cusps and is called the **16**.___***tricuspid***_____**valve**. These valves are connected to the **17**.____***papillary***_______ **muscles** by the threadlike **18**.__***chordae tendinae***____ which prevent the valves from being sucked into the atria.

The ventricles open to large vessels, the left ventricle to the **19**.___***aorta***___ and the right ventricle to the **20**.___***pulmonary artery***___. The openings are guarded by the pocket-like **21**.__***semi - lunar***_ **valves**. There are no true valves between the atria and the incoming veins, the **22**.___***vena cavae***___ on the right and the **23**.__***pulmonary veins***_ on the left.

Figure 1A: Schematic Representation of the mammalian circulatory system

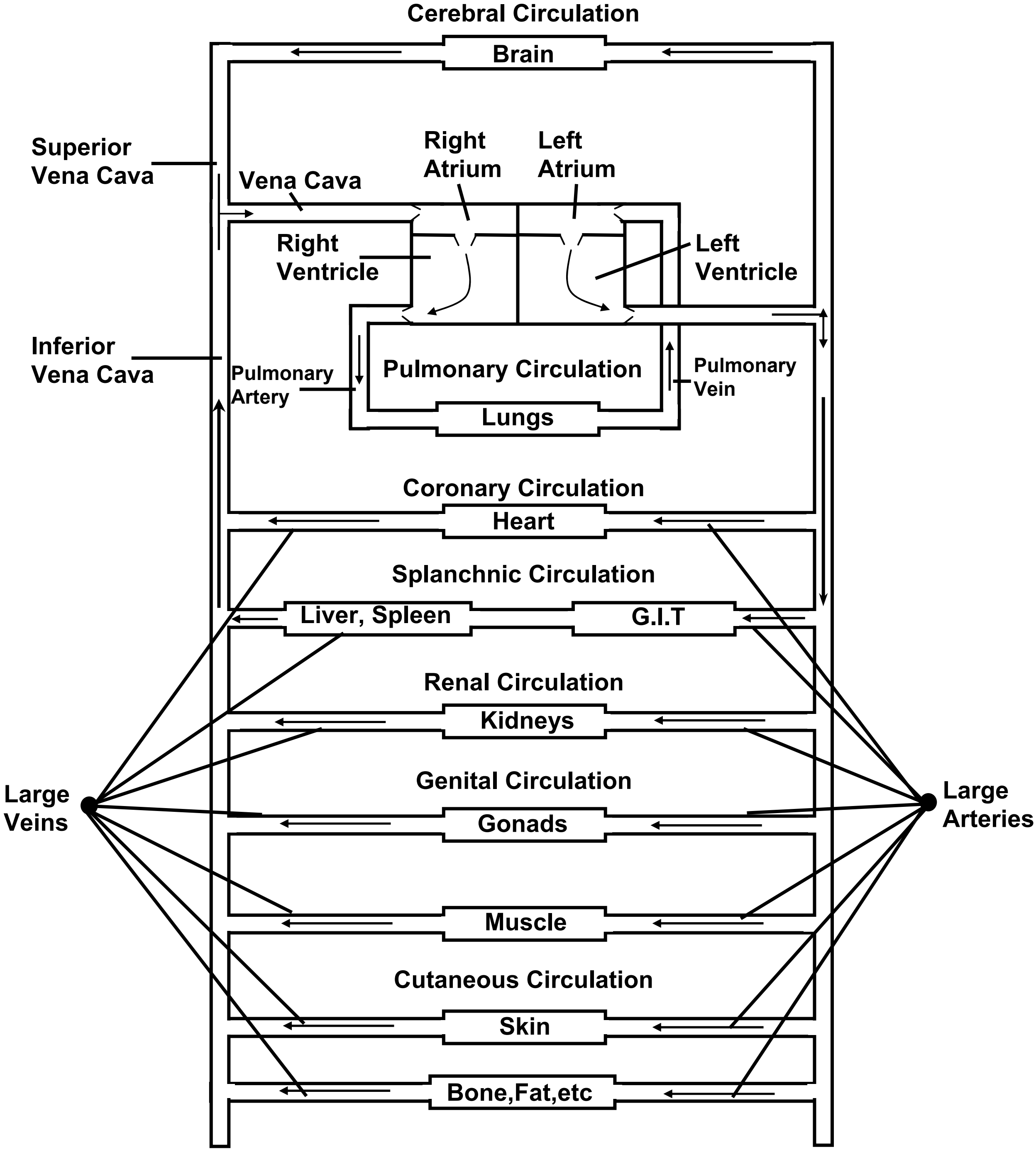


Figure 1B: Composition of an organ or tissue circulation

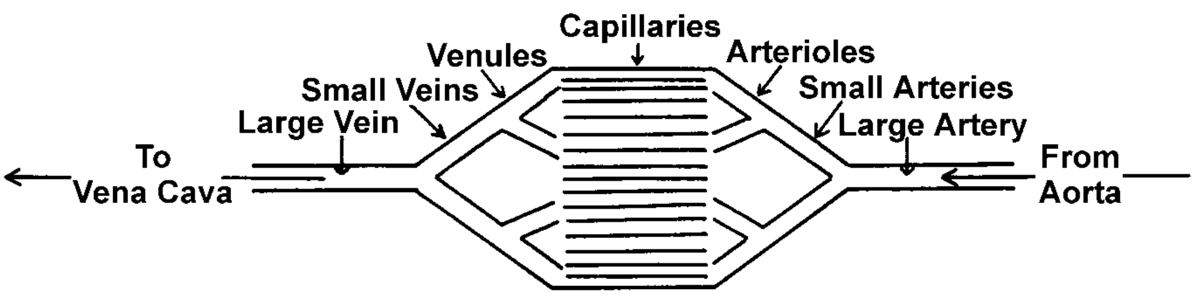


Figure 2A

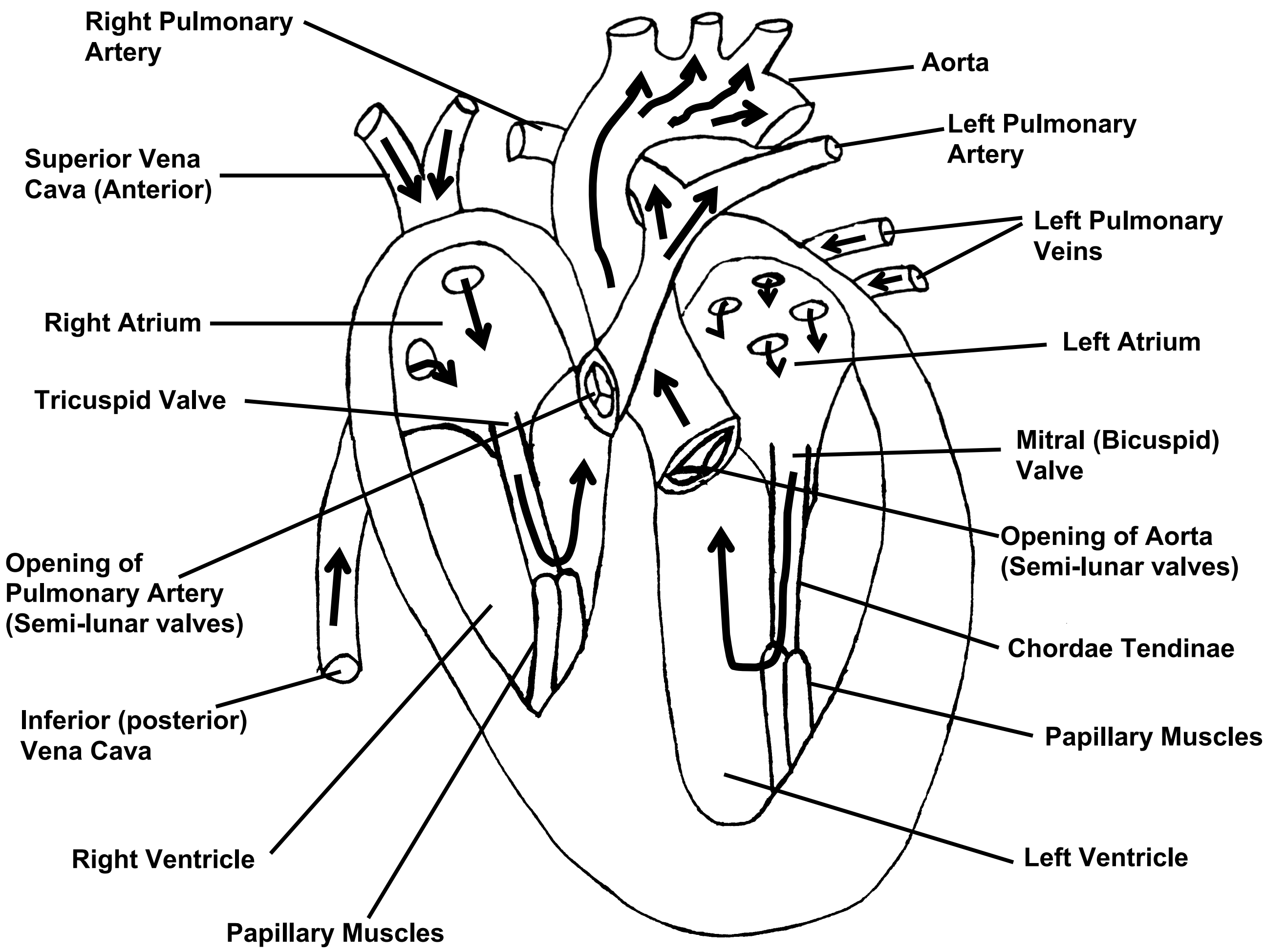


Figure 2B

The cells constituting the walls of the heart do not exchange nutrients and metabolic end-products with the blood in the heart chambers. They receive their blood from arteries which arise from the aorta. Look at Figure 2B. These are the **24.**___***coronary***___ **arteries.** Note also that the circulation to the heart is shown as a separate circulation in Figure 1A.

The contraction of the cardiac muscles is initiated by the depolarization of the membranes of certain cardiac fibres in specialised areas. These cardiac cells are capable of spontaneous, rhythmic self-excitation and are therefore said to be **autorhythmic**. Figure 3 shows the ***electrical conducting system*** in the heart. There are 3 main areas of spontaneous activity where contraction may be initiated. The area with the fastest spontaneous rhythm will be the "pacemaker". This area, where excitation in the heart usually originates is situated at the opening of the superior vena cava into the right atrium and is called the **25.**__***SA node***__. The wave of excitation spreads across the atria to another group of pacemaker cells at the junction of the right atrium and the ventricles called the **26.**__***AV node***__ and then enters the wall between the two ventricles via the conducting system fibres termed the **27.**_***Bundle of His***_. This then divides into right and left bundle branches and from these **28.**__***purkinje fibres***__ extend and spread throughout the ventricular myocardium. The electrical events of the heart can be recorded as the **electrocardiogram (ECG or EKG).**

The ***mechanical events*** of the heart immediately follow the electrical events. Figure 4A shows the heart, or more specifically the valves, in the heart during the relaxation phase. Note that the **29.**__***atrioventricular***__ **valves** are open while the **30.**_***semi - lunar***_ **valves** are closed so that blood does not flow out. Figure 4B shows the ventricles in the contraction phase called **systole.** During this phase blood is pumped from both ventricles into the circulation. The **31.**__***semi - lunar***__ **valves** are open to permit this to occur.

In the adult person each ventricle pumps 70-80ml/beat **(the stroke volume).** Since the **heart rate** is about 65-75/min, the **cardiac output** (or volume pumped from either ventricle each minute) must be about **32.**___***4.5 to 6***_____ litres/min. Note that each ventricle must pump equal volumes of blood per beat. Therefore, the cardiac output may refer to either ventricle.

THE BLOOD VESSELS

Arteries are blood vessels that conduct blood away from the heart. Figure 5A shows the distribution of the main arteries in man. Figure 5B gives a more detailed description of blood vessels in the upper thorax and neck region.

The main artery from the heart to the systemic circulation is the **aorta**. Note that it ascends from the left ventricle, arches over and then descends on the posterior (or dorsal) side of the heart. Look at Figure 5B. Note the main artery on the right side is the **33.**_***brachiocephalic***__ or **34.**_***innominate***__ **artery** which branches, a little further up, into the **35.**__***right subclavian***__ **artery** and the **36.**__***right common carotid***_ **artery**. The corresponding arteries on the left side i.e. the **37.** _***left subclavian***__ **artery** and the **38.**__***left common carotid***__ **artery** arise separately from the aortic arch.

Trace the **common carotid artery** to where it bifurcates into the **internal carotid** and the **external carotid arteries**. At this point there is a slight dilation (or swelling) of the artery forming the **39.**____***carotid sinus***____. This is a collection of mechanoreceptors sensitive to blood pressure changes called baroreceptors. Note also another structure, the **carotid body**. This is a collection of chemoreceptors which is important in detecting and regulating blood oxygen content. Both these structures are innervated by branches of the **glossopharyngeal nerves**.

Figure 3: Electrical conducting system of the heart

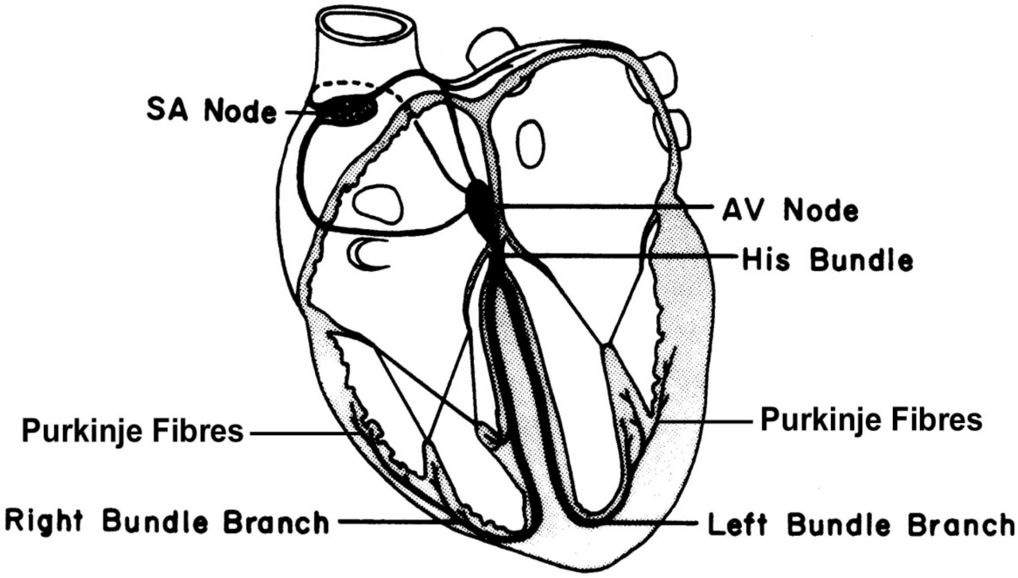


Figure 4A & B: Direction of blood flow in the heart during diastole and systole

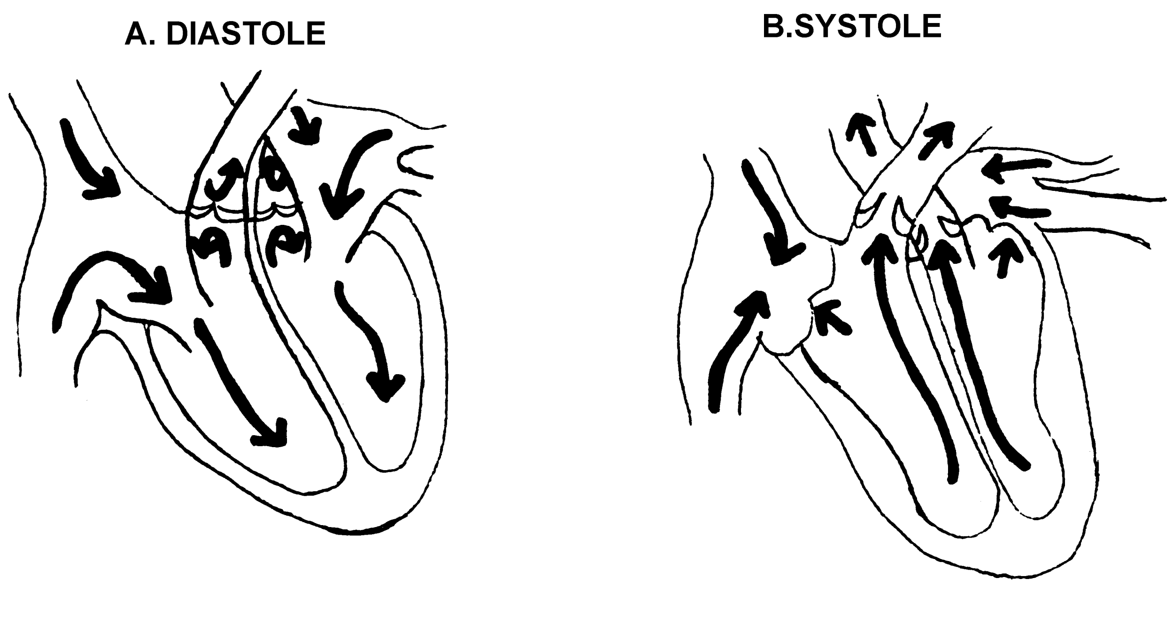


__Figure 5A: Main arteries of the body__

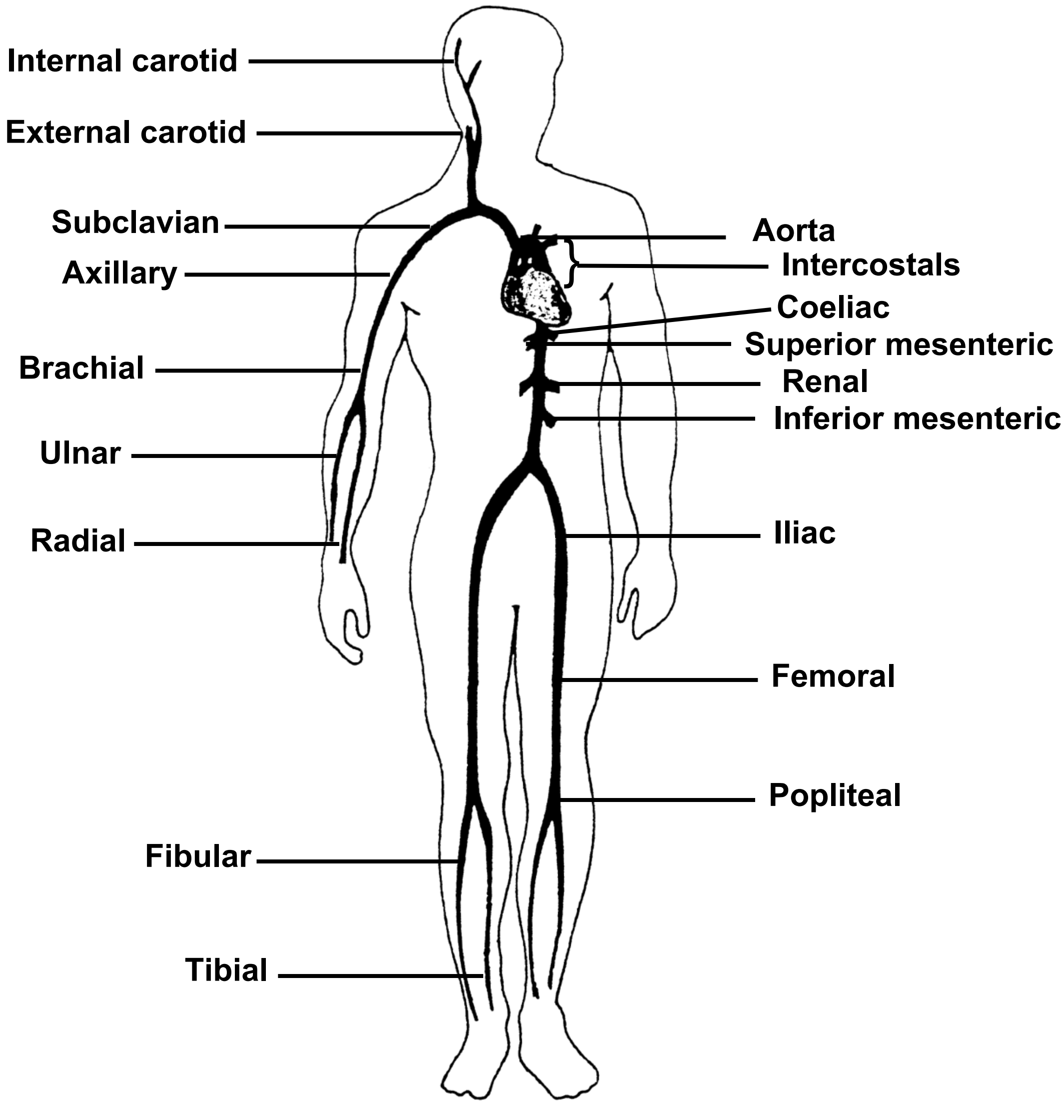


__Figure 5B: Vessels of the trunk and neck__

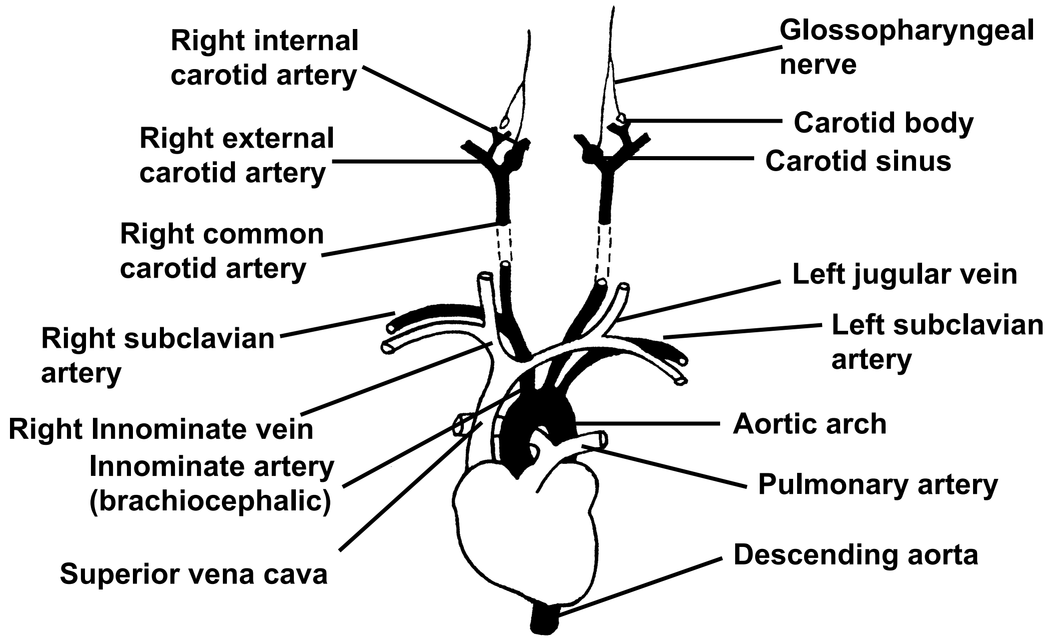
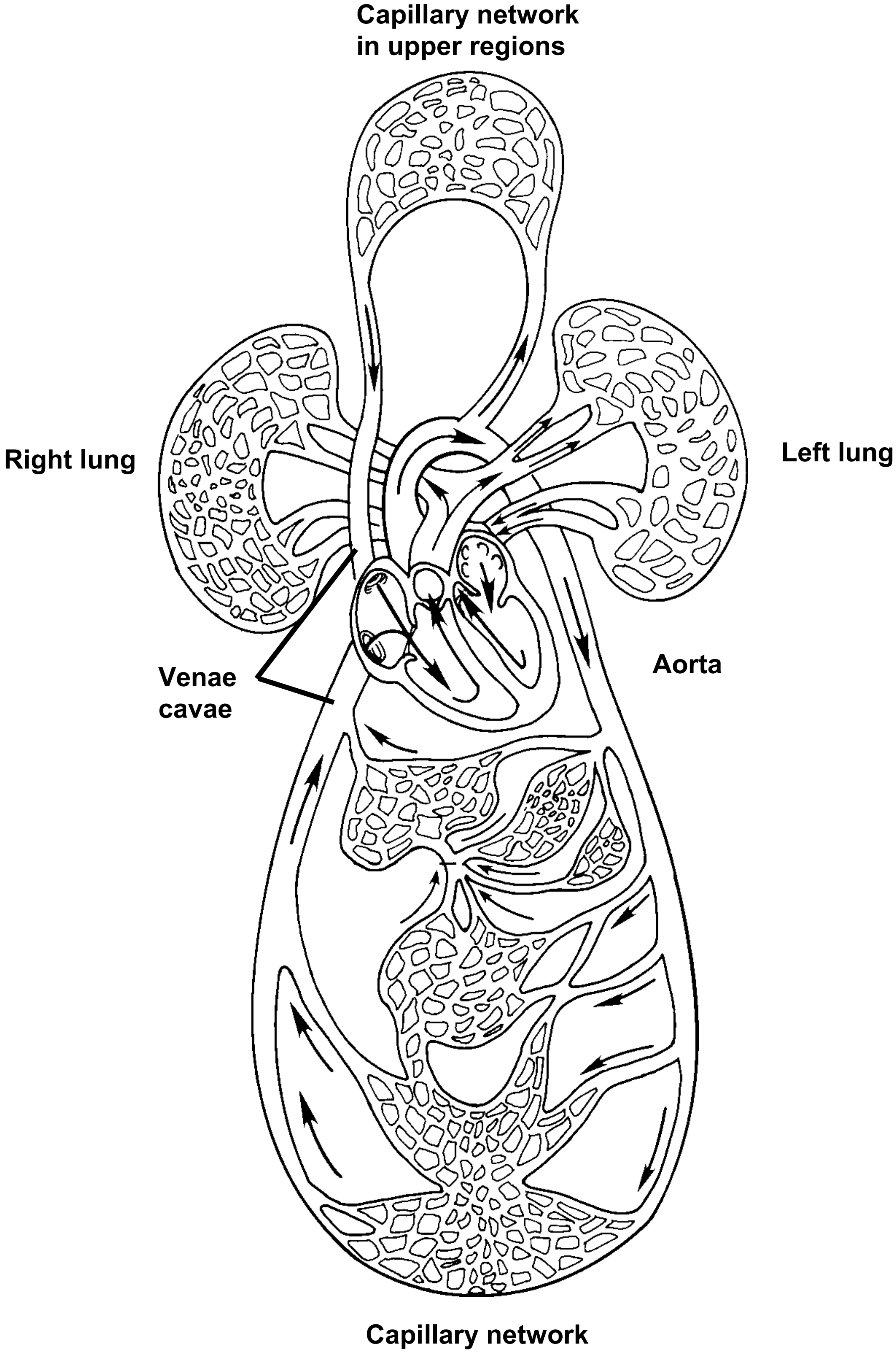


__Figure 5C: Schematic representations of pulmonary and systemic circulation__

(Modified from Principles of Anatomy and Physiology; Learning Guide for Tortora & Grabowski).



Look now at Figure 5A and study the arterial supply to the arm. Note that the **subclavian artery** becomes the **40**.___***axillary***___ **artery** and further on the **41**.___***brachial***____ **artery** in the upper arm. This then divides into the **42**.____***ulnar***____ and **43**.____***radial***____ **arteries** in the lower arm.

Now look at the arteries in the trunk region. A number of arteries go from the **aorta** to the rib region. These are the **44**.___***intercostal***___ **arteries**. Note the arteries that originate from the descending **aorta** which supply the various organs, e.g. the kidneys, the gonads and the gastrointestinal tract. The **coeliac artery** usually divides into the **hepatic**, **splenic** and **left gastric arteries**.

The **aorta** divides into the left and right **iliac arteries** in the lower abdominal region. The main artery in the upper leg is the **45**.___***femoral***___ **artery**. It becomes the **46**.___***popliteal***____ **artery** at the knee before it divides into the **47**.___***fibular***_____ and **48**. ____***tibial***__ **arteries** in the lower leg.

The vascular system is a series of connected vessels which can be classified into different types due to differences in structure and function that is, the different types of vessels will be considered "in series". **Arteries** divide into **arterioles** which in turn divide into **capillaries**. These join into **venules** which in turn join into **veins** which are the blood vessels conducting blood back to the heart. See Figure 1A.

The distribution of the main veins in humans is similar to that of the arteries. Names of the veins are also the same as the corresponding arteries in most cases. However, the main veins draining the neck region are the **jugular veins** (see Fig. 5B) which then drain to the **innominate vein** and the **superior vena cava**. The main vein from the lower body region is the **inferior vena cava**. The junction of these vessels with the heart can be noted in Fig. 2A.

Now consider the **structure of the blood vessels**. In general all vessels are said to have three analogous zones (coats or tunica) i.e. the **tunica intima** (on the inside), the **tunica media** (in the middle) and the **tunica adventitia** (on the outside). The **tunica intima** generally consists of a single layer of **endothelial cells** that provide a low-friction lining. This is the one structural component that is common to all the blood vessels and the heart. The endothelial cells are generally supported by a sub-endothelial layer of connective tissue with a predominantly longitudinal section. The fibromuscular **tunica media** has a circumferential organization while the **tunica adventitia** is a **connective tissue coat** with largely longitudinal organization.

We can now consider the structure of the various "series-coupled" sections of the vascular system, ie. the **arteries, arterioles, precapillary sphincters, capillaries, venules, veins** and sometimes **shunt vessels**, and try to relate the structure to the function of the vessels. Look at Table 1. Note that the different vessels have different diameters and varying amounts of elastic, muscular and collagenous tissues.

Large arteries transport the blood out to the periphery as quickly and as efficiently as possible. Hence they must offer as little resistance as possible and must also be able to withstand large pulsatile pressures. These arteries therefore have large diameters (to reduce resistance) and their walls contain large amounts of **49**.___***elastic***____ tissue.

Arterioles contribute the most to the total resistance to flow in the vascular system. By changing their radius, they can determine the blood supply to any region and the hydrostatic pressure to capillaries in that region. They have more **50**._______***muscular***___________ **tissues** in order to do this. There is a high degree of intrinsic muscle tone which can be modified by local factors and can be influenced by sympathetic nerves to alter the vessel radius and hence the blood flow.

Precapillary sphincters determine the extent of capillary exchange by modifying the number of capillaries perfused with blood at any one time.

Capillaries are really the key point of the vascular system. This is where exchange takes place between blood and the surrounding tissue. They lack **51**._***muscle and elastic***___ **tissues**. Thus they consist of a cylinder of one cell thickness and this subserves their function as **52**._______***exchange***___________ vessels.

Venules and **small veins** contribute little to peripheral resistance but are important in determining blood volume by influencing the hydrostatic pressure in capillaries and therefore the net fluid transfer between blood and interstitial fluid.

Veins are capacitance vessels. Note the size of their diameter compared to that of arteries. Changes in capacity are affected by changes in diameter.

Sometimes blood does not flow through capillaries but can flow directly from small arteries to veins by **arterio-venous anastomoses (shunt vessels).** These are found particularly in the ears, fingers and toes.

Although the various vessels have been considered in the series-couples sequence, note that the vessels themselves are also connected in parallel to one another in each organ and in between each organ or tissue. Look again at Figure 1B and note this.