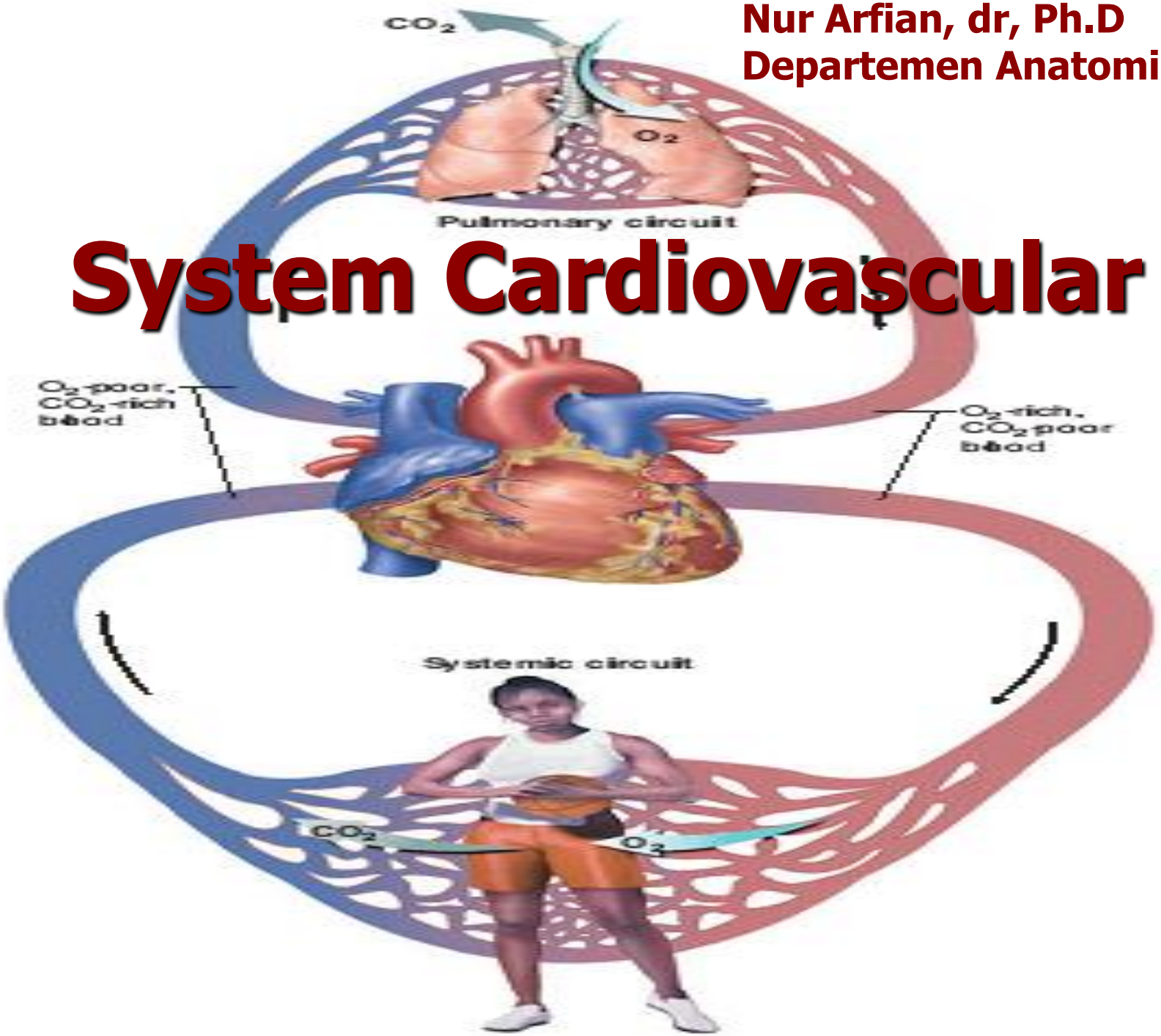
Nur Arfian, dr, Ph.D
Departemen Anatomi FK UGM

System Cardiovascular



Fungsi Sistem Kardiovaskuler

Darah: cairan komplex yang mengalir dengan fungsi:

- Transportasi: O2, CO2, nutrient, produk limbah, hormon, enzym
- Regulasi: pH, normal body temperature, cairan sel
- Proteksi melawan: toxin & mikroba asing, kehilangan darah

Sistem tersusun oleh: cor (jantung) dan sejumlah besar vasa (pembuluh)

Jantung / Cor

Lokasi Cor

- Cor terletak serong di antara kedua paru di dalam mediastinum
- Sekitar 2/3 massanya berada di sebelah kiri linea mediana/midline (garis tengah)
- Ukuran sedikit lebih besar dari kepalan tangan

Lokasi jantung di Cavum thorax

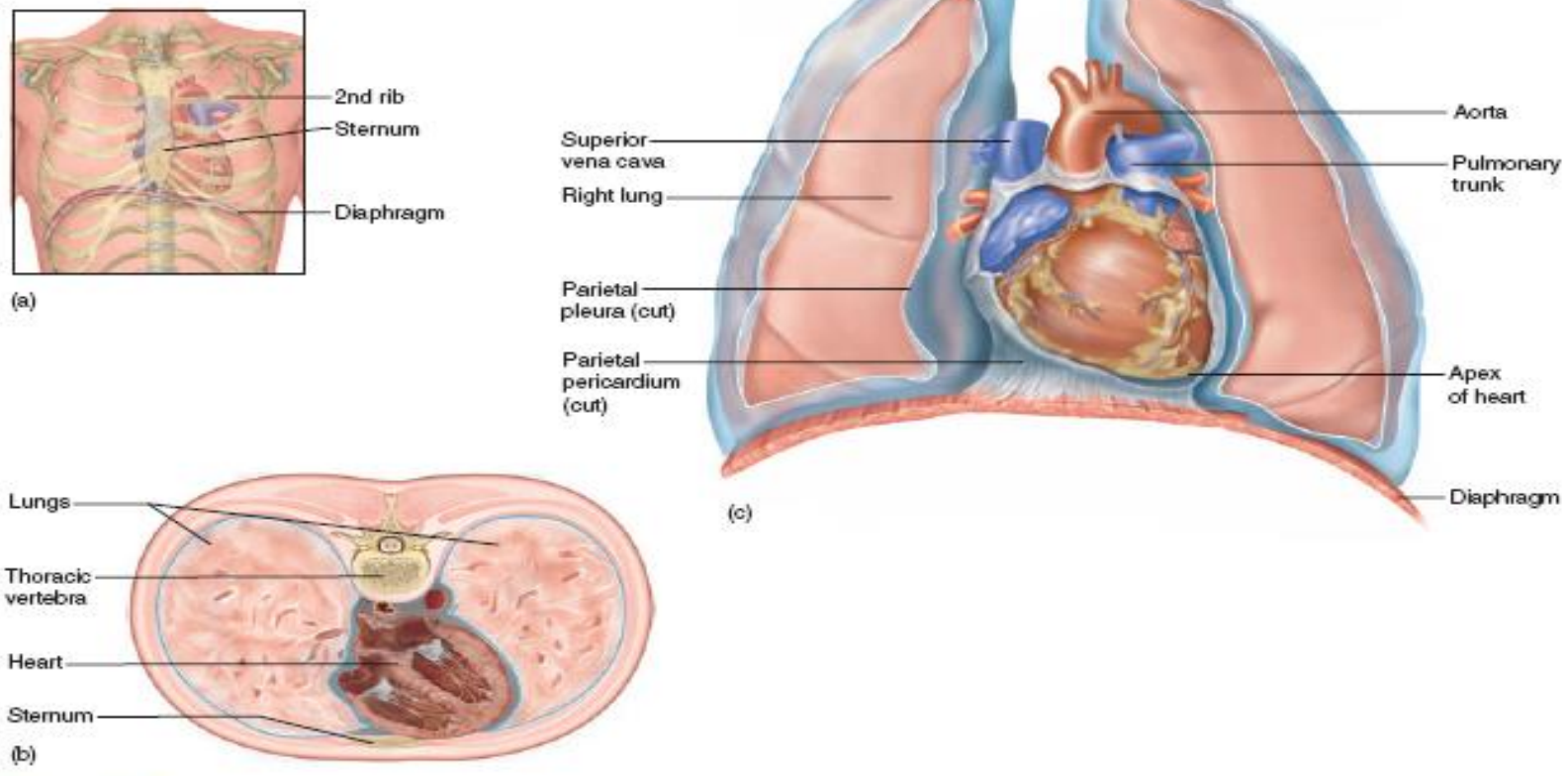


Figure 19.2 **Position of the Heart in the Thoracic Cavity.** (*a*) Relationship to the thoracic cage; (*b*) cross section of the thorax at the level of the heart; (*c*) frontal section of the thoracic cavity with the lungs slightly retracted and the pericardial sac opened.
Does most of the heart lie to the right or left of the median plane?

Terletak di mediastinum: ruang diantara dua pulmo, Tepatnya mediastinum media

Proyeksi Jantung

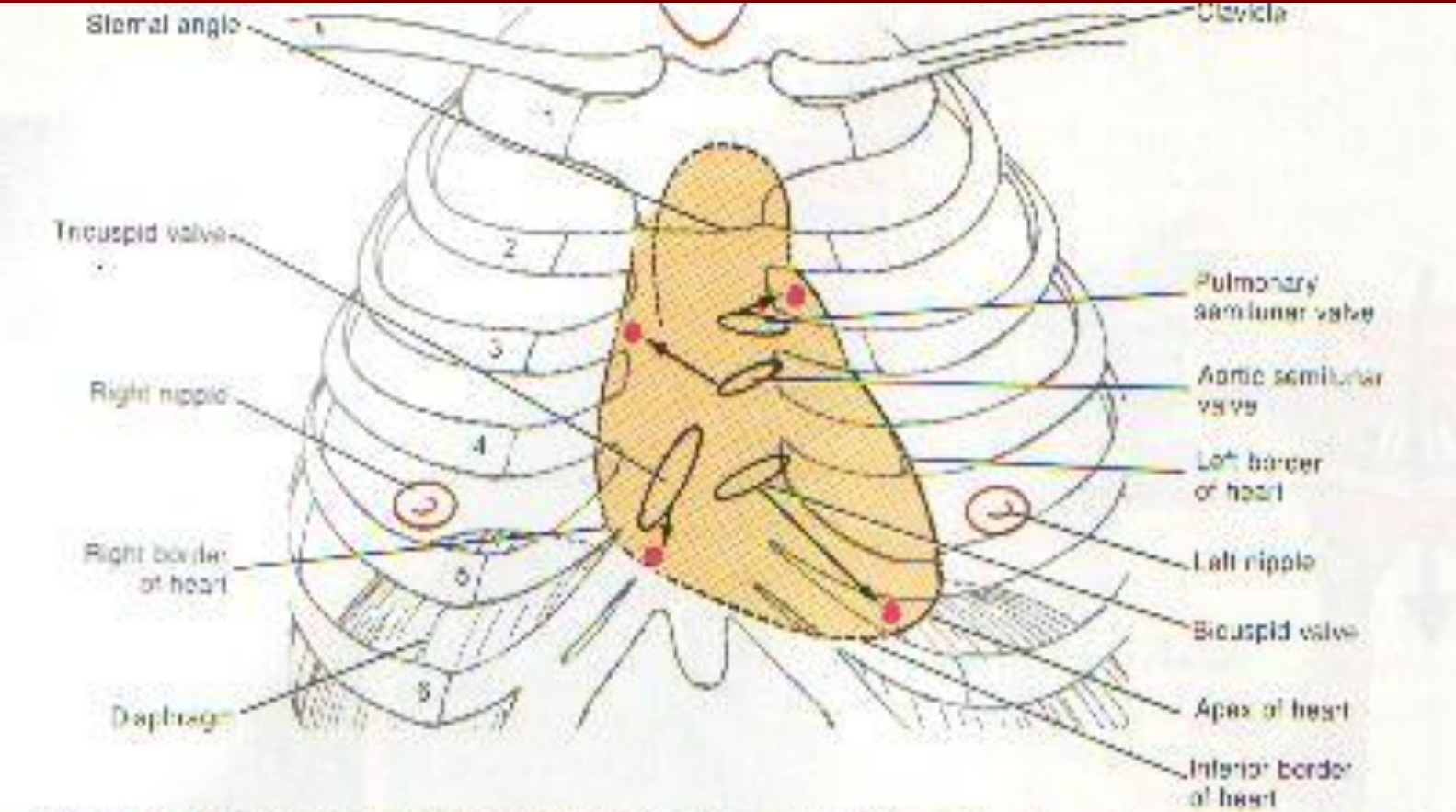


FIGURE 20-5 Surface projection of the heart. The red dots indicate where heart sounds caused by the respective valves are best heard.

- Batas bawah cartilago costa ke2 kiri 3.5 cm dari mid line
- Batas atas cartilago costa ke3 kanan 2.5 cm dari mid line
- Spatium intercostalis ke5 kiri 7-9 cm dari mid line (apex)
- cartilage costa ke6 kanan 2.5 cm dari mid line

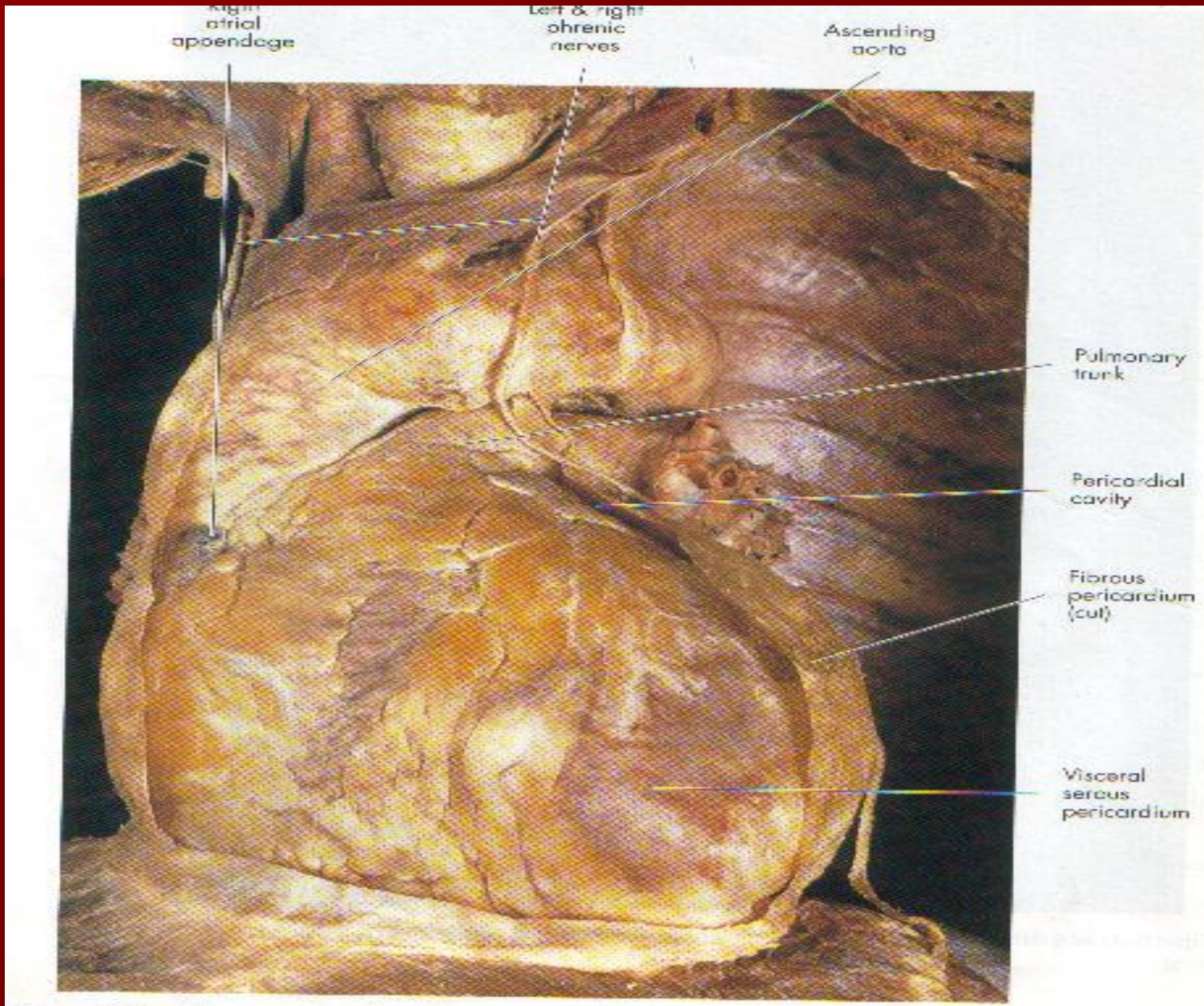
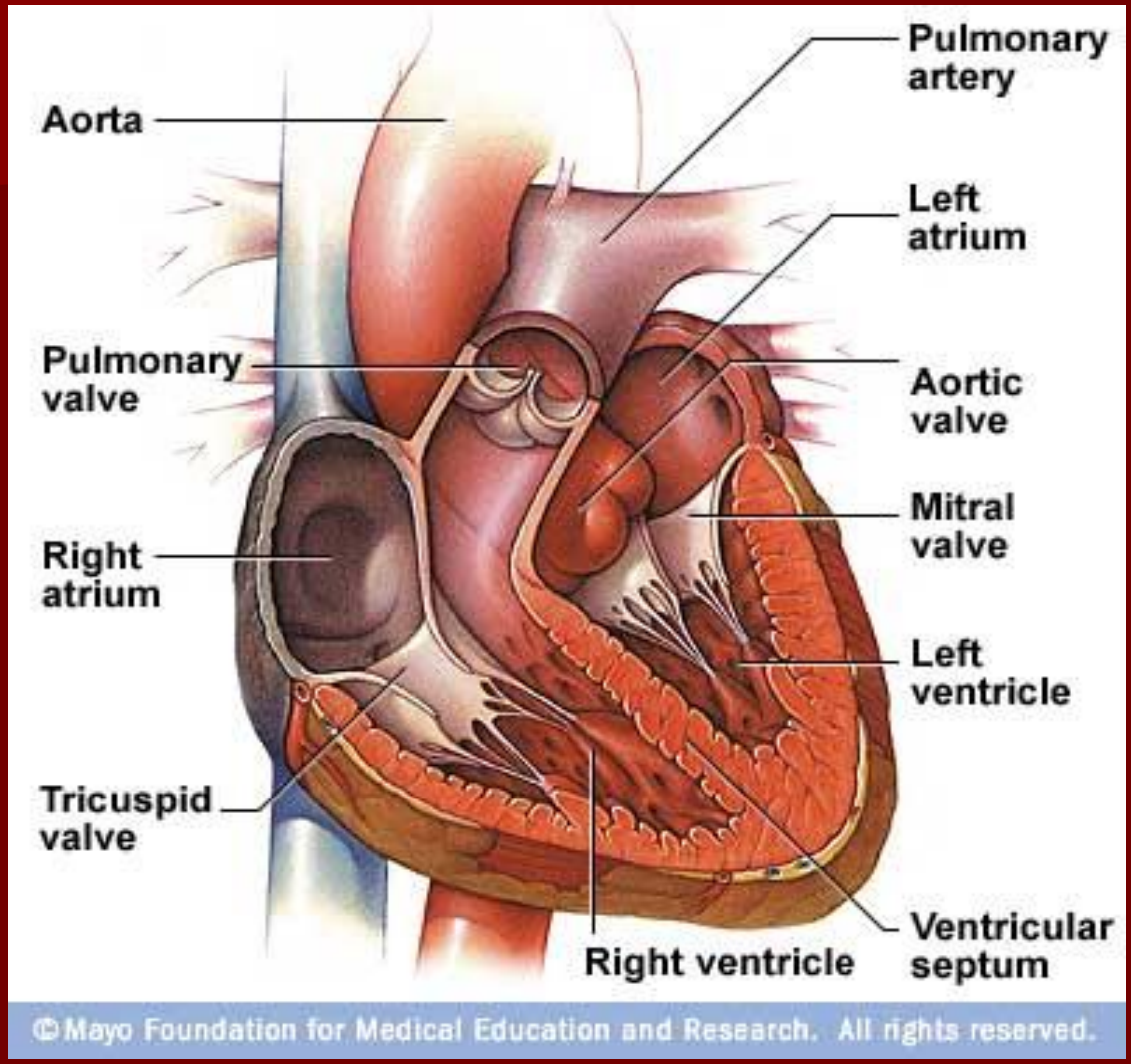


Figure 1-33 Fibrous pericardium opened to expose the visceral pericardium covering the anterior surface of the heart.

Bagian jantung

- Mempunyai :
  - Apex : ventrikel kiri
  - Basis : terutama atrium sinister
  - Batas kanan : atrium dexter
  - Batas anterior : ventrikel kanan
  - Batas kiri&posterior : ventrikel kiri

- Terdiri dari 4 ruang :
  - Atrium dexter
  - Ventrikel dexter
  - Atrium sinister
  - Ventrikel sinister



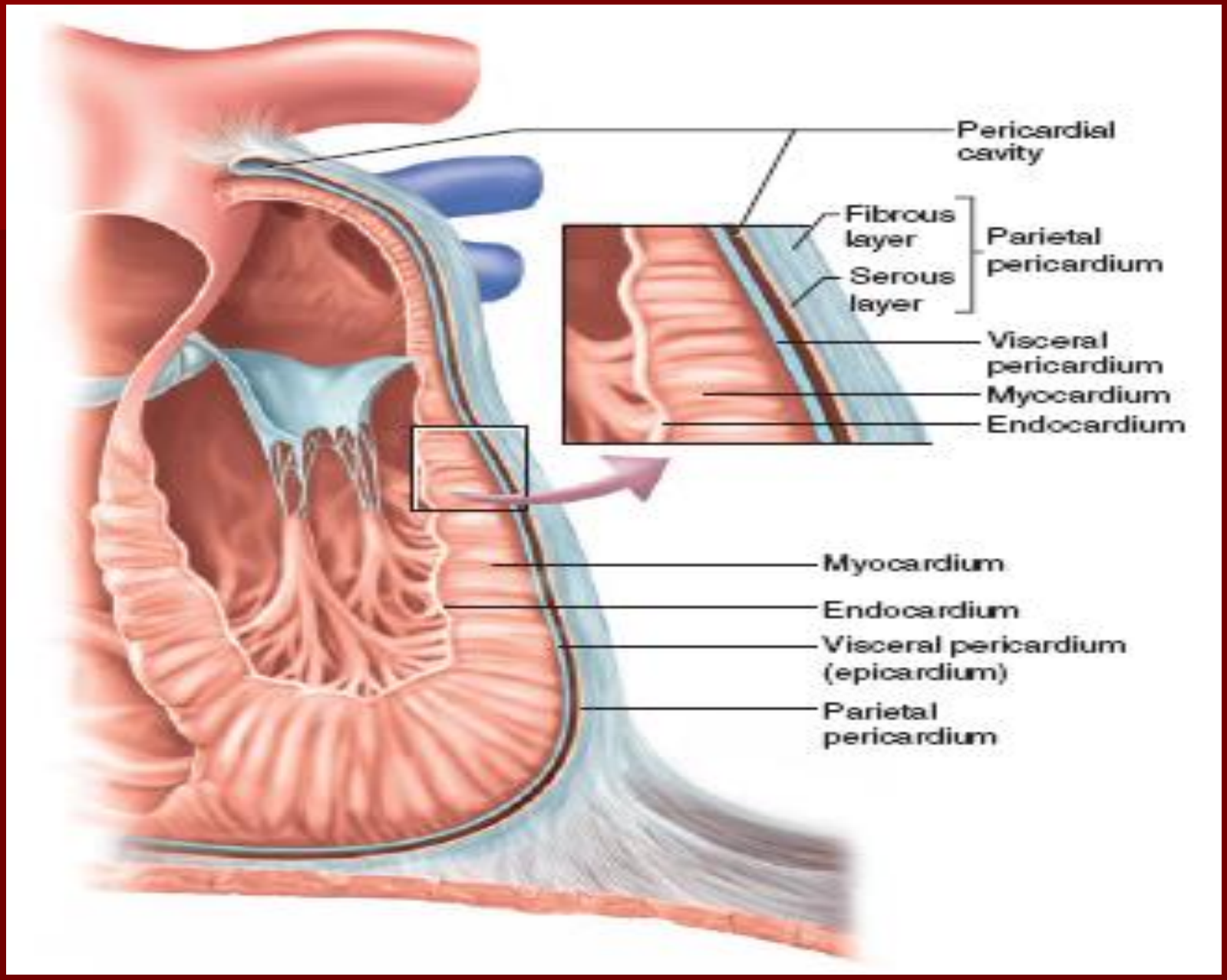
Penampakan internal jantung

Pericardium

- Pembungkus jantung
- pericardium terdiri dari lapisan fibrosa terluar dan lapisan serosa di baian dalamnya
- pericardium serosa terdiri dari lapisan parietal (melekat pd lap.fibrosa) dan lap.visceral(mlekat di jantung)
- Antara dua lapisan serosa : Cavum pericardii : ruangan berisi cairan pericardii yg mencegah friksi (gesekan) antara dua membran

Dinding, Ruang & valvula

- Terdiri dari : epicardium, myocardium, and endocardium.
- Epicardium: terdiri dari jaringan serosa & mesothelium
- Myocardium:otot jantung, involunter, tersusun dalam serabut silang-menyilang (interlacing bundles of fibers)
- Endocardium: lapisan endothelium tipis

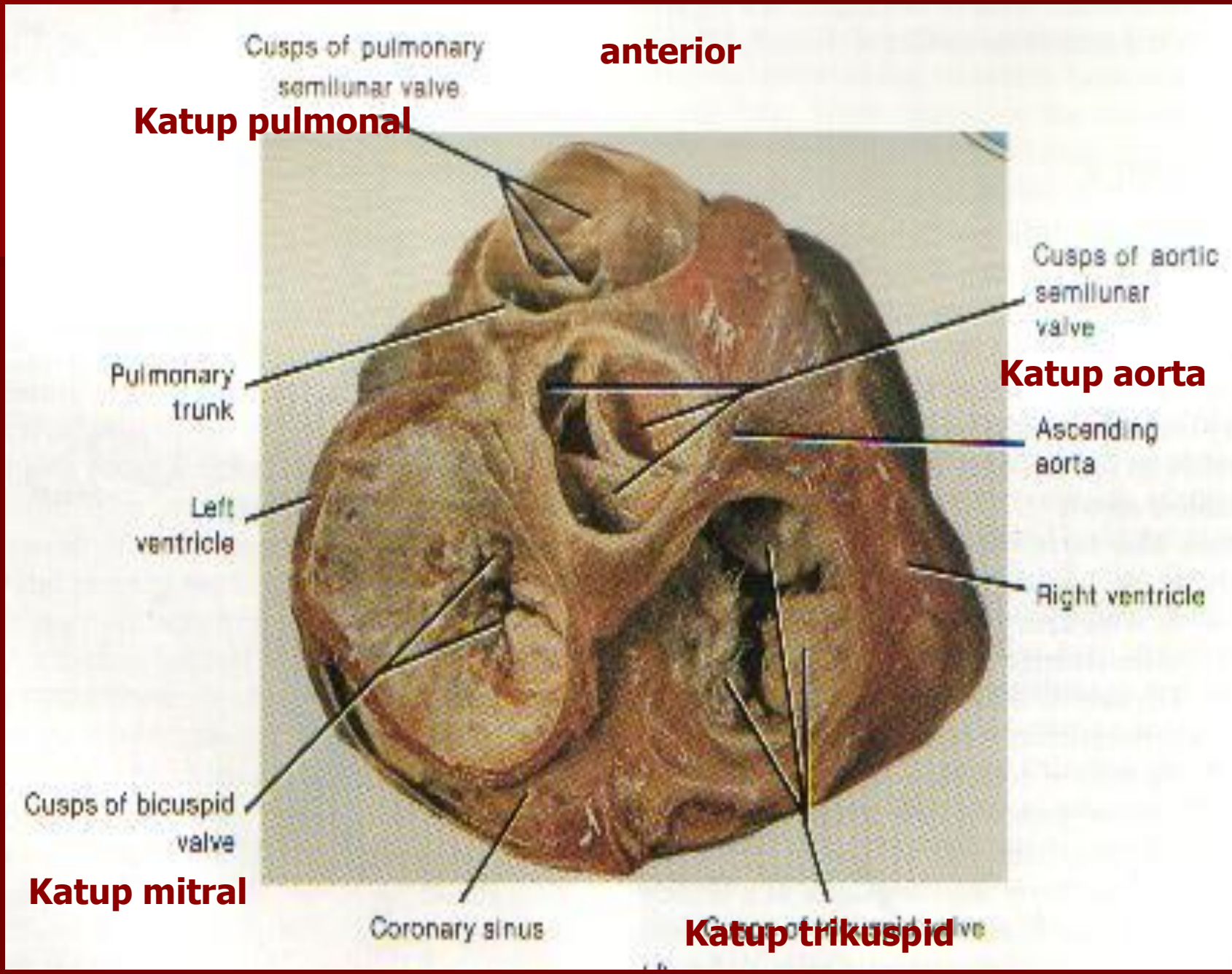

Pericardial cavity
Fibrous layer
Serous layer
Parietal pericardium
Visceral pericardium
Myocardium
Endocardium
Myocardium
Endocardium
Visceral pericardium (epicardium)
Parietal pericardium

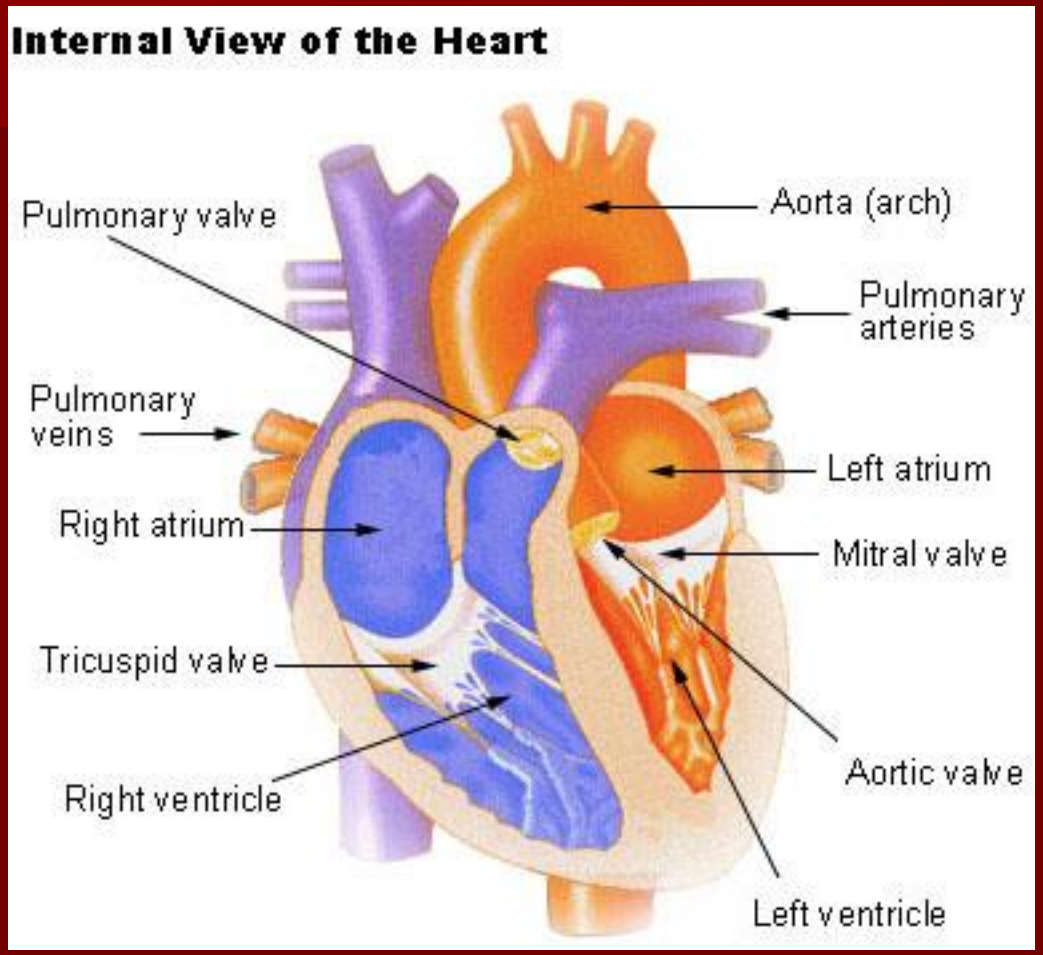
Valvula

- Valvula mencegah aliran balik dalam jantung
- Terdapat dua arteri yg meninggalkan jantung : aorta & artery pulmonary; yg mempunyai valvula semilunaris
- Valvula **Atrioventricular** (AV) antara atria and their ventricles:

  - valvula tricuspid di bagian kanan
  - valvula bicuspid (mitral) di bagian kiri

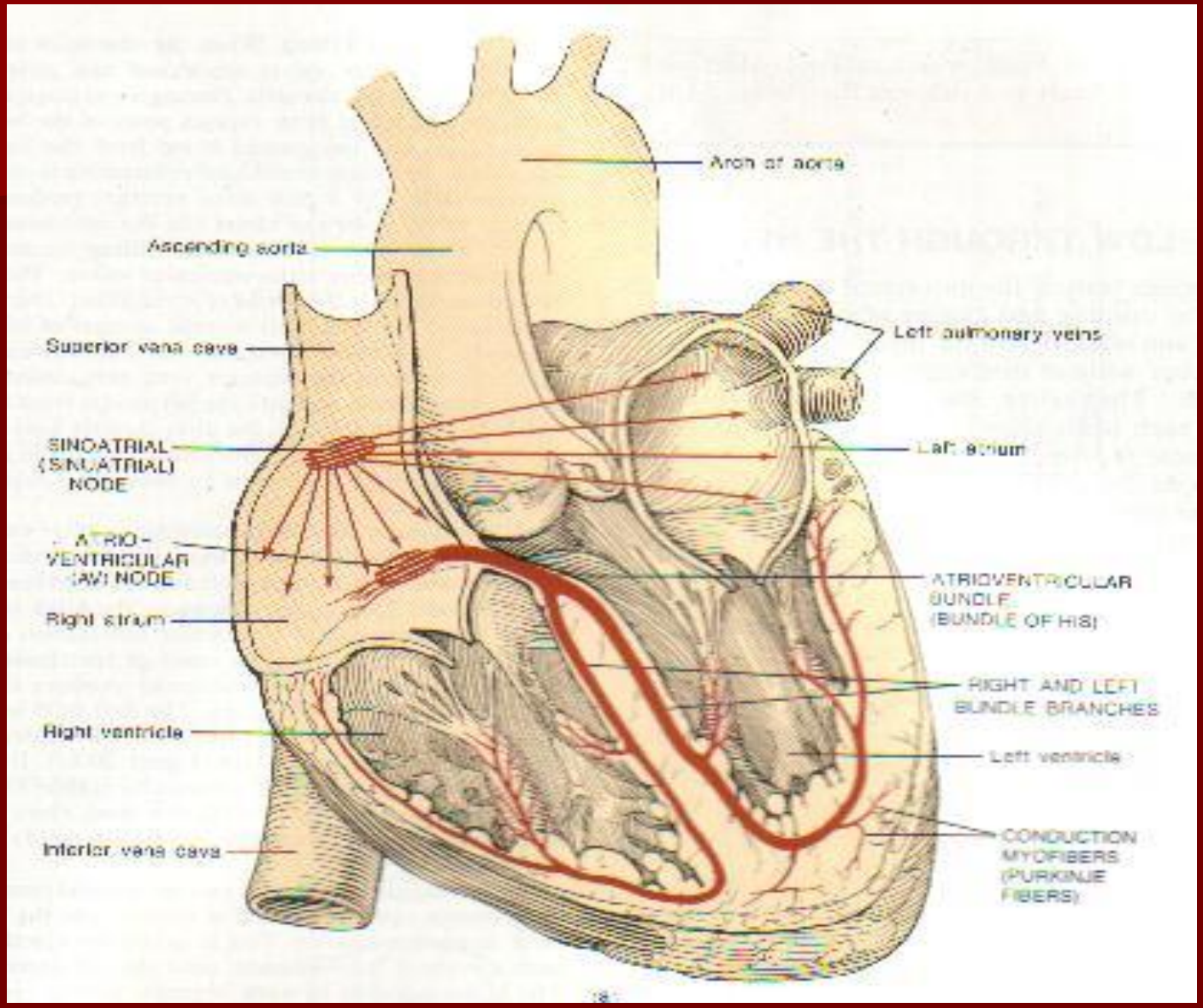
- Bagian dilekatkan pada chodae tendinea dan ototnya menentukan pembukaan valvula sesuai aliran darah


Cusps of pulmonary semilunar valve
anterior
Katup pulmonal
Cusps of aortic semilunar valve
Katup aorta
Pulmonary trunk
Ascending aorta
Left ventricle
Right ventricle
Cusps of bicuspid valve
Katup mitral
Coronary sinus
Katup trikuspid

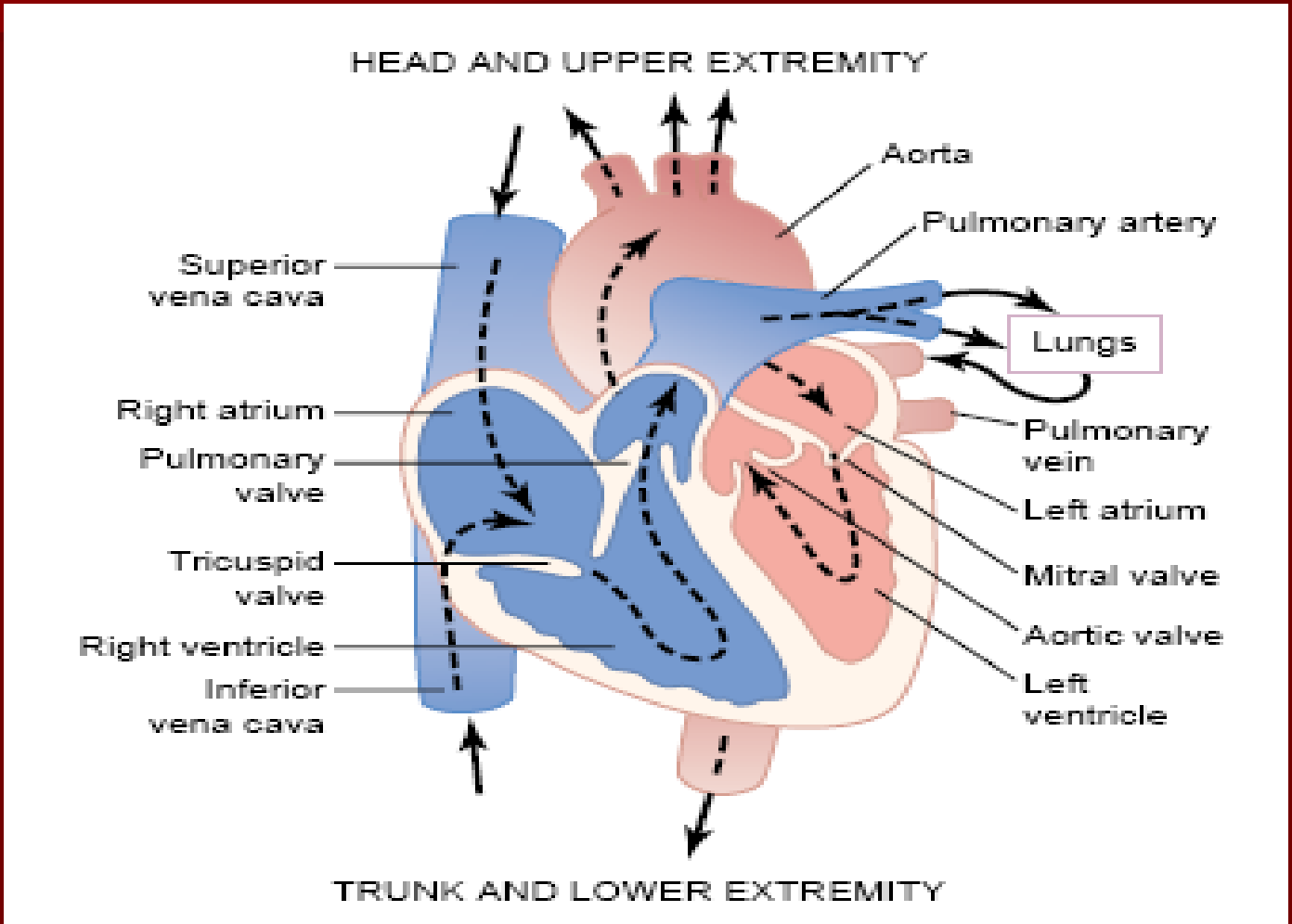

Internal View of the Heart
Pulmonary valve
Aorta (arch)
Pulmonary arteries
Pulmonary veins
Left atrium
Right atrium
Mitral valve
Tricuspid valve
Aortic valve
Right ventricle
Left ventricle

System Conduksi Jantung

- Terdiri dari jaringan khusus untuk konduksi impuls
- Components :
  - nodus sinoatrial (SA) (pacemaker) / NSA
  - Nodus atriventricular (AV) / NAV
  - atrioventricular bndl (bundle of His)
  - bundle branches, and
  - conduction myofibers (Purkinje fibers).


Arch of aorta
Ascending aorta
Superior vena cava
Left pulmonary veins
SINOATRIAL (SINUATRIAL) NODE
Left atrium
ATRIO-VENTRICULAR (AV) NODE
ATRIOVENTRICULAR BUNDLE (BUNDLE OF HIS)
Right atrium
RIGHT AND LEFT BUNDLE BRANCHES
Right ventricle
Left ventricle
Inferior vena cava
CONDUCTION MYOFIBERS (PURKINJE FIBERS)

Aliran darah pada jantung



Siklus Cardiac

- Dimulai dari potensial aksi NSA secara spontan
- Impuls akan menyebar ke otot atrium dan berlanjut ke ventrikel
- Kontraksi atrium akan lebih cepat dari ventrikel
- Atrium berperan sbg primer pump untuk atrium dan ventrikel menghasilkan tenaga untuk memompa darah ke seluruh tubuh

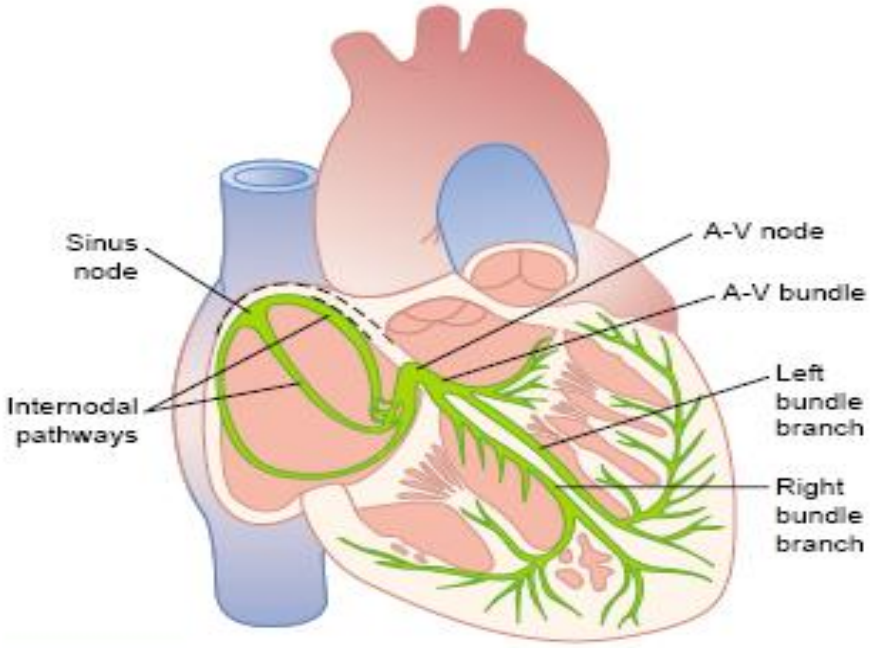
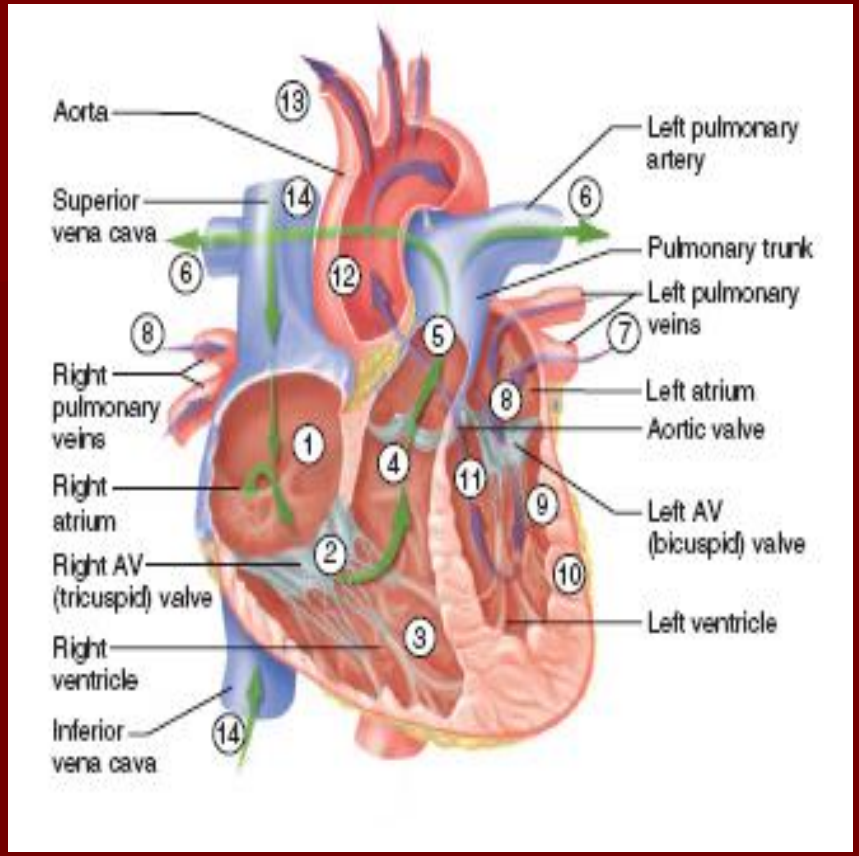


Figure 10–1

Sinus node, and the Purkinje system of the heart, showing also the A-V node, atrial internodal pathways, and ventricular bundle branches.



Aliran darah jantung

Fase dlam siklus

- Terdiri dari dua fase :

  - Diastole relaksasi dmn darah akan mengisi jantung

  - Systole : kontraksi dmn jantung memompa darah

Atrium

- Dinding tipis ada mm.pectinati
- Bentuk seperti auricula
- Antara atrium dextrum & sinistrum terdapat septum interatrialis yang mempunyai cekungan: fossa ovalis

Atrium dextrum:

- muara dari: v.cava superior & inferior, sinus coronarius
- Ada valva tricuspidalis

Atrium sinsitrum:

- muara: vv.pulmonales dextra & sinistra
- Ada valva bicuspidalis / mitralis

Pengisian atrium & Aksi Atrium sbgai pompa primer

- Darah dari vena akan masuk ke atrium
- Valvula Atrioventrikuler terbuka
- 80 % darah akan langsung masuk ke ventrikel (rapid filling)
- 20 % darah akan dipompa atrium ke ventrikel
- 100 % darah masuk ke ventrikel

Pengisian Ventrikel

- Saat ventrikel kontraksi (systole) valvula atrioventrikuler tertutup
- Saat ventrikel relaksasi, valvula atrioventrikuler terbuka darah akan masuk ke ventrikel melalui 2 fase :

  - rapid filling

  - kontraksi atrium
- Pengaruh perbedaan tekanan atrium dan ventrikel
- Darah di ventrikel : Volume diastole akhir

Pengosongan ventrikel saat systole

- Ventrikel berkontraksi untuk menaikkan tekanan;
- Valvula AV tertutup
- Melawan tekanan dalam aorta dan arteri pulmonal
- Disebut fase : Isovolumic contraction

Ejeksi

- Terjadi saat tekanan ventrikel mampu mengatasi tekanan aorta & a.pulmonal
- Disebut fase ejeksi
- Volume darah yg dikeluarkan disebut stroke volume (Volume sekuncup)

- Ventrikel relaksasi & terjadi penutupan katup semilunar
- disebut relaksasi isovolumic
- Penurunan tekanan intraventrikuler
- Tekanan aorta & a.pulmonal naik; mendorong darah balik ke arah ventrikel menyebabkan menutupnya valvula semilunaris

Volume semenit jantung

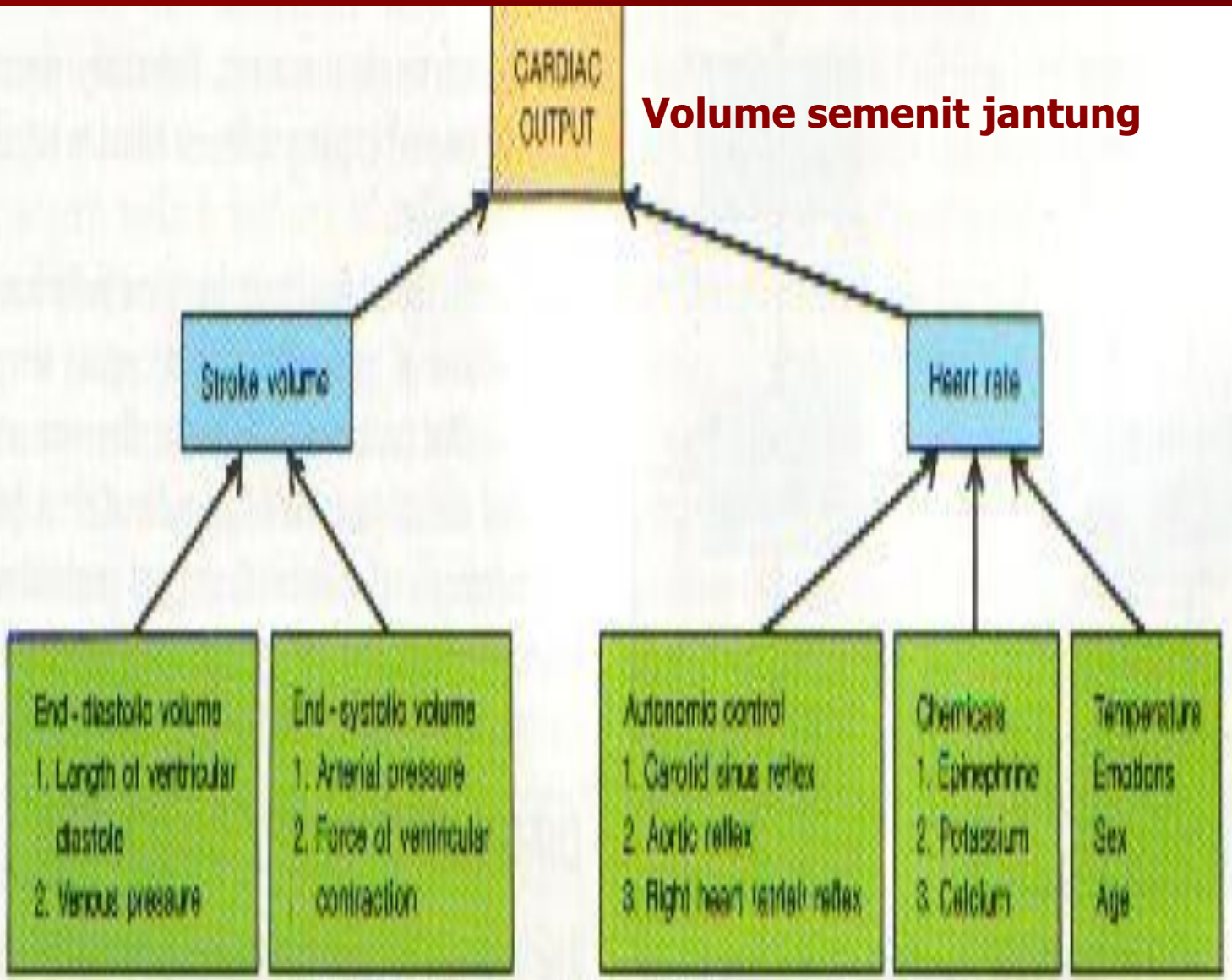
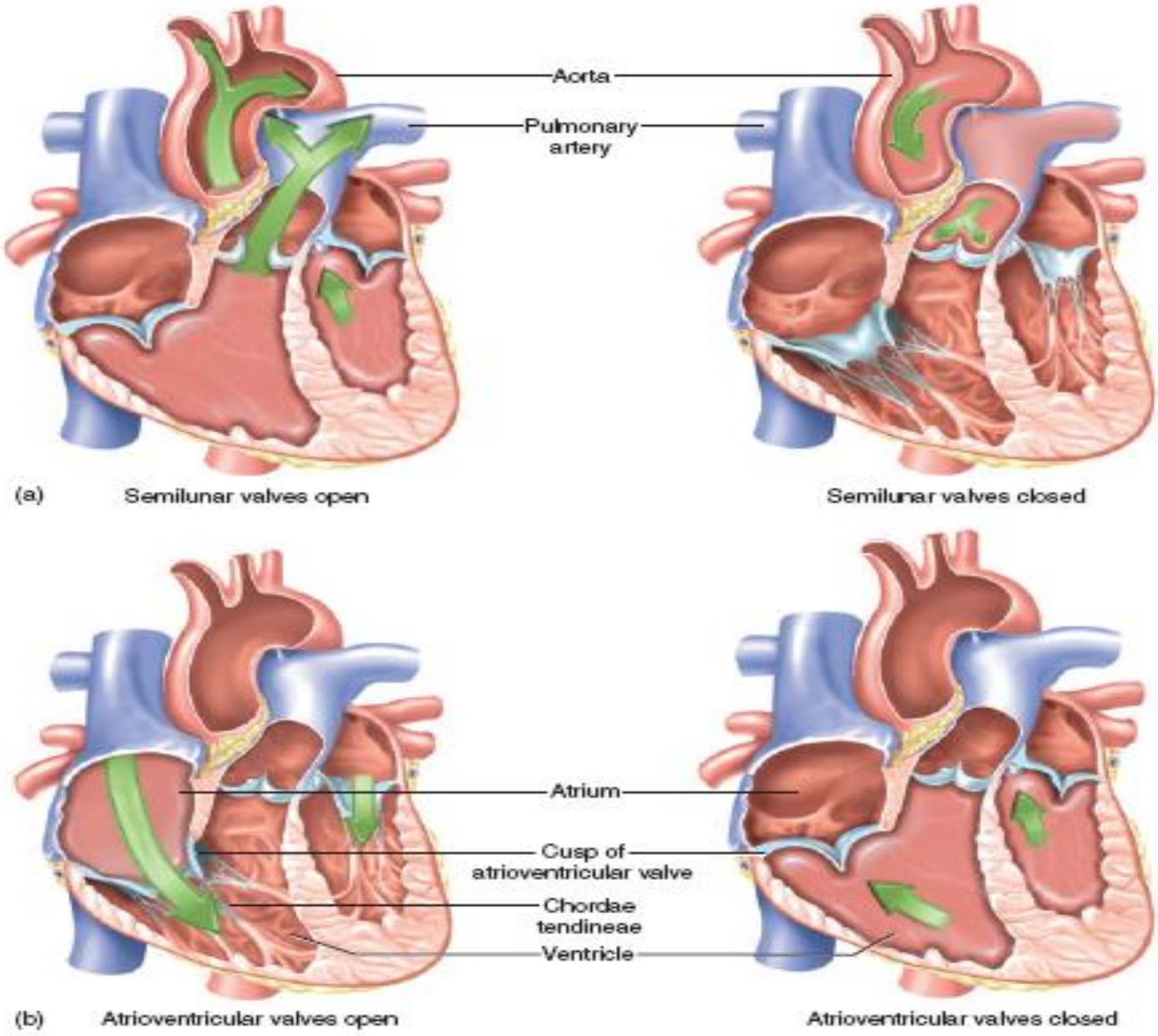
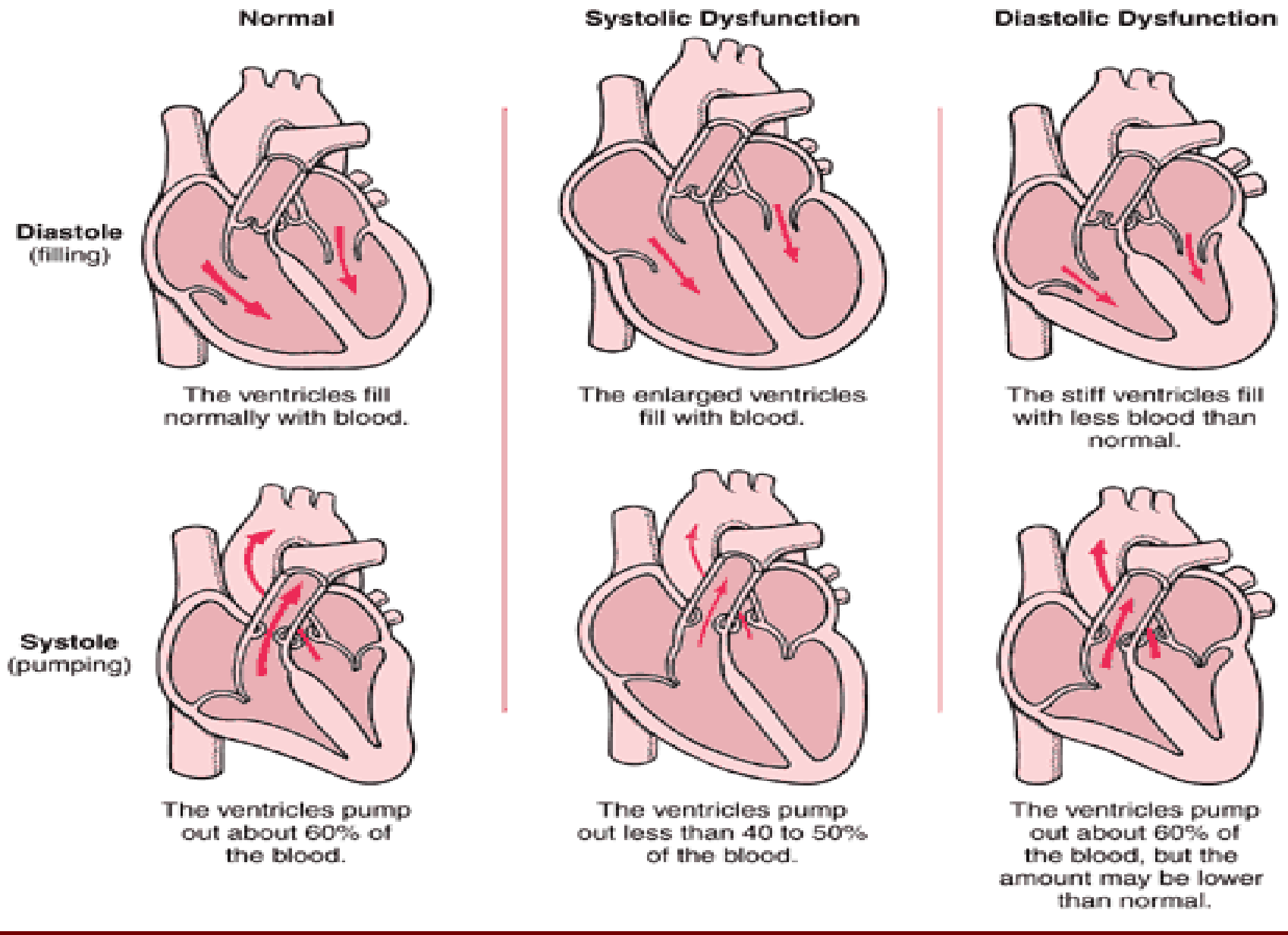


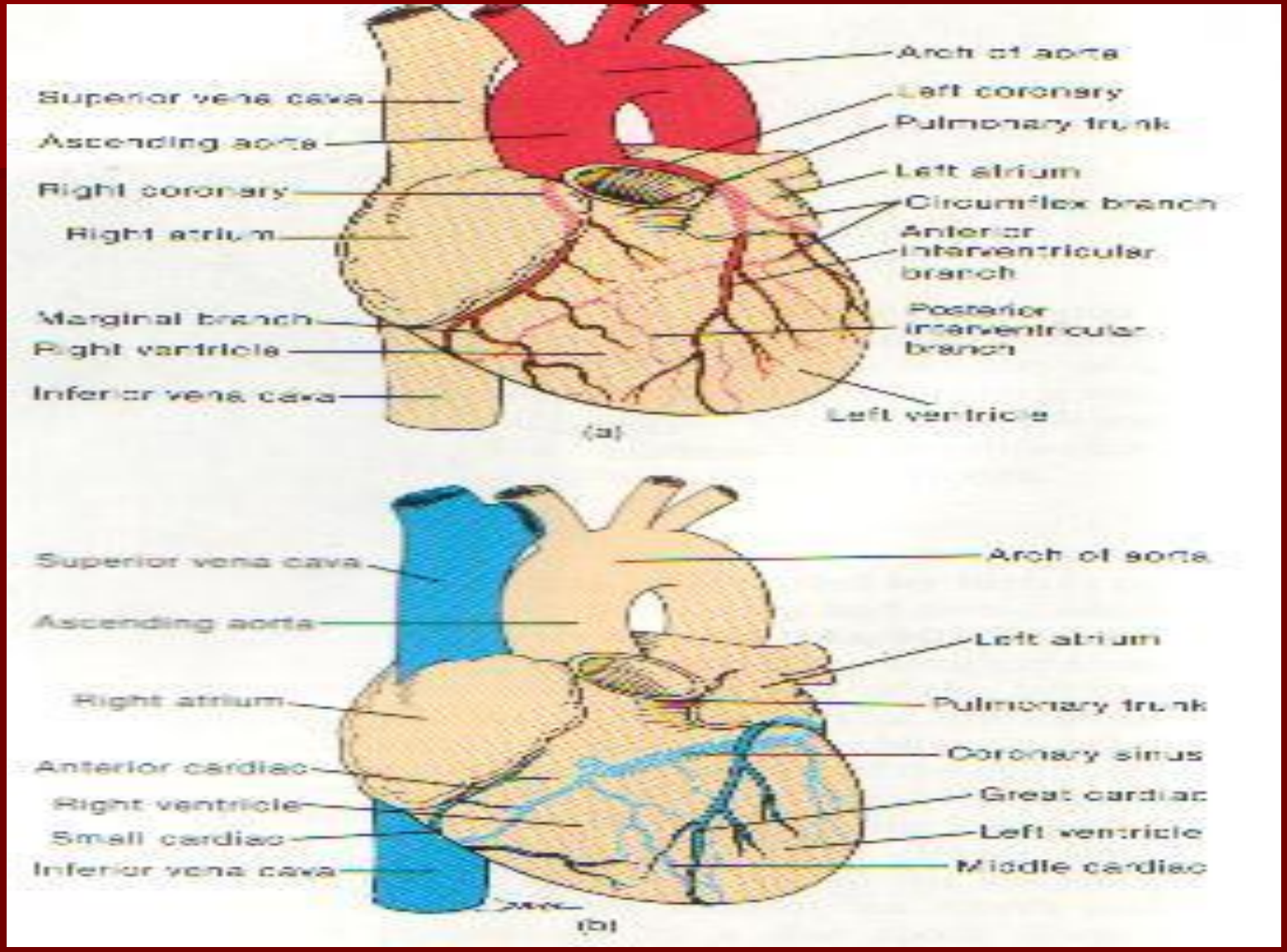
FIGURE 20-11 Summary of factors that influence cardiac output.


Aorta
Pulmonary artery
(a) Semilunar valves open
Semilunar valves closed
Atrium
Cusp of atrioventricular valve
Chordae tendineae
Ventricle
(b) Atrioventricular valves open
Atrioventricular valves closed

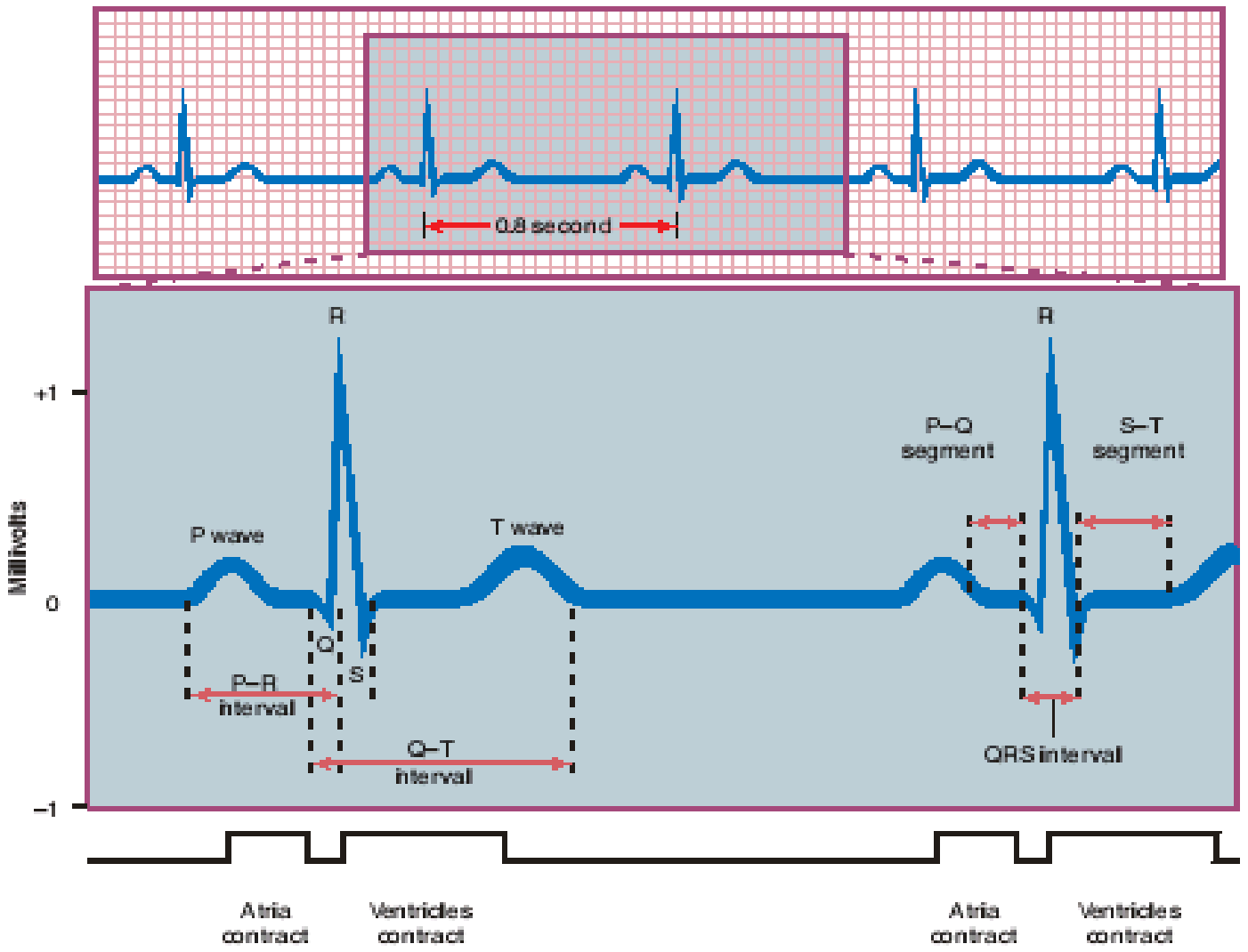

Normal
Systolic Dysfunction
Diastolic Dysfunction
Diastole
(filling)
Systole
(pumping)
The ventricles fill normally with blood.
The enlarged ventricles fill with blood.
The stiff ventricles fill with less blood than normal.
The ventricles pump out about 60% of the blood.
The ventricles pump out less than 40 to 50% of the blood.
The ventricles pump out about 60% of the blood, but the amount may be lower than normal.

Vasa coronaria

- Cabang aorta ascendens: 2
- A.coronaria dextra → r.descendens / interventricularis posterior
- A.coronaria sinistra → r.descendens / interventricularis anterior
- Venosa:
- Bermuara ke sinus coronarius
- Ada yg langsung ke atrium dextrum


Arch of aorta
Superior vena cava
Left coronary
Ascending aorta
Pulmonary trunk
Left atrium
Right coronary
Circumflex branch
Right atrium
Anterior interventricular branch
Marginal branch
Posterior interventricular branch
Right ventricle
Inferior vena cava
Left ventricle
(a)
Superior vena cava
Arch of aorta
Ascending aorta
Left atrium
Right atrium
Pulmonary trunk
Anterior cardiac
Coronary sinus
Right ventricle
Great cardiac
Small cardiac
Left ventricle
Inferior vena cava
Middle cardiac
(b)

EKG


0.8 second
R
R
+1
0
−1
Millivolts
P wave
T wave
P–Q segment
S–T segment
Q
S
P–R interval
Q–T interval
QRS interval
Atria contract
Ventricles contract
Atria contract
Ventricles contract

Blood Vessels

- Arteries (vasa konduksi dan distribusi)
- Arterioles (vasa resisten)
- Capillaries (pemb.darah pertukaran)
- Venules (vasa kapasitan & reservoar)
- Veins (vasa kapasitan & reservoar)

Aliran Darah

↓

Aortae

↓

Arteri

↓

Arteriola

↓

Kapiler

↓

Venula

↓

Vena

↓

jantung

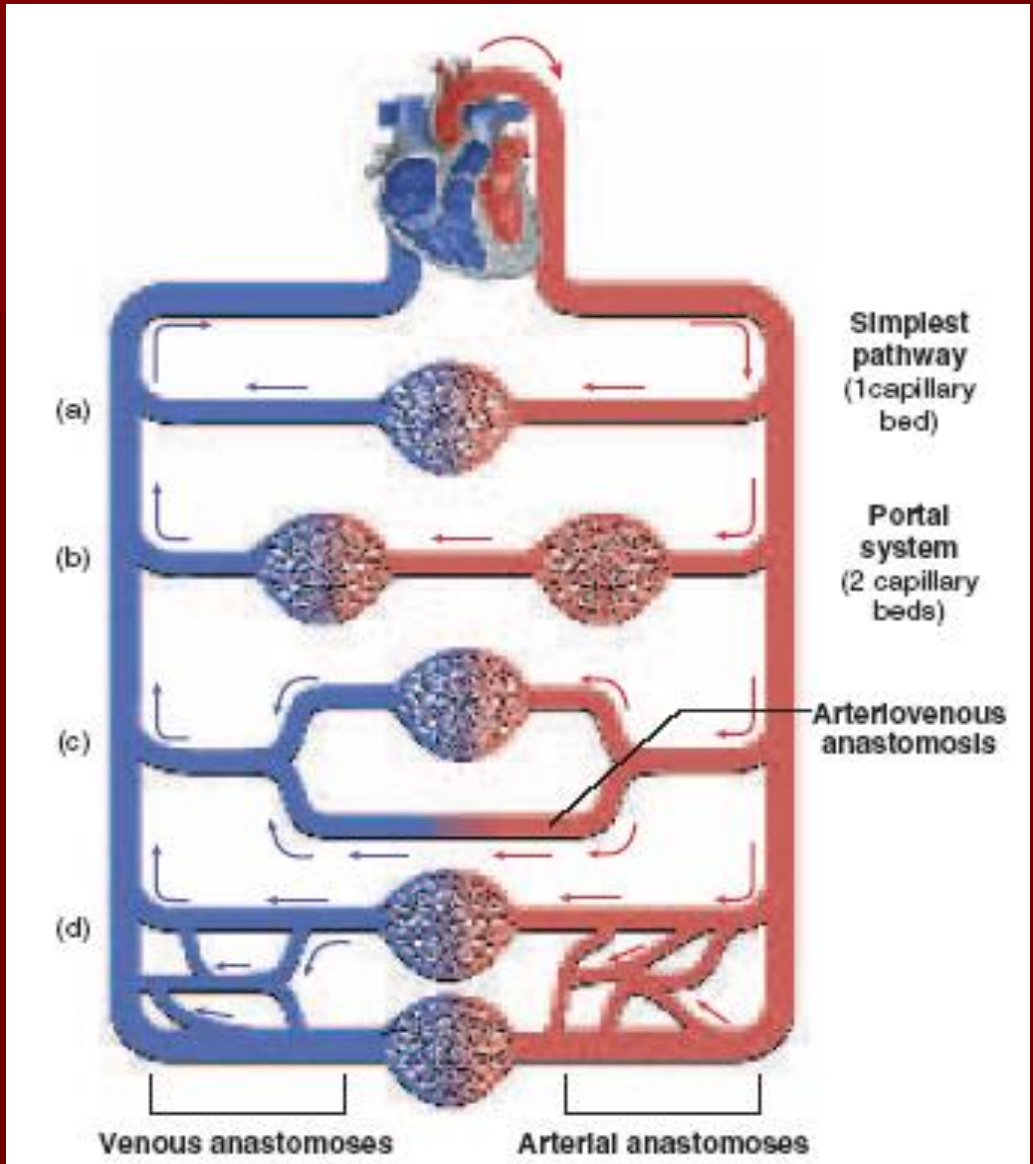
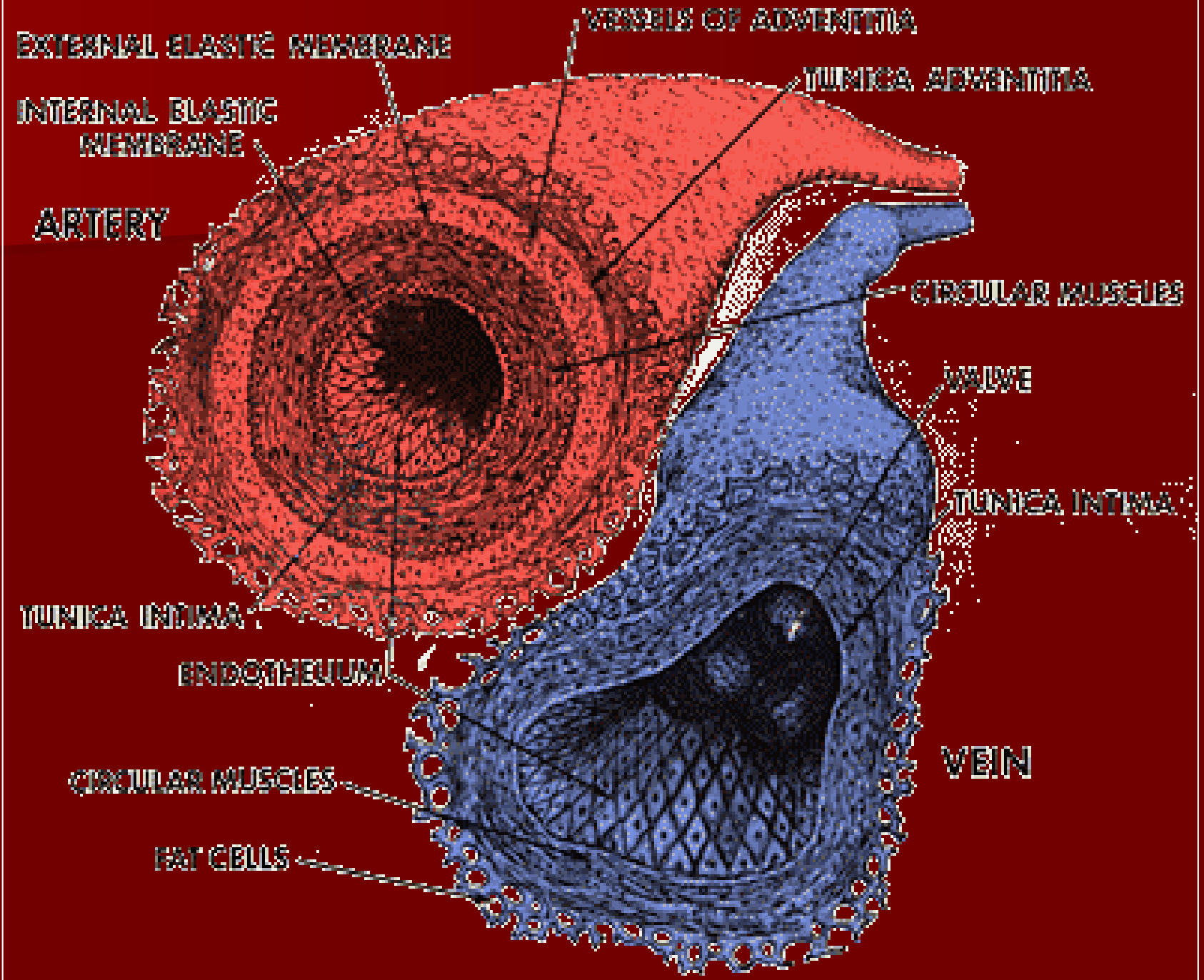


Figure 20.1 Variations in Circulatory Pathways.

Jumlah vasa dan ukuran

- **aorta**: tunggal, diameter: 30 mm pd orang dewasa
- **arteries**: ratusan, diameter semakin berkurang
- **Arterioles**: ± 4 juta,
  diameter: → 10 mikrometer,
- **Capillaries**: ± 16 juta
- **Venules**: ± 4 juta
- **Veins**: ratusan
- **Vena cava**: superior & inferior


EXTERNAL ELASTIC MEMBRANE
VESSELS OF ADVENTITIA
TUNICA ADVENTITIA
INTERNAL ELASTIC MEMBRANE
ARTERY
CIRCULAR MUSCLES
VALVE
TUNICA INTIMA
TUNICA INTIMA
ENDOTHELIUM
VEIN
CIRCULAR MUSCLES
FAT CELLS

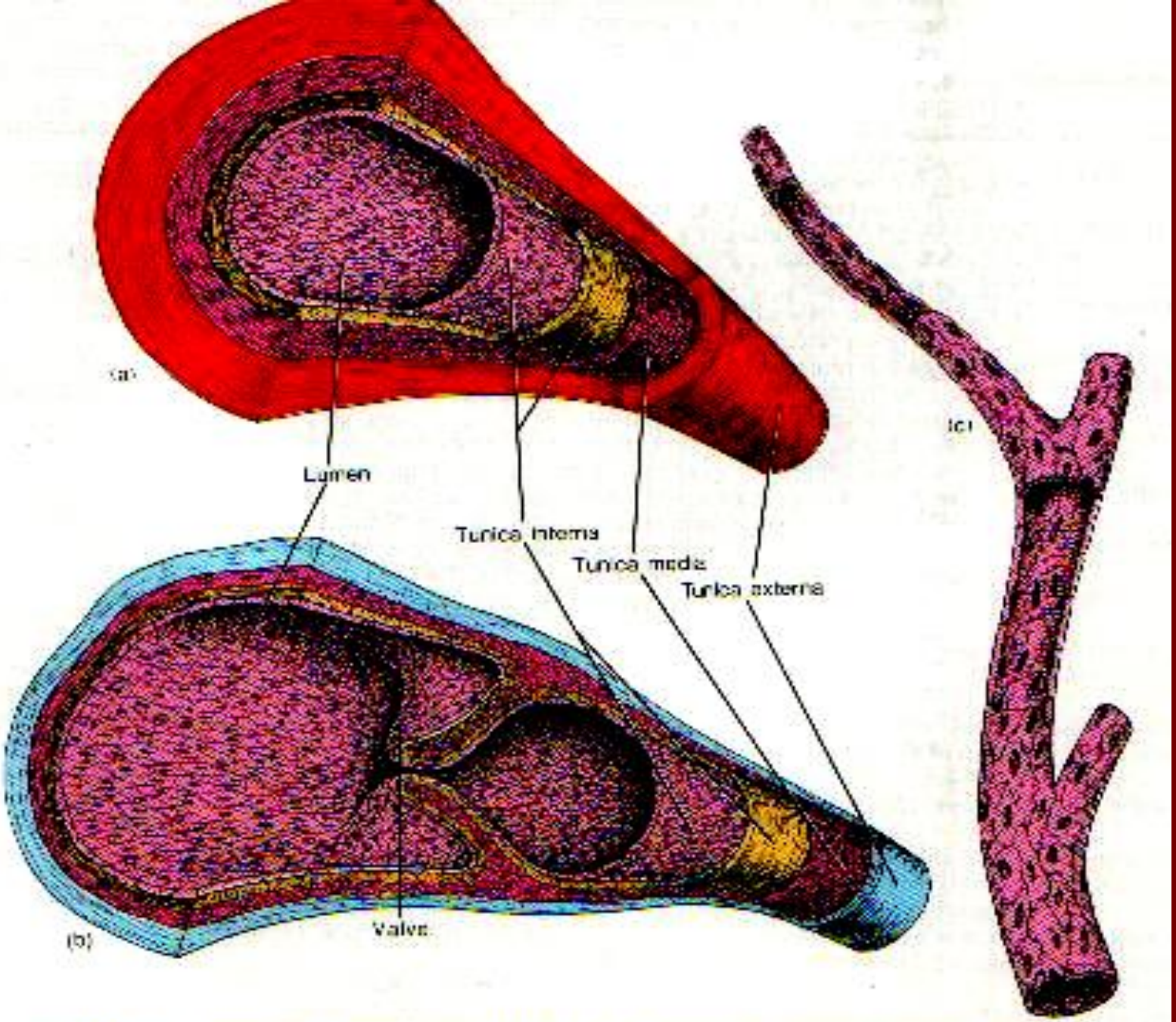


FIGURE 21-1 Comparative structure of (a) an artery, (b) a vein, and (c) a capillary. The relative size of the capillary is enlarged for emphasis.

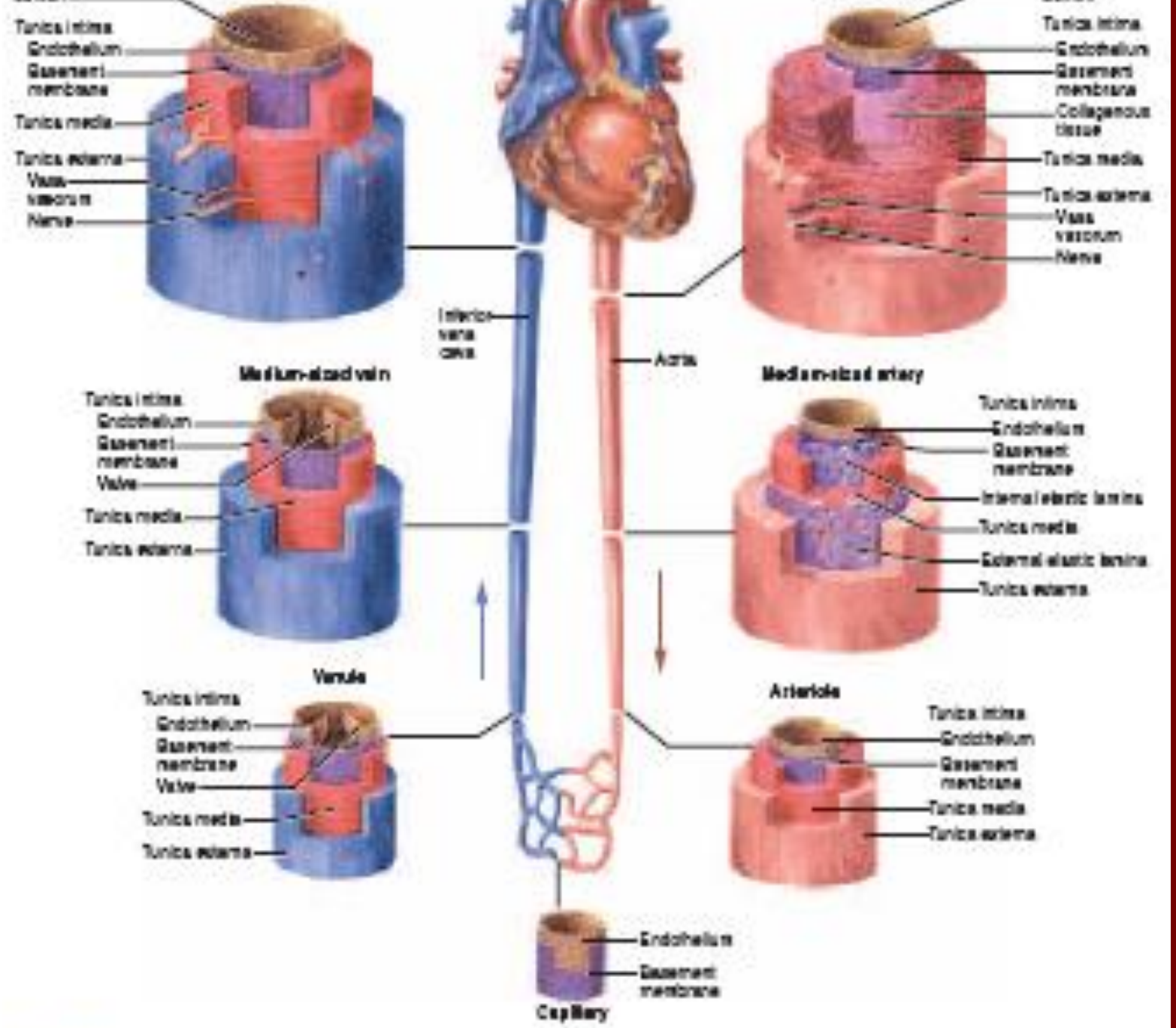


Figure 20.2 The Structure of Arteries and Veins.

Arteri

- **Dinding:**
  - **tunica interna**
  - **tunica media (kontraksi; tdpt otot polos)**
  - **tunica externa**
- **Besar: arteries elastic/conducting**
  - **dinding:tipis dibanding proporsinya dgn lumen**
  - **t. media: > serabut elastic, kurang otot polos**
- **Medium: arteriesmuscular/distributing**
  - **dinding: relatif tebal karena sejumlah besar otot**
  - **media: lebih banyak otot polos daripada serabut elastik**

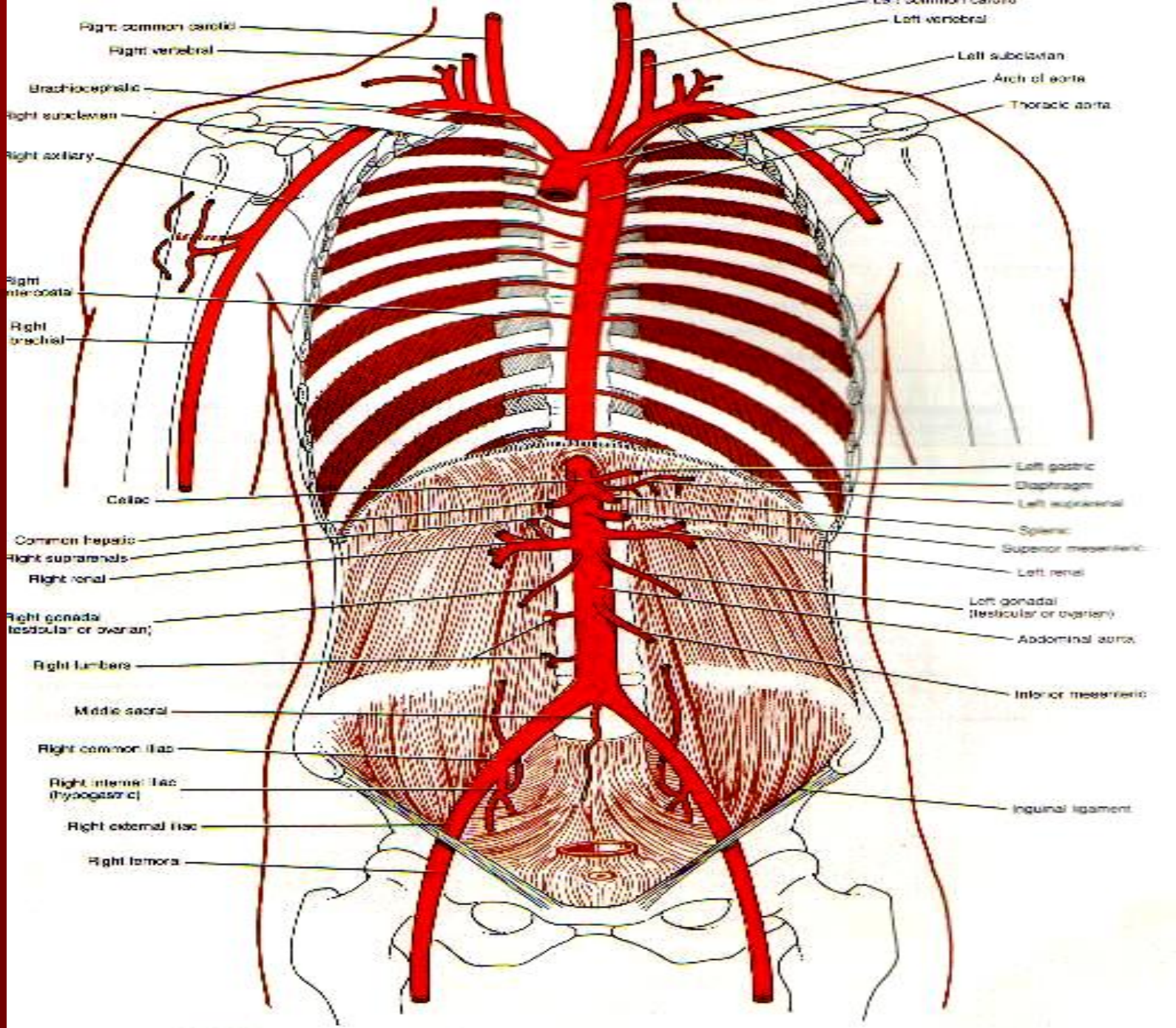
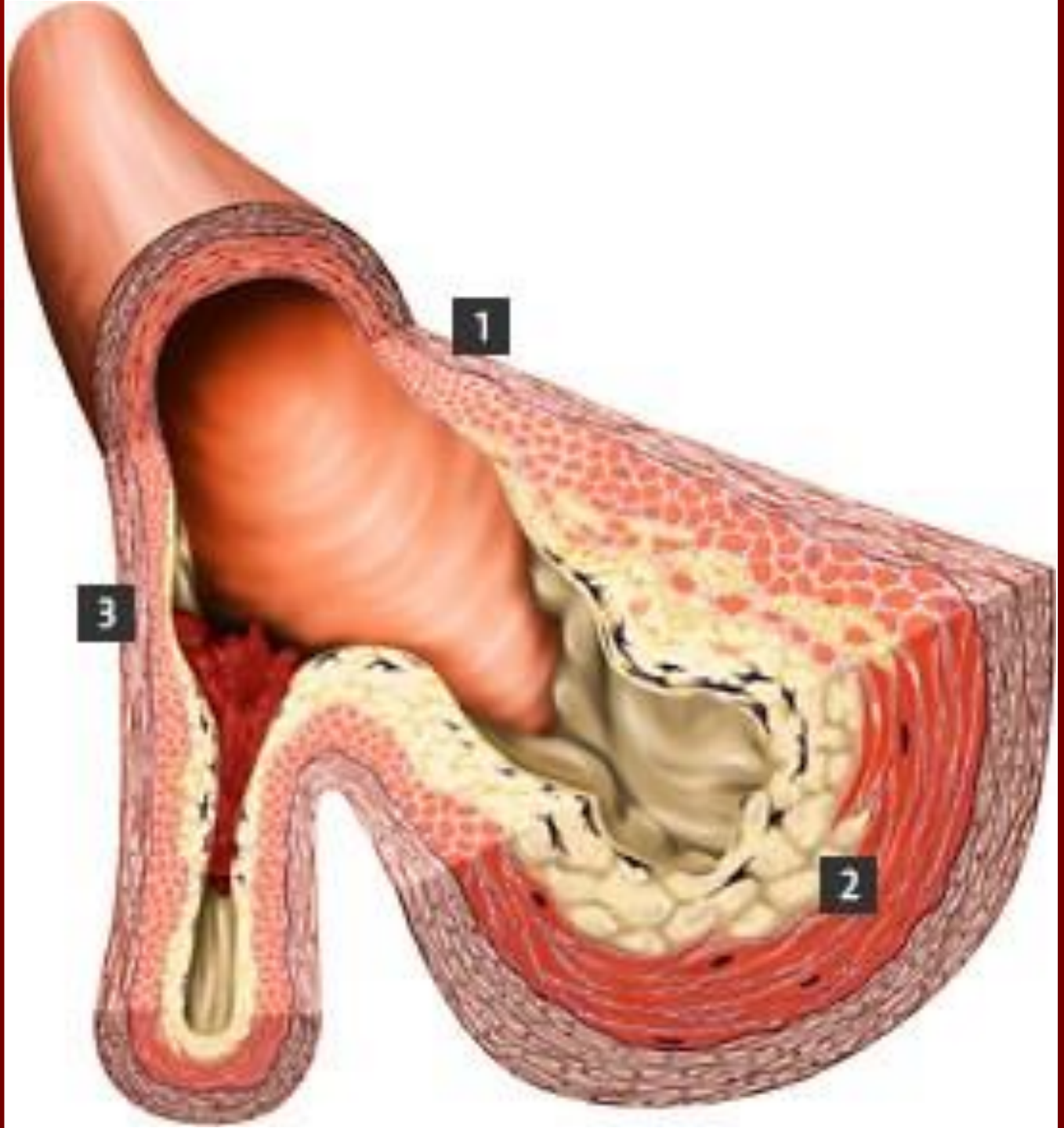


FIGURE 21-15 Thoracic and abdominal aorta and their principal branches in anterior view.


1
2
3

Arteriola

- Arteri kecil yang menghantarkan darah ke kapiler
- Disebut vasa resistance
- Melalui kontriksi & dilatasi : mengatur aliran darah dari arteri ke kapiler

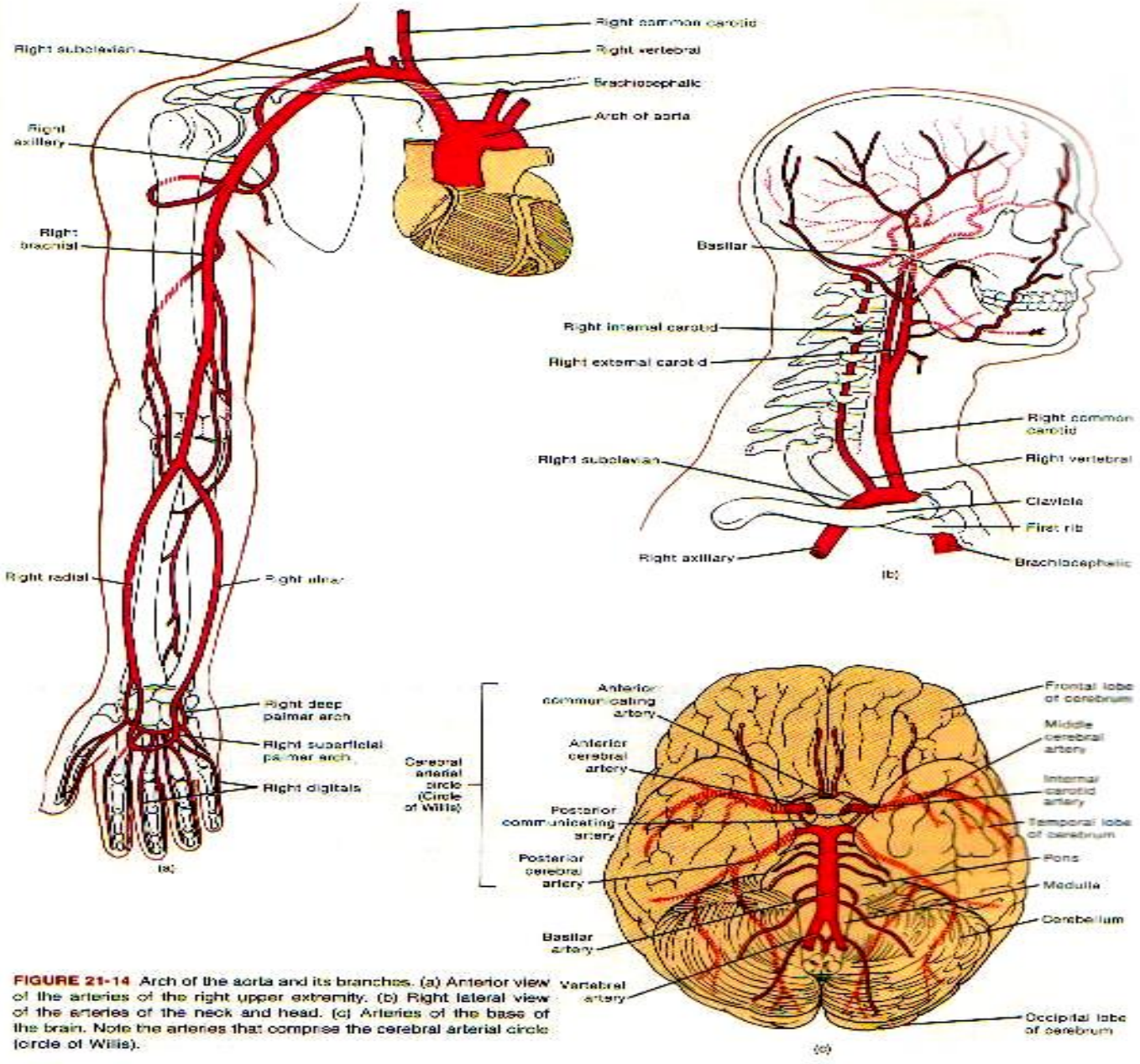


FIGURE 21-14 Arch of the aorta and its branches. (a) Anterior view of the arteries of the right upper extremity. (b) Right lateral view of the arteries of the neck and head. (c) Arteries of the base of the brain. Note the arteries that comprise the cerebral arterial circle (circle of Willis).

Capillaries

- Vasa mikroskopik dimana terjadi pertukaran material / substansi dari darah & jaringan
- Cabang – cabng kapiler membentuk jaringan kapiler (“extensive capillary network”) pada jaringan
- Jaringan ini meningkatkan area permukaan shg mempercepat pertukaran
- Sphincter Precapiller mengatur aliran darah melalui kapiler

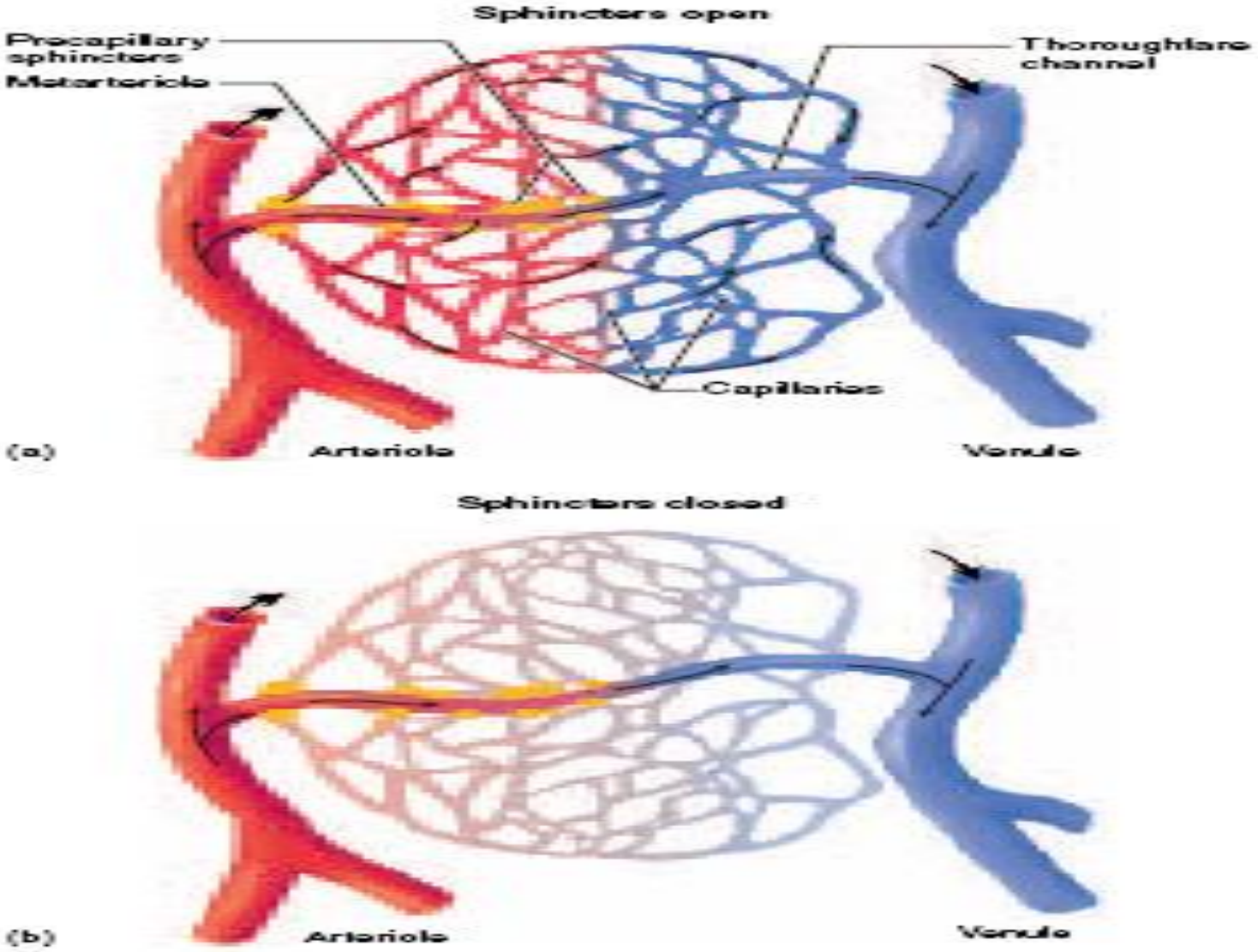
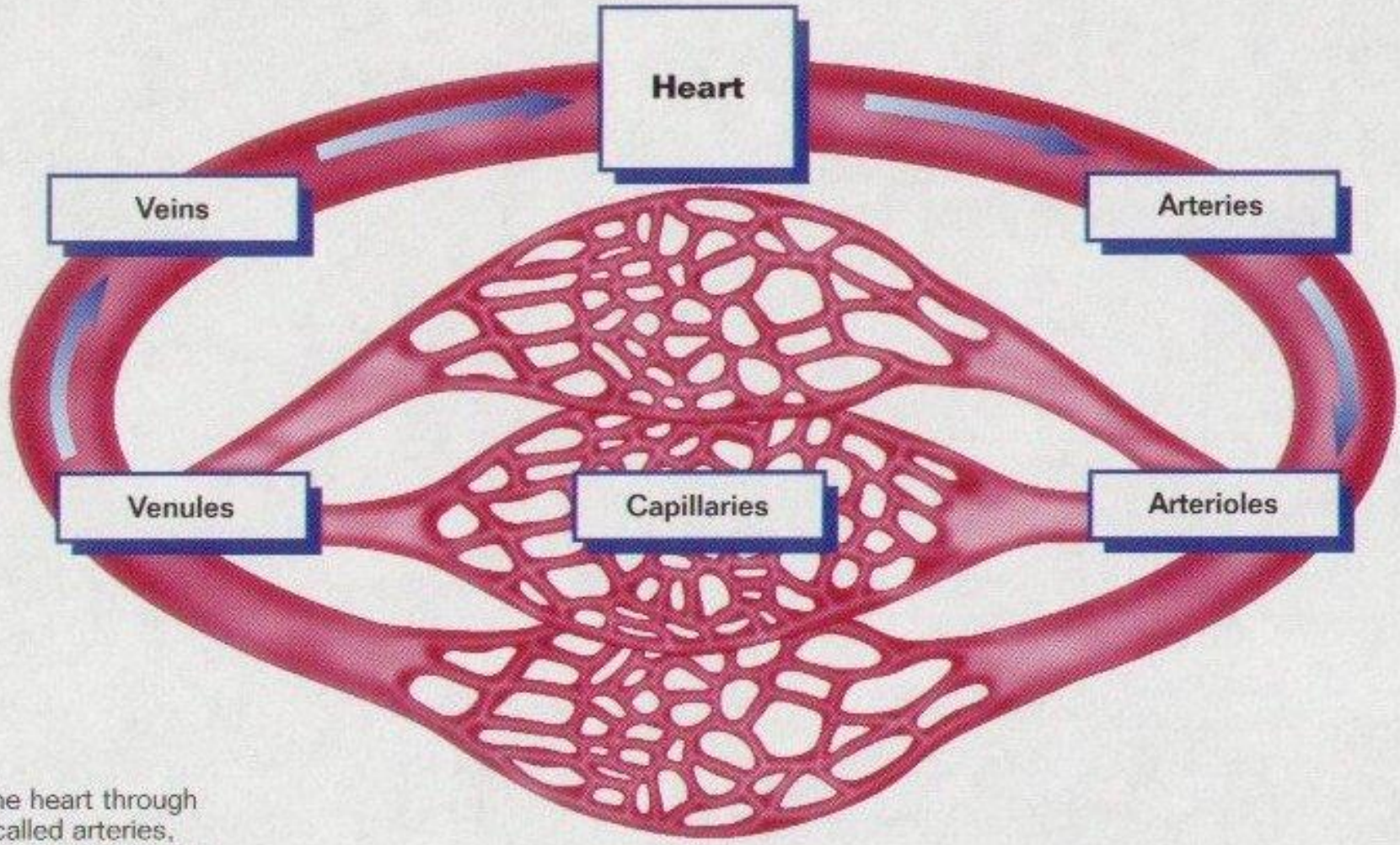


Figure 20.5 Control of Perfusion of a Capillary Bed.
(a) Precapillary sphincters dilated and capillaries well perfused.
(b) Precapillary sphincters closed, with blood bypassing the capillaries.



Blood leaves the heart through blood vessels called arteries, which branch into many smaller arterioles. The smallest and most numerous blood vessels are capillaries. Blood returns to the heart through venules and veins.

Venula

- Vasa kecil ; merupakan lanjutan kapiler dan bergabung membentuk vena
- Aliran darah dari kapiler ke vena

Vena.....

- Terdiri dari tiga tunika sperti arteri dgn jaringan elastik dan otot lebih tipis
- Terdapat katup yang mencegah aliran balik darah kelemahan katup menyebabkan varicoa atau hemorroid
- Sinus venosus : Vena dgn dinding yang sangat tipis

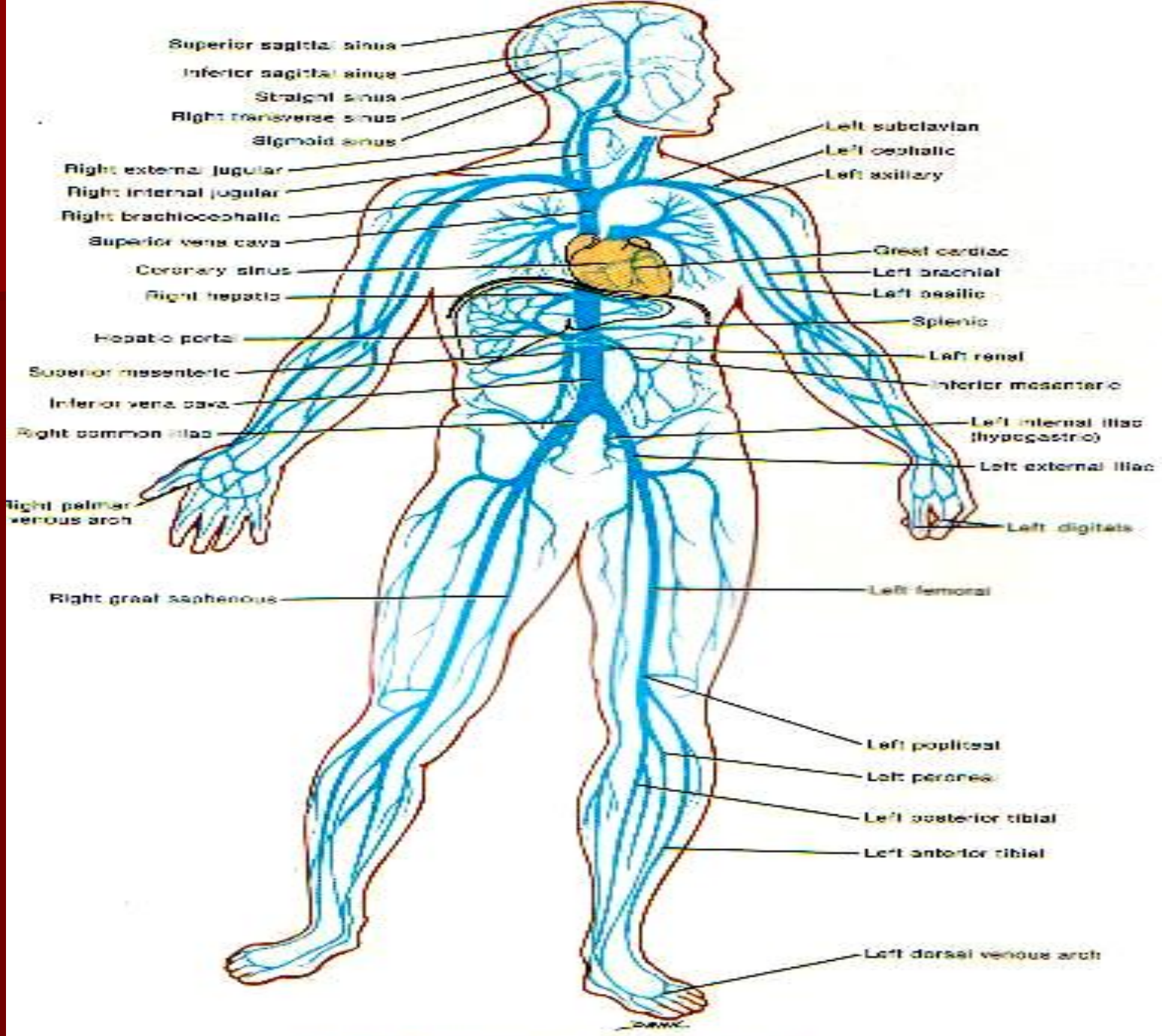
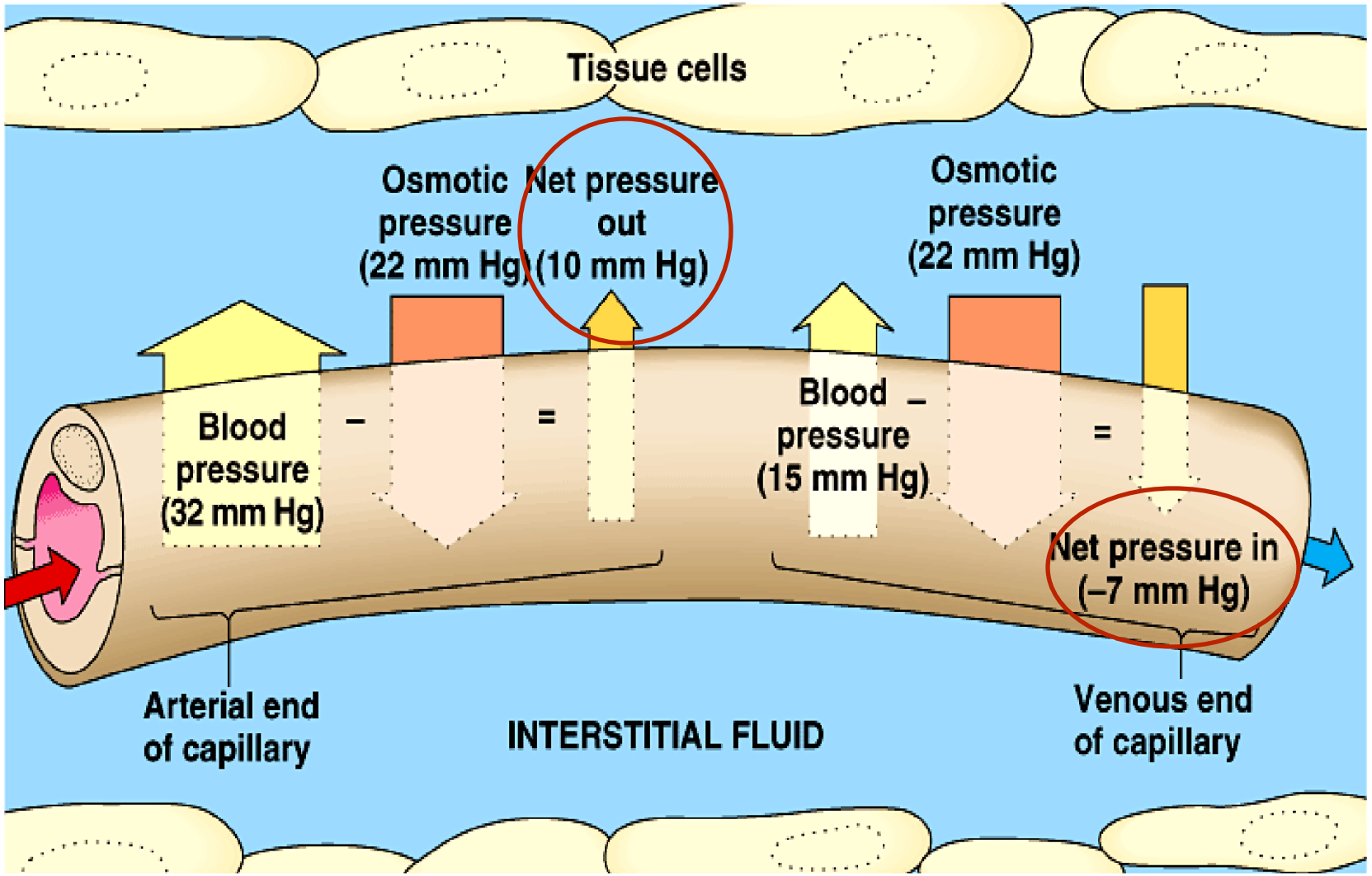


FIGURE 21-17 Principal veins in anterior view.

Interstisial Ex-change principle



Lymphatic system

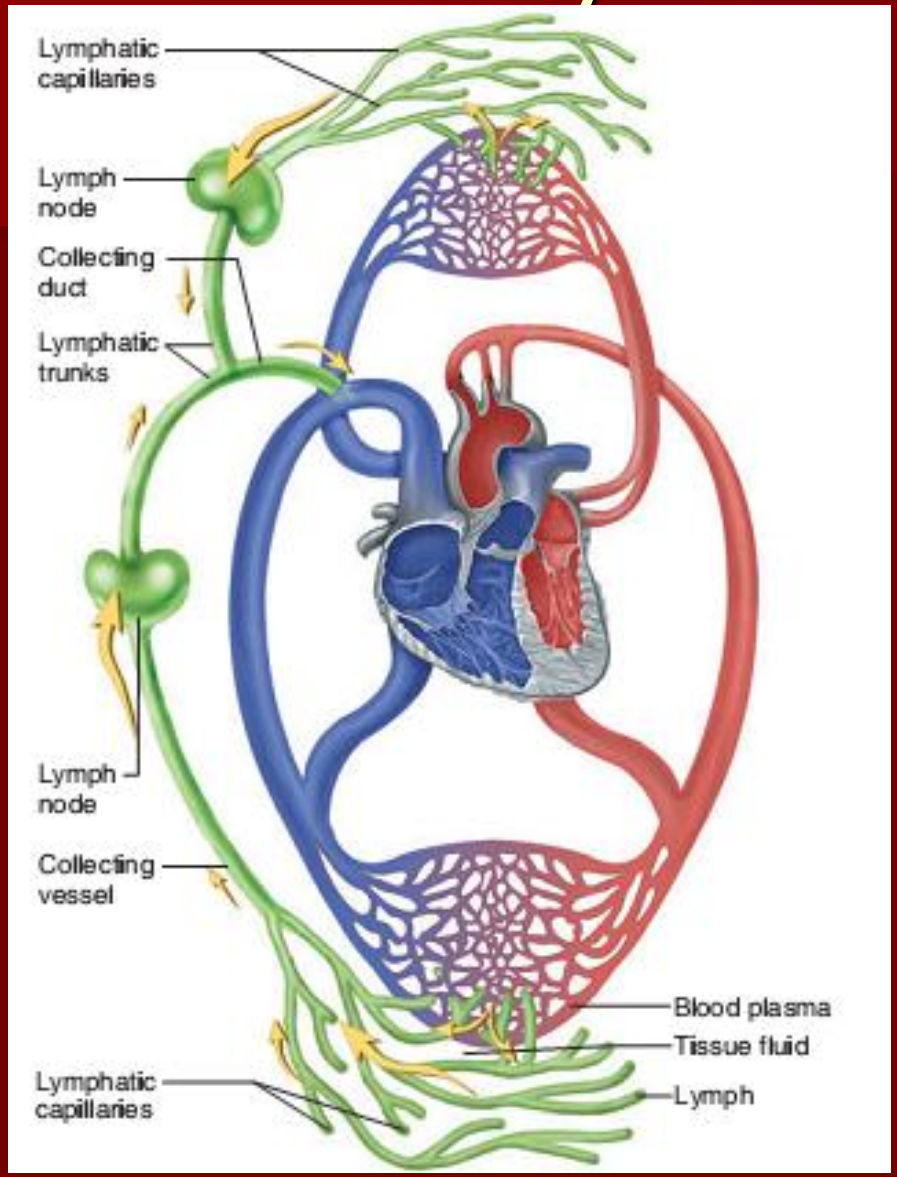
- a network of lym-phatic vessels interconnected with lymphoid organs, such as lymph nodes, spleen and Peyer's patches in the small intestine, that are distributed throughout most of the body.
- critical to the maintenance of **normal interstitial fluid volume and protein concentration.**
- daily return of 20–50% of the plasma volume and 50–200% of the plasma proteins from the interstitium to the systemic circulation

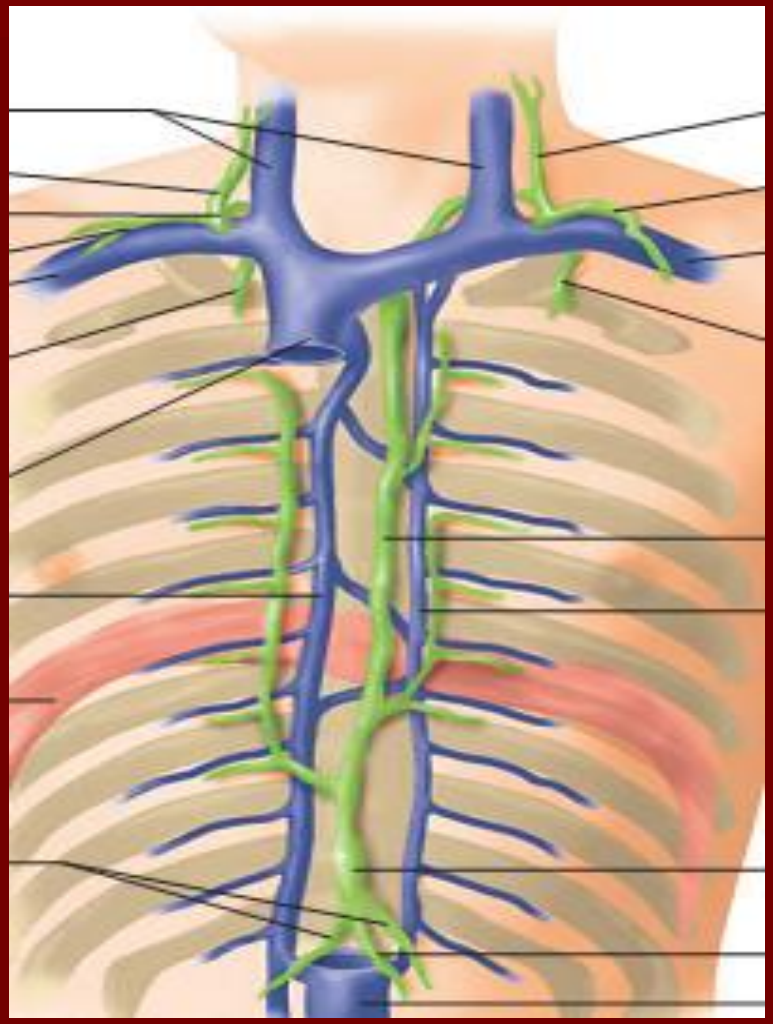
Von der Weid, 2010.

- lymphatic vessels or lymphatics:
  - Parallel to blood vasculature
  - necessary for the controlled trans-port of lymph, which contains immune cells, antigens, lipids, macromolecules, fluid and particulate matter.
  - Except in :
    - Avascular tissue
    - The central nervous system
    - Splenic pulp
    - Bone marrow

- Transport fats from GI tracts to the blood
- Surveillance & defense: **lymphocytes** + macrophages protect the body from foreign cells, microbes & cancer cells:
  - T cells: destroy them directly or indirectly
  - B cells: differentiate into plasma cells that secrete antibodies against foreign substances

System limfatik....





- Lymph.of the skin: travel in subcutaneous tissue generally follow veins
- Lymph.of the viscera: follow arteries forming plexuses around them
- Principal lymph trunk: lumbar, intestinal, brochomediastinal, subclavian & jugular
- Thoracic (Left Lymphatic) Duct:
  - About 38 – 45 cm,
  - Begins as cisterna chyli, empties into left angulus venosus
- Right Lymphatic Duct
  - About 1.25 cm, empties into right angulus venosus

Lymphoid tissue

is organized in various ways:

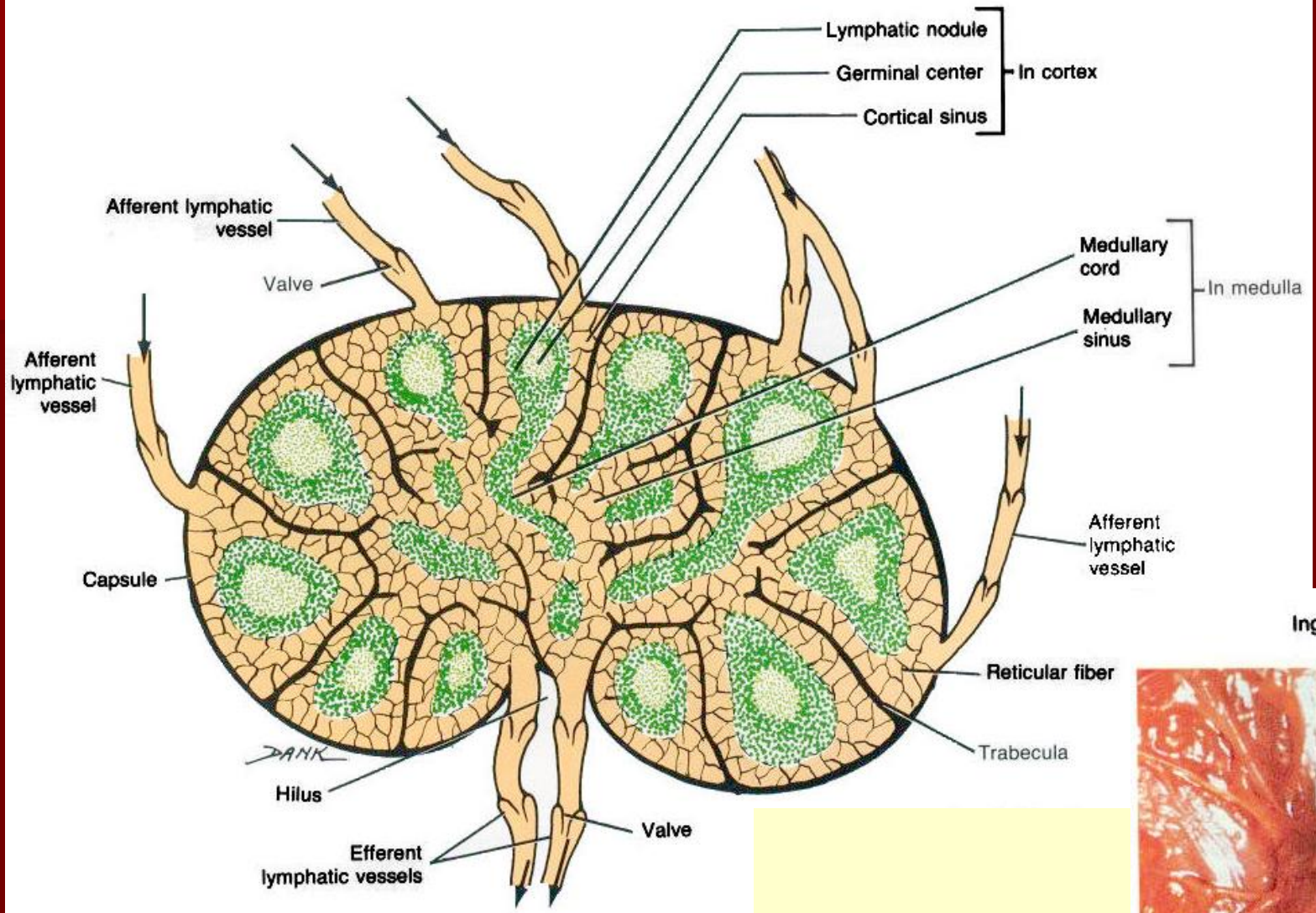
- **Epithelium-associated lymphoid tissue**
  - Diffuse lymphatic tissue
  - Lymphatic nodules
- **Lymphoid organs**

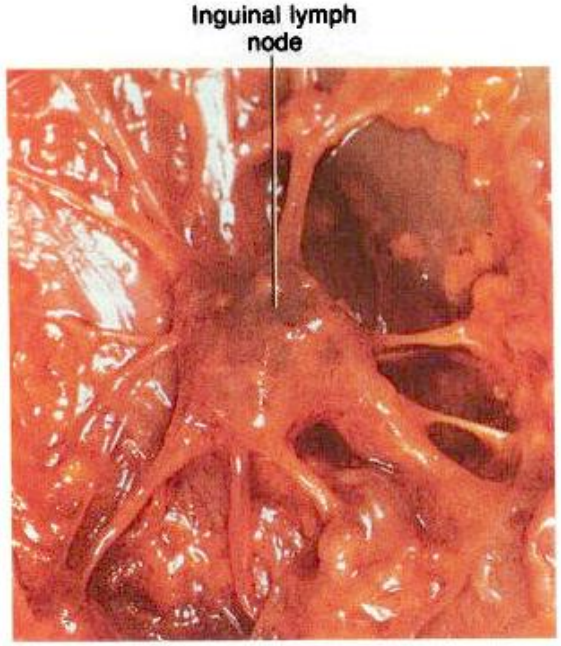
  contain lymphoid tissue enclosed by a connective tissue capsule:
  - lymph nodes, spleen, thymus, bone marrow

- The simplest form of lymphatic tissue is **diffuse lymphatic tissue—a sprinkling of lymphocytes in the mucous** membranes and connective tissues of many organs.
- In some places, lymphocytes and other cells congregate in dense masses called **lymphatic nodules (follicles), cluster of follicles: tonsil & Peyer's Patch**

Lymphoid organs

- Primary lymphoid organs:
  - Medulla ossium (bone marrow)
  - Thymus
- Secondary or peripheral lymphoid organs:
  - Lymph nodes
  - Lien (spleen)


Lymphatic nodule
Germinal center
Cortical sinus
In cortex
Afferent lymphatic vessel
Valve
Medullary cord
Medullary sinus
In medulla
Afferent lymphatic vessel
Capsule
Afferent lymphatic vessel
Reticular fiber
Trabecula
Hilus
Valve
Efferent lymphatic vessels


Inguinal lymph node

(b)

Jalur Sirkulasi

- Paling besar : sirkulasi sistemik; terapat pula :
  - the coronary (cardiac) circulation
  - the hepatic portal circulation.
- Other routes include:
  - the cerebral circulation
  - the pulmonary circulation
  - the fetal circulation

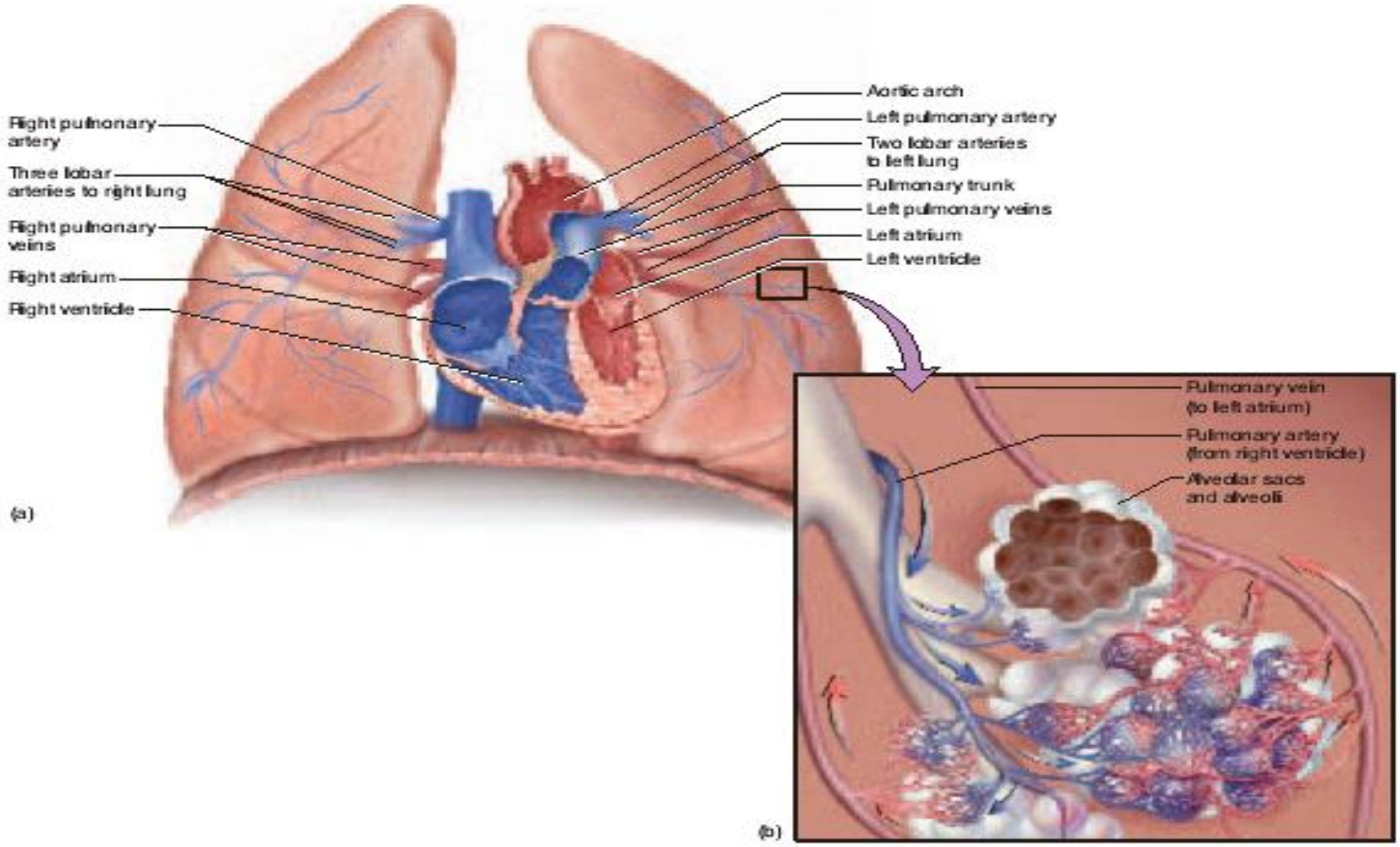
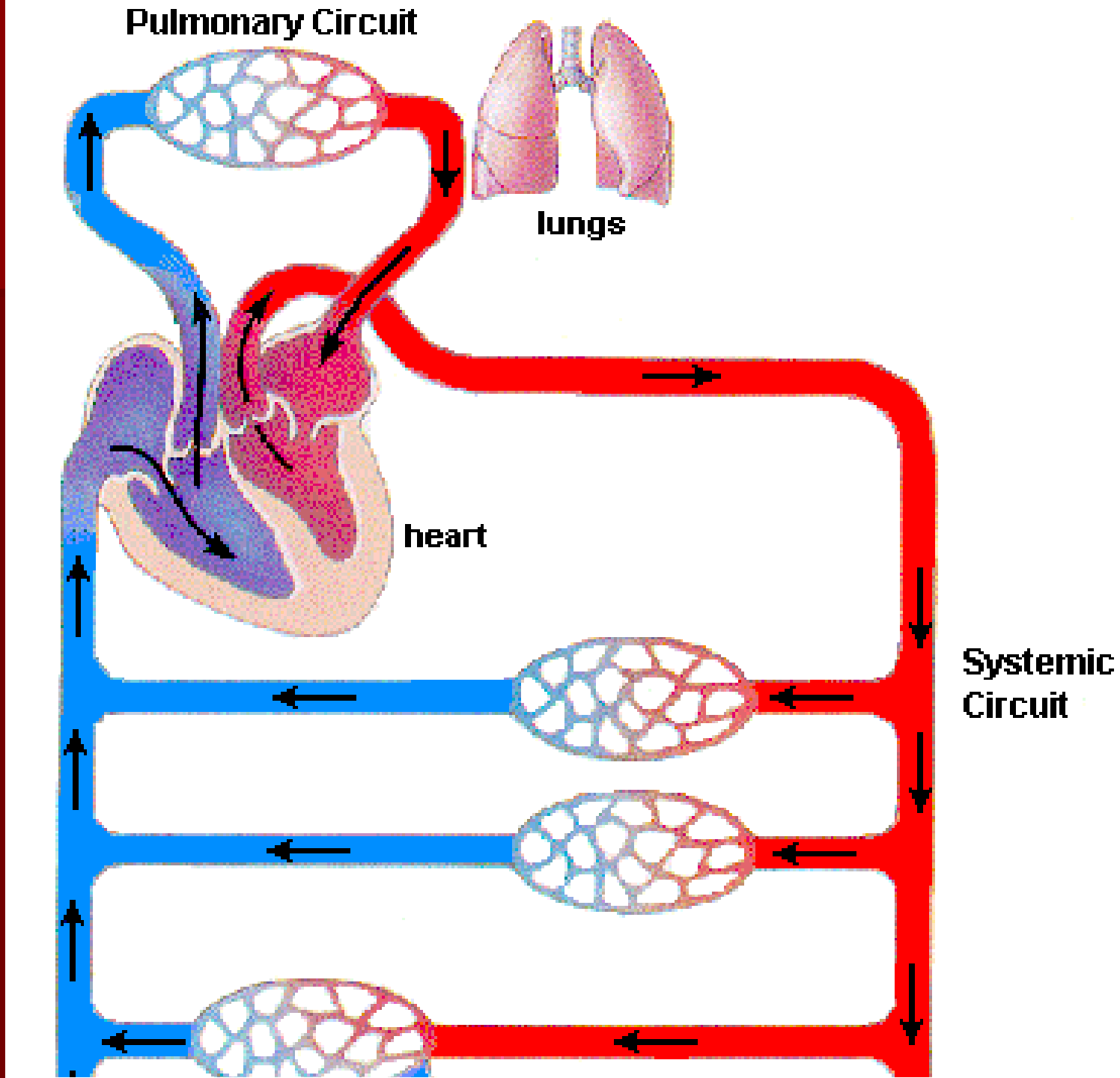
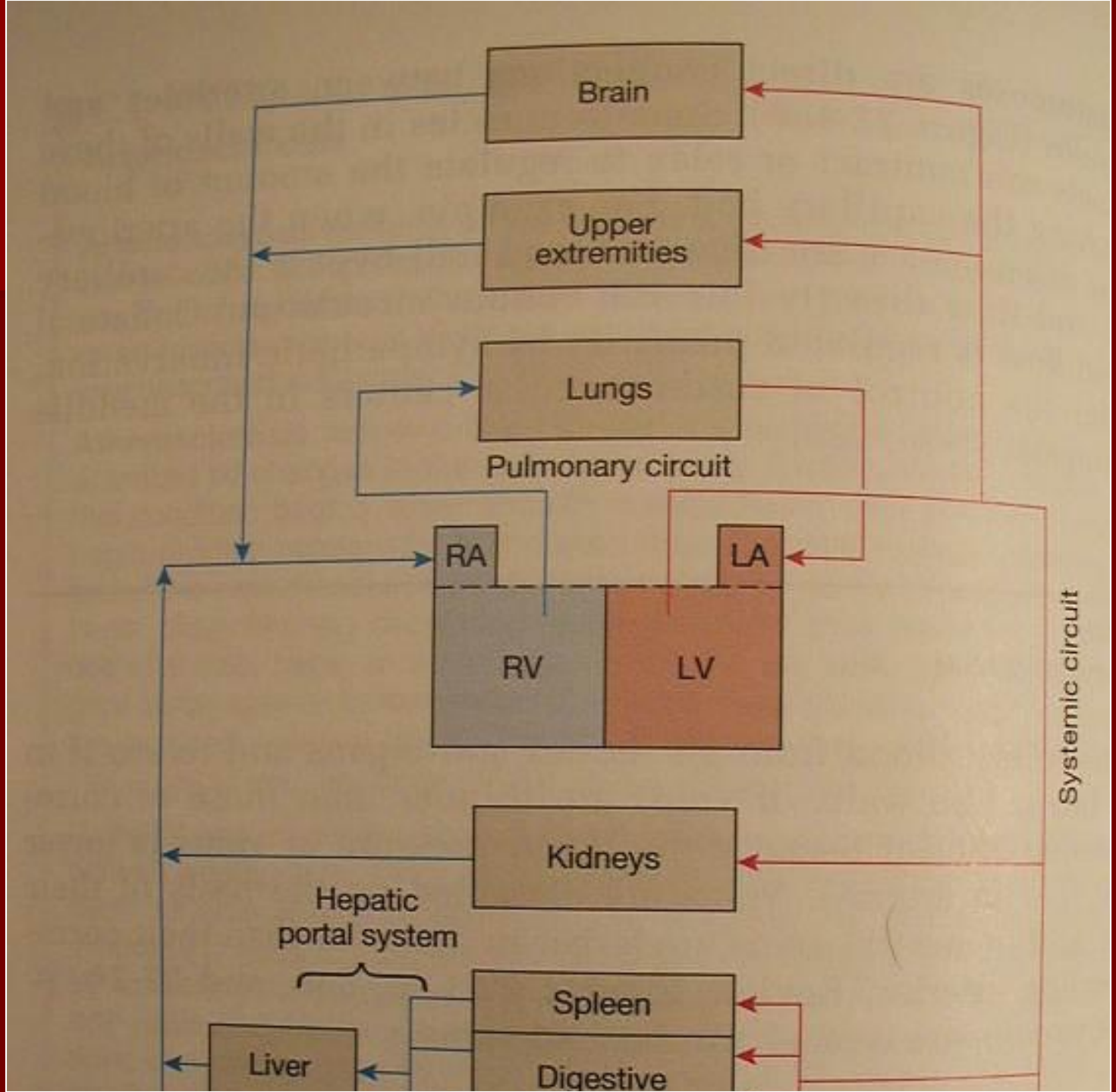


Figure 20.19 The Pulmonary Circulation. (a) Gross anatomy. (b) Microscopic anatomy of the blood vessels that supply the pulmonary alveoli.

Chapter 20

Sirkulasi pulmonal : pertukaran O2 & Co2 pada alveolus


Pulmonary Circuit
lungs
heart
Systemic Circuit


Brain
Upper extremities
Lungs
Pulmonary circuit
RA
LA
RV
LV
Systemic circuit
Kidneys
Hepatic portal system
Spleen
Liver
Digestive

Distribusi Volume darah :

- Arterioles & Capillaries 7%
- The Heart 9%
- Pulmonary Vessels 12%
- Arteries 13%
- Veins, Venules & Venous Sinuses 59% (principal reservoirs)

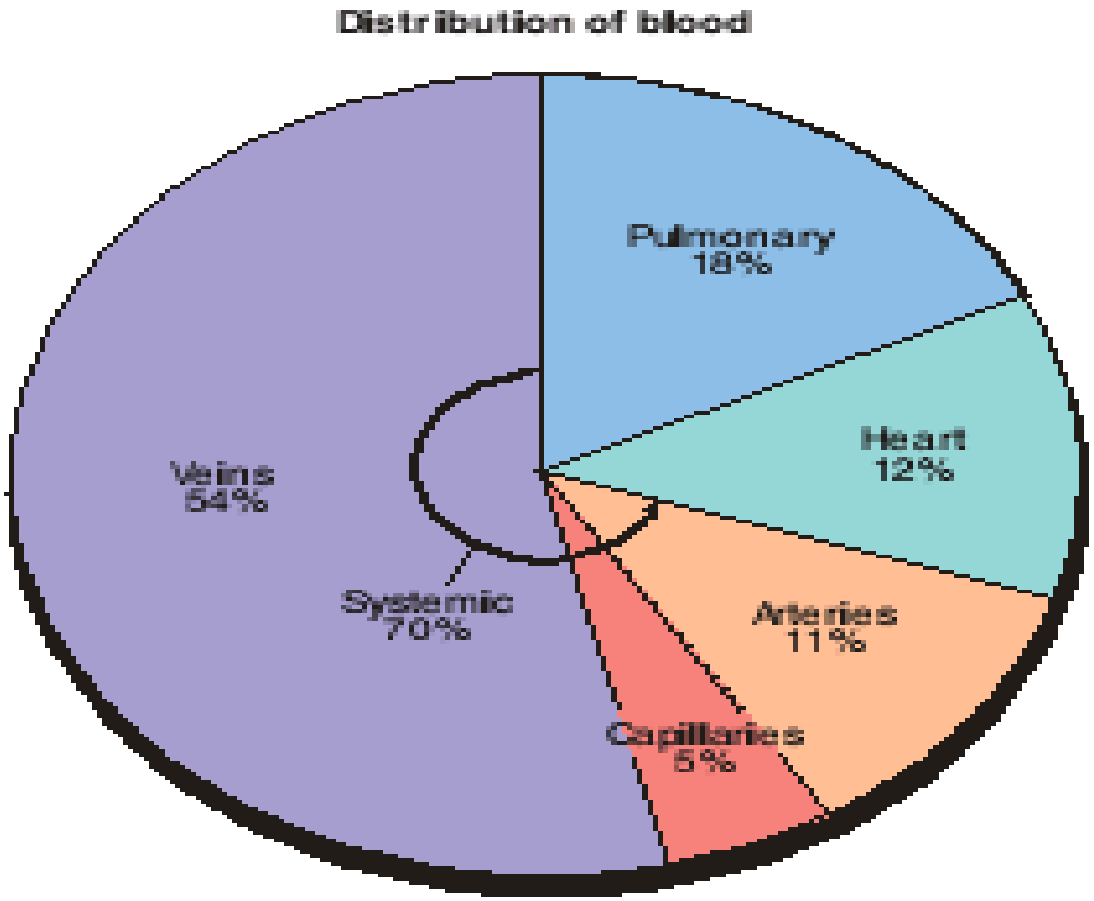
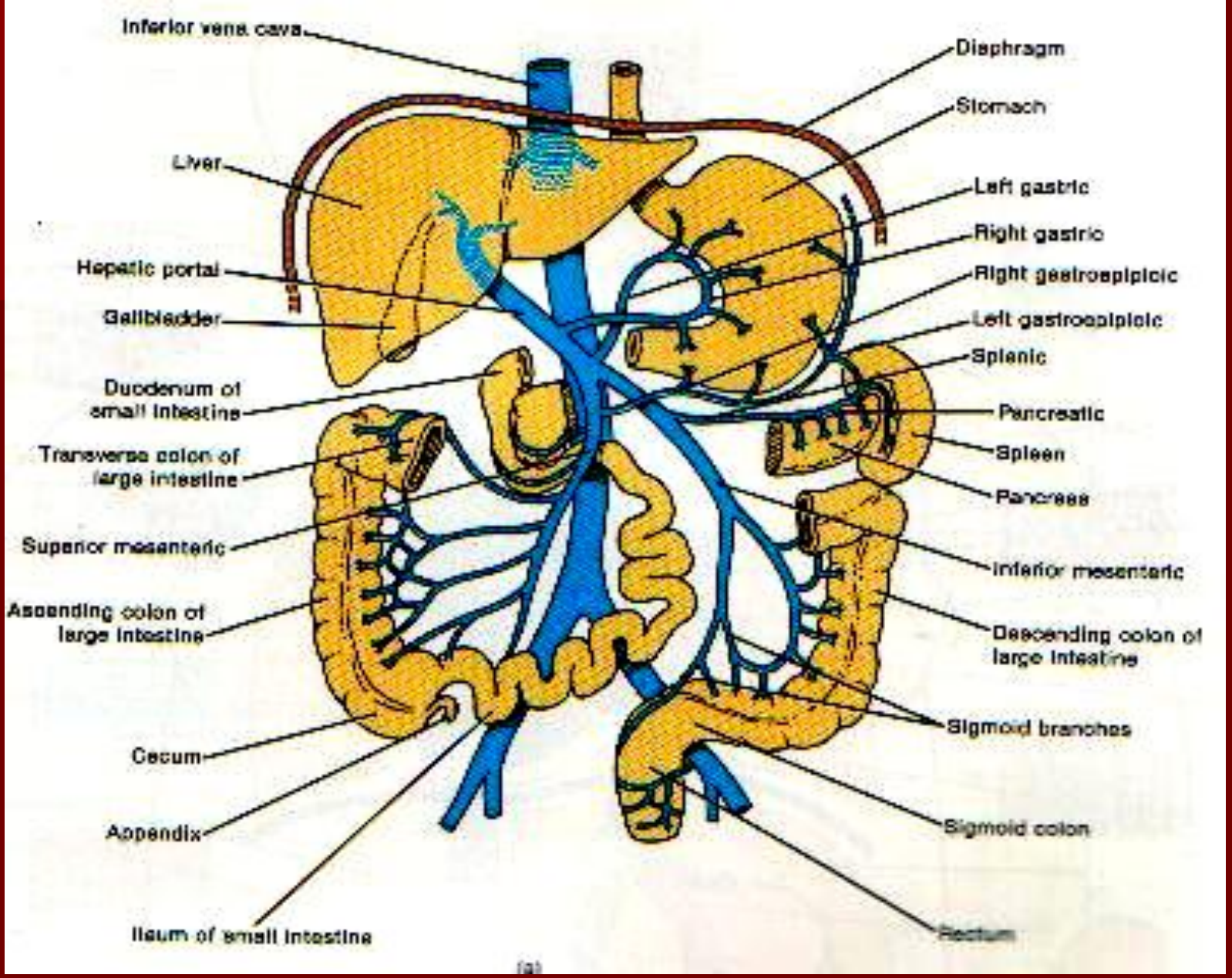


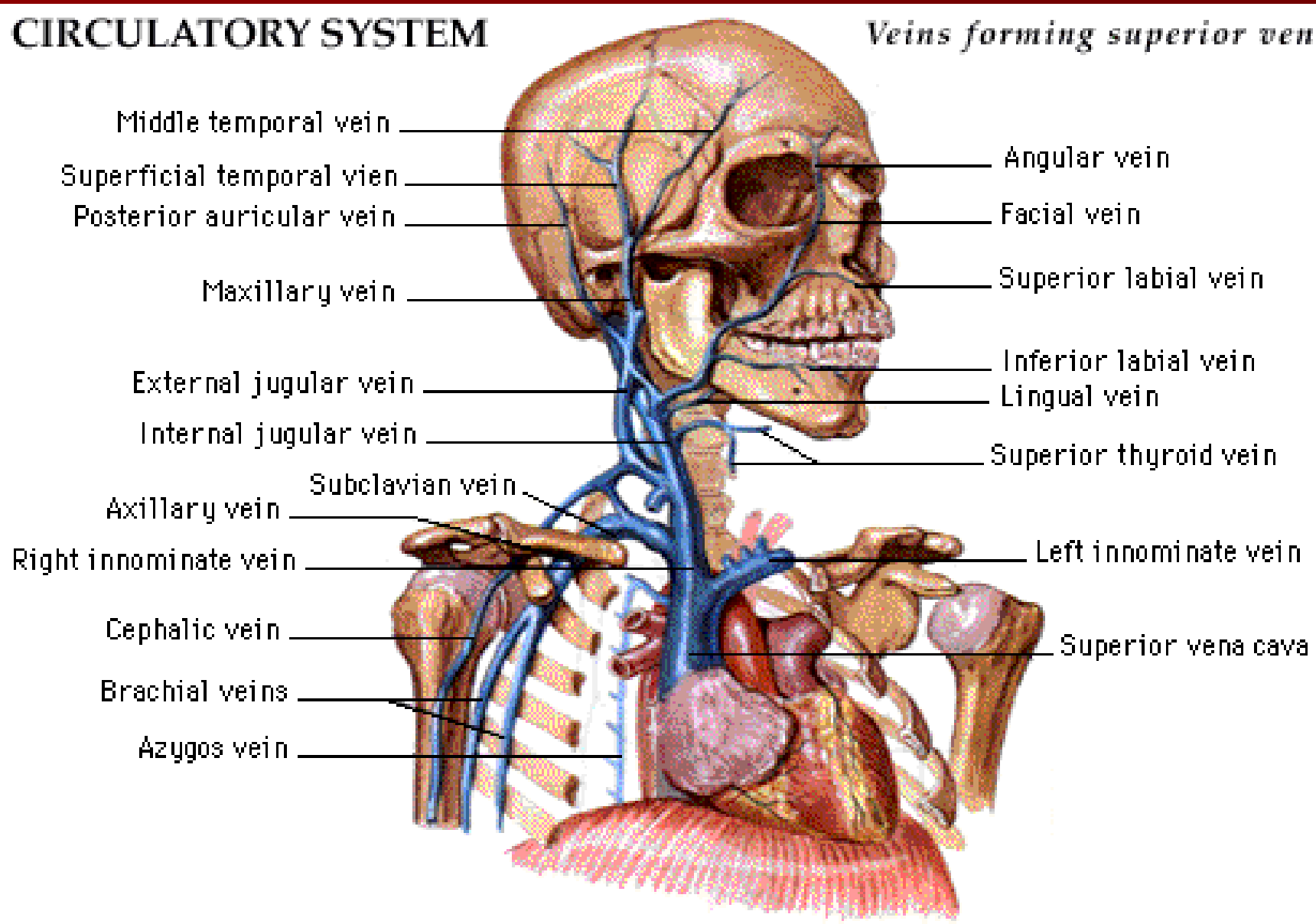
Figure 20.7 Average Distribution of Blood in a Resting Adult.

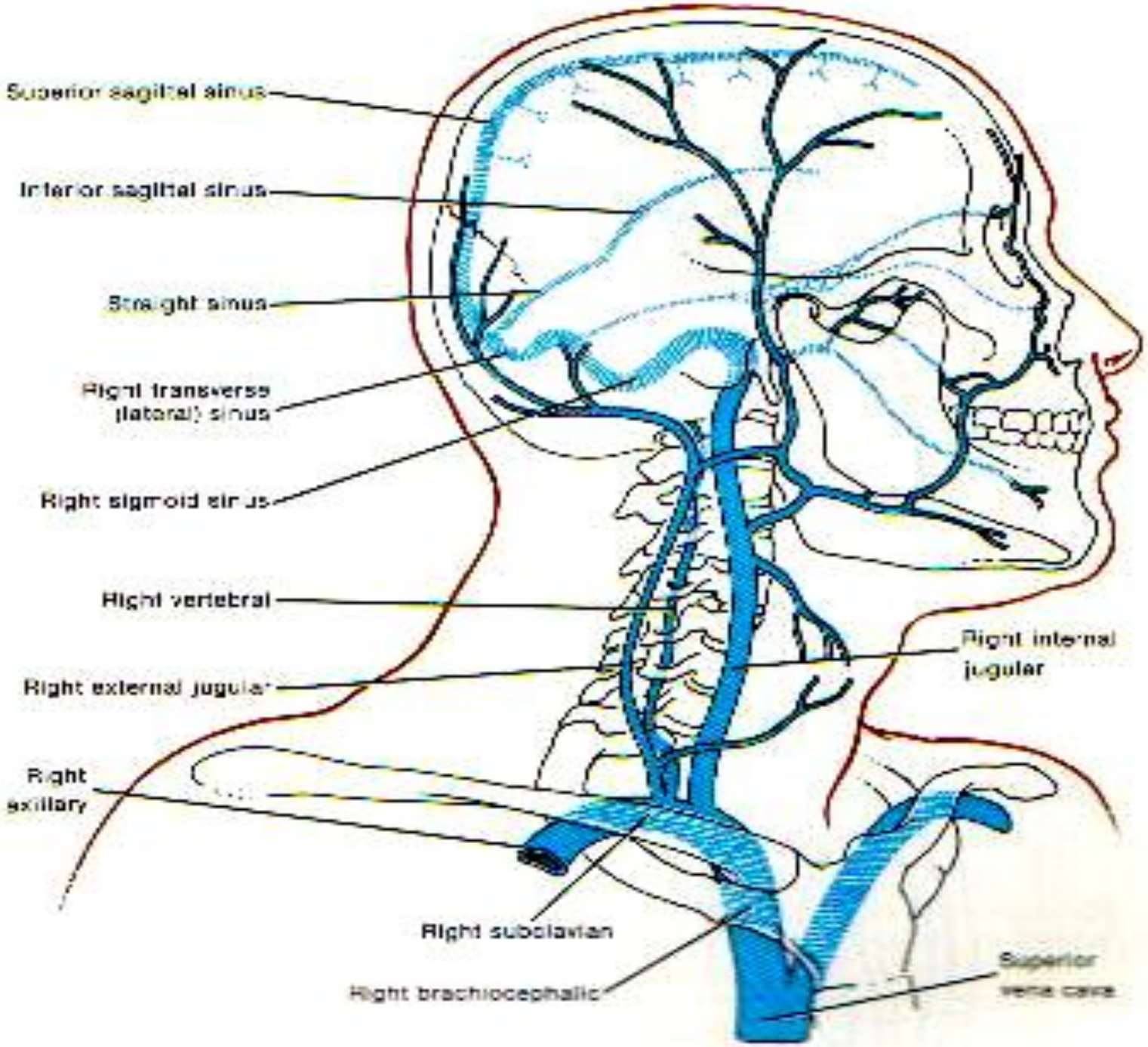


Vena dari saluran pencernaan akan masuk ke hepar melalui vena porta

CIRCULATORY SYSTEM

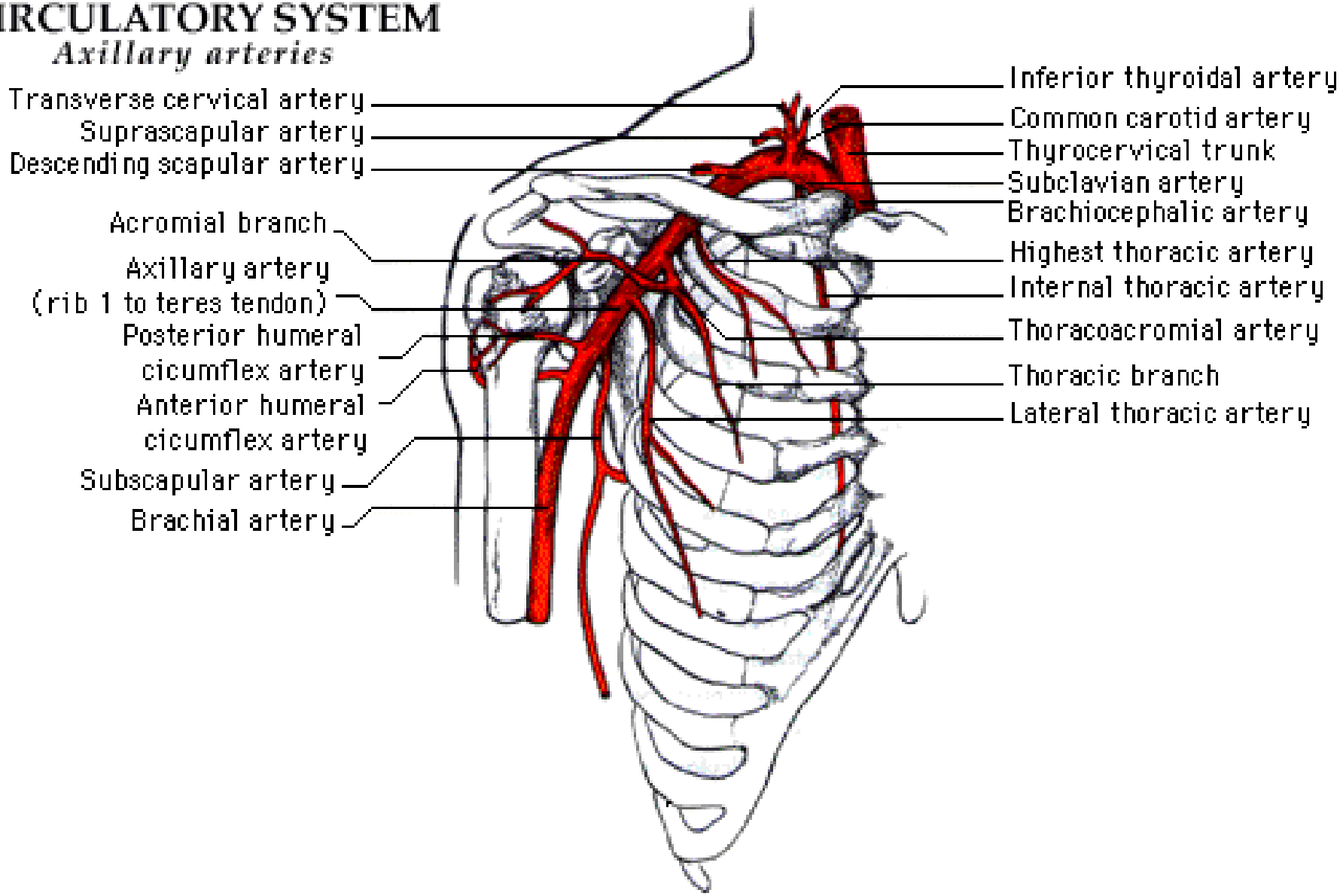
Veins forming superior vena cava

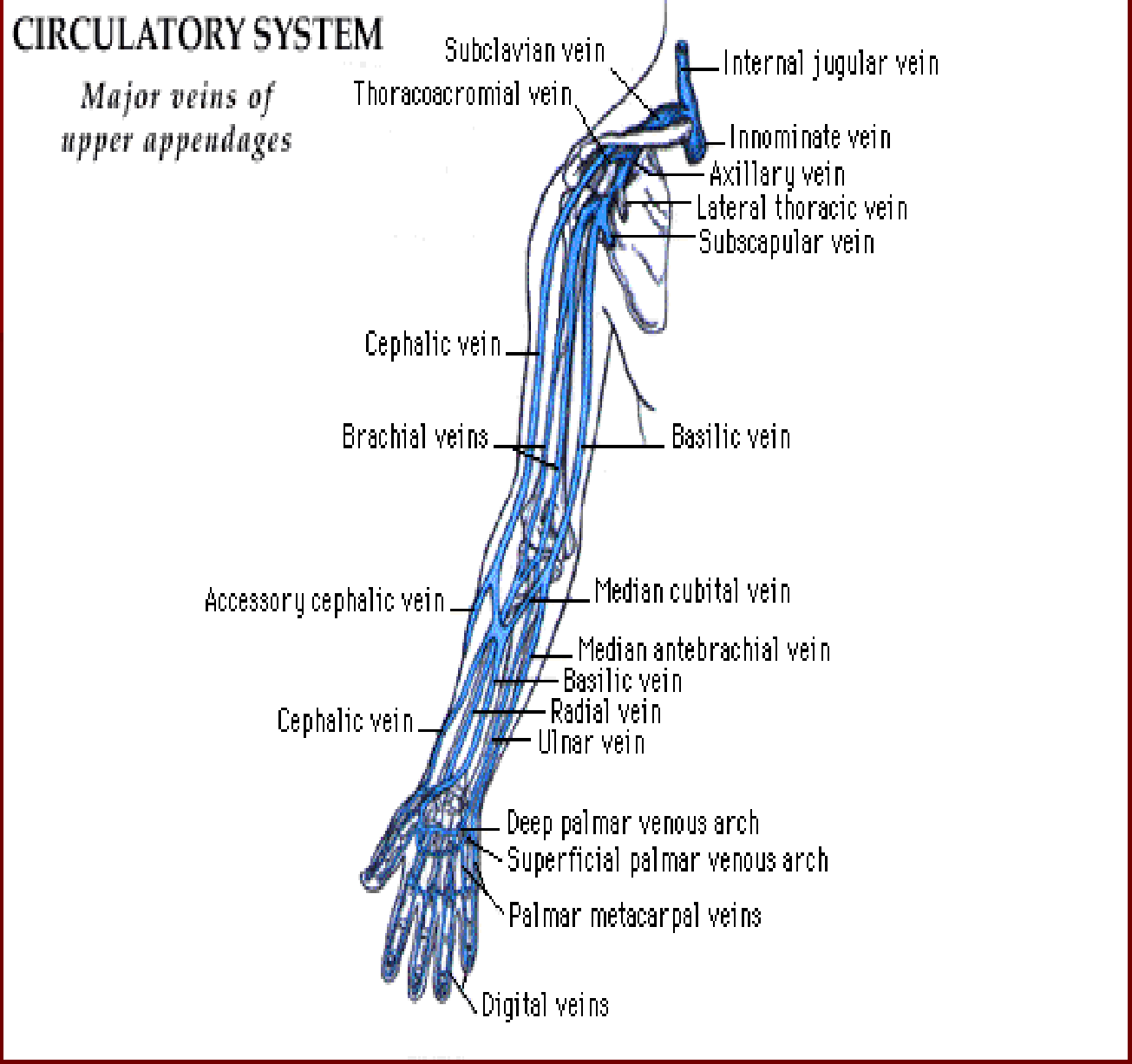



Superior sagittal sinus
Inferior sagittal sinus
Straight sinus
Right transverse (lateral) sinus
Right sigmoid sinus
Right vertebral
Right internal jugular
Right external jugular
Right axillary
Right subclavian
Right brachiocephalic
Superior vena cava

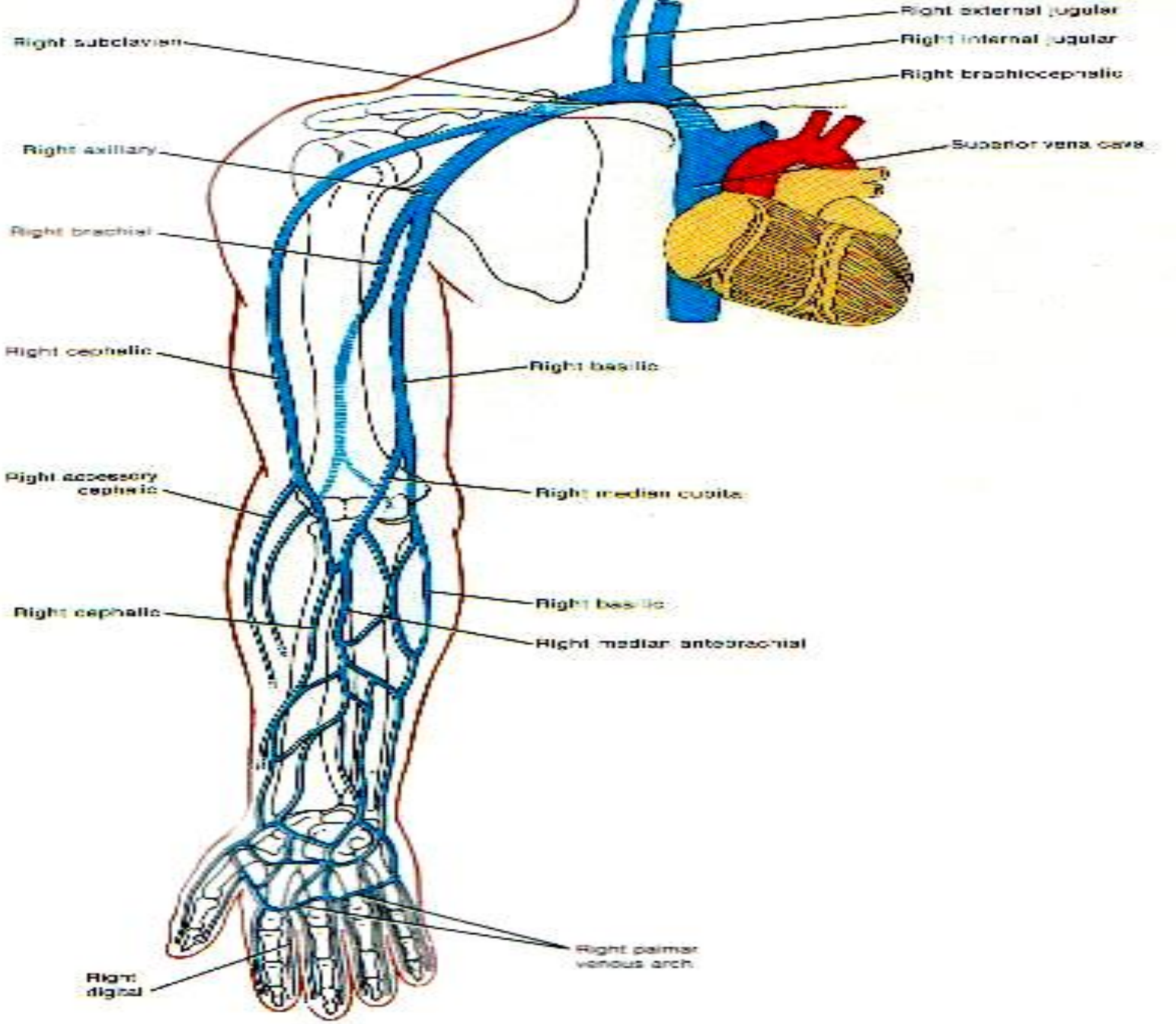
CIRCULATORY SYSTEM

Axillary arteries





Pada vena xtremitas terdapat dua system vena : superficial & profundus



(a)

FIGURE 21-19 Veins of the right upper extremity in anterior view. (a) Diagram.

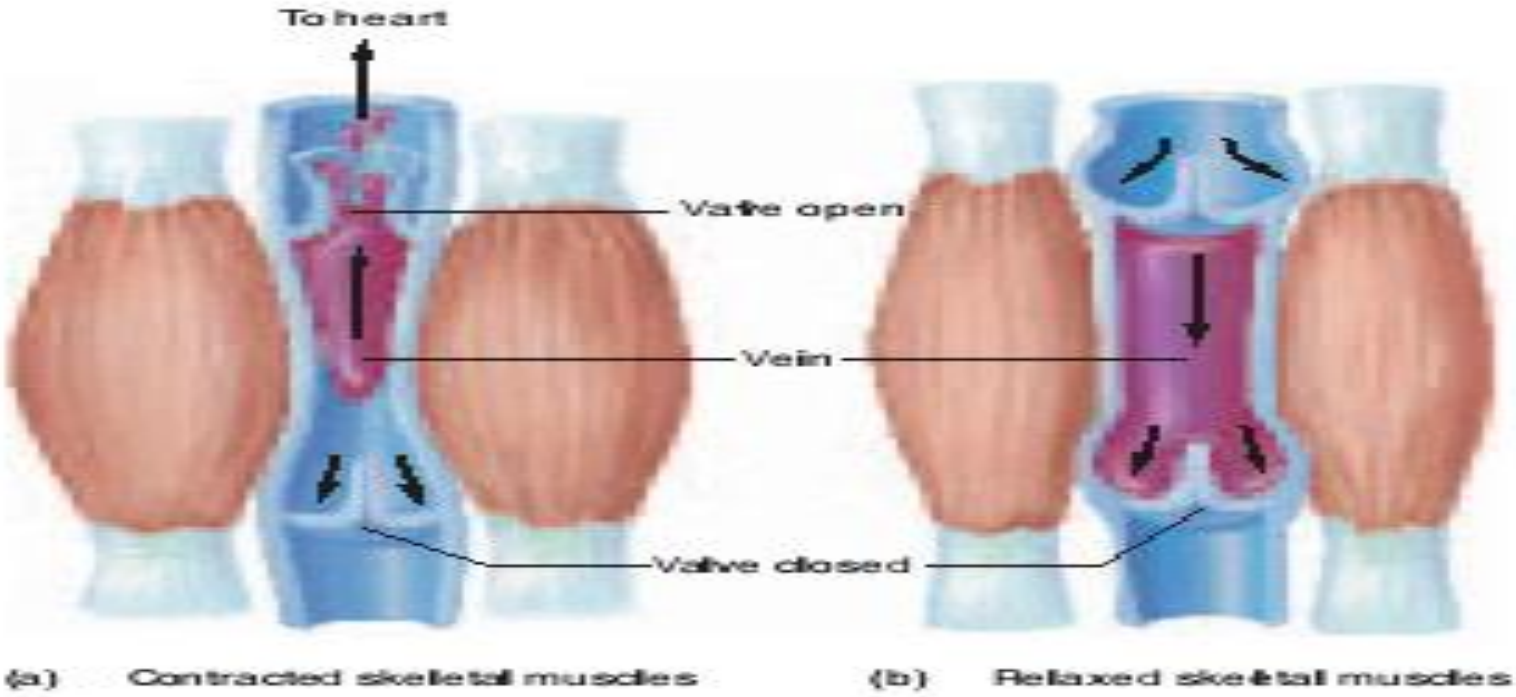


Figure 20.18 The Skeletal Muscle Pump. (a) When the muscles contract and compress a vein, blood is squeezed out of it and flows upward toward the heart; valves below the point of compression prevent backflow of the blood. (b) When the muscles relax, blood flows back downward under the pull of gravity but can only flow as far as the nearest valve.

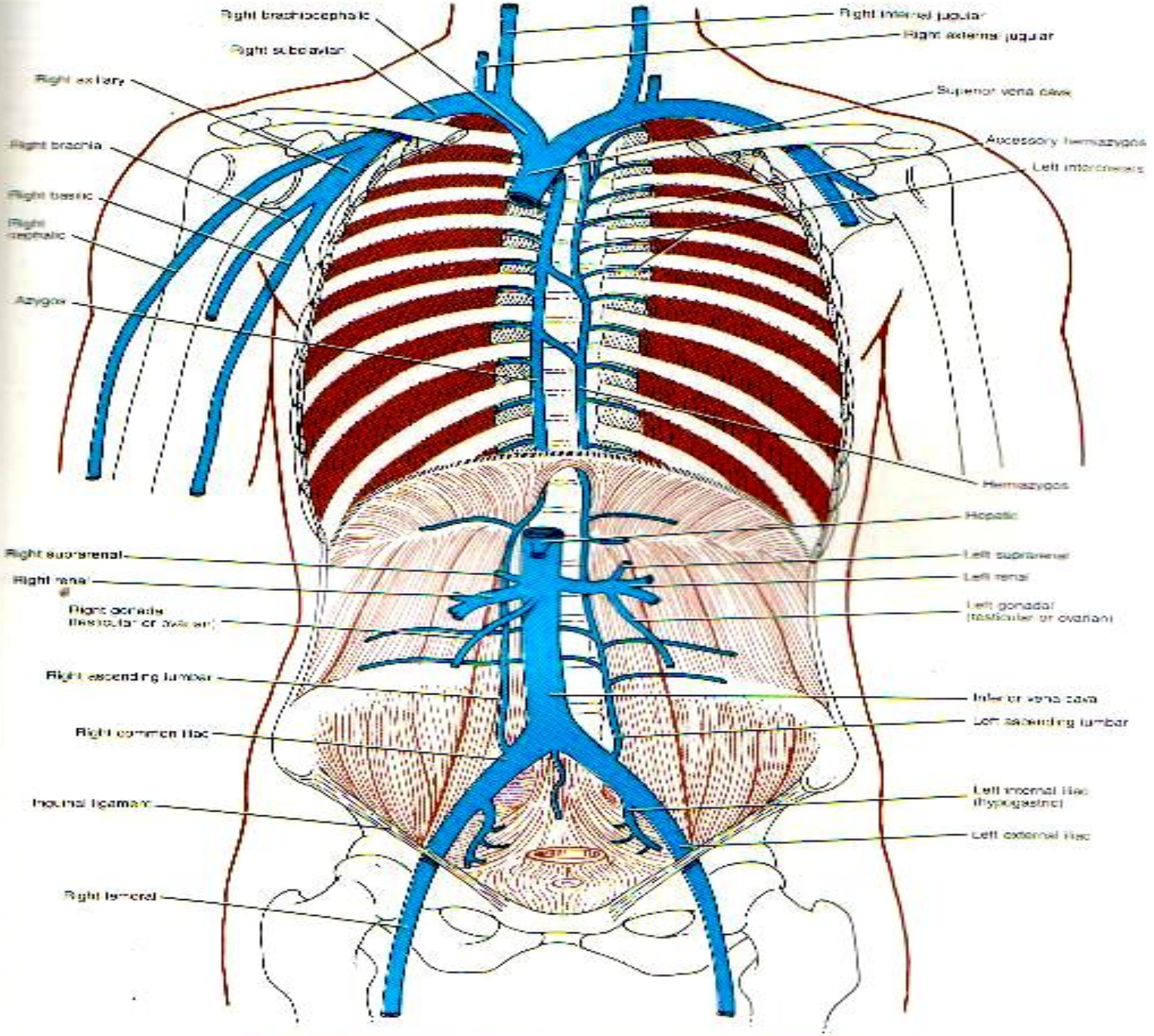
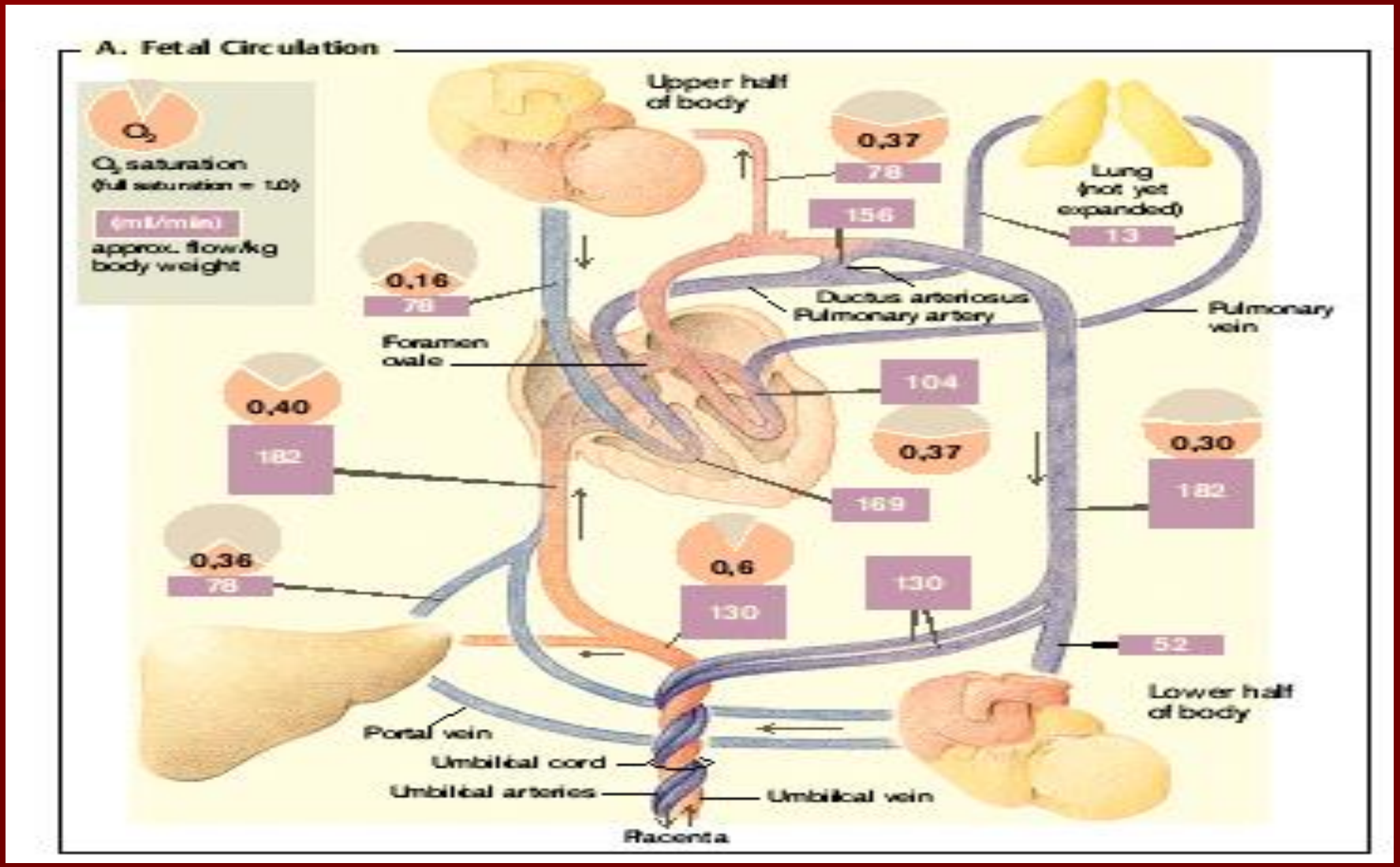
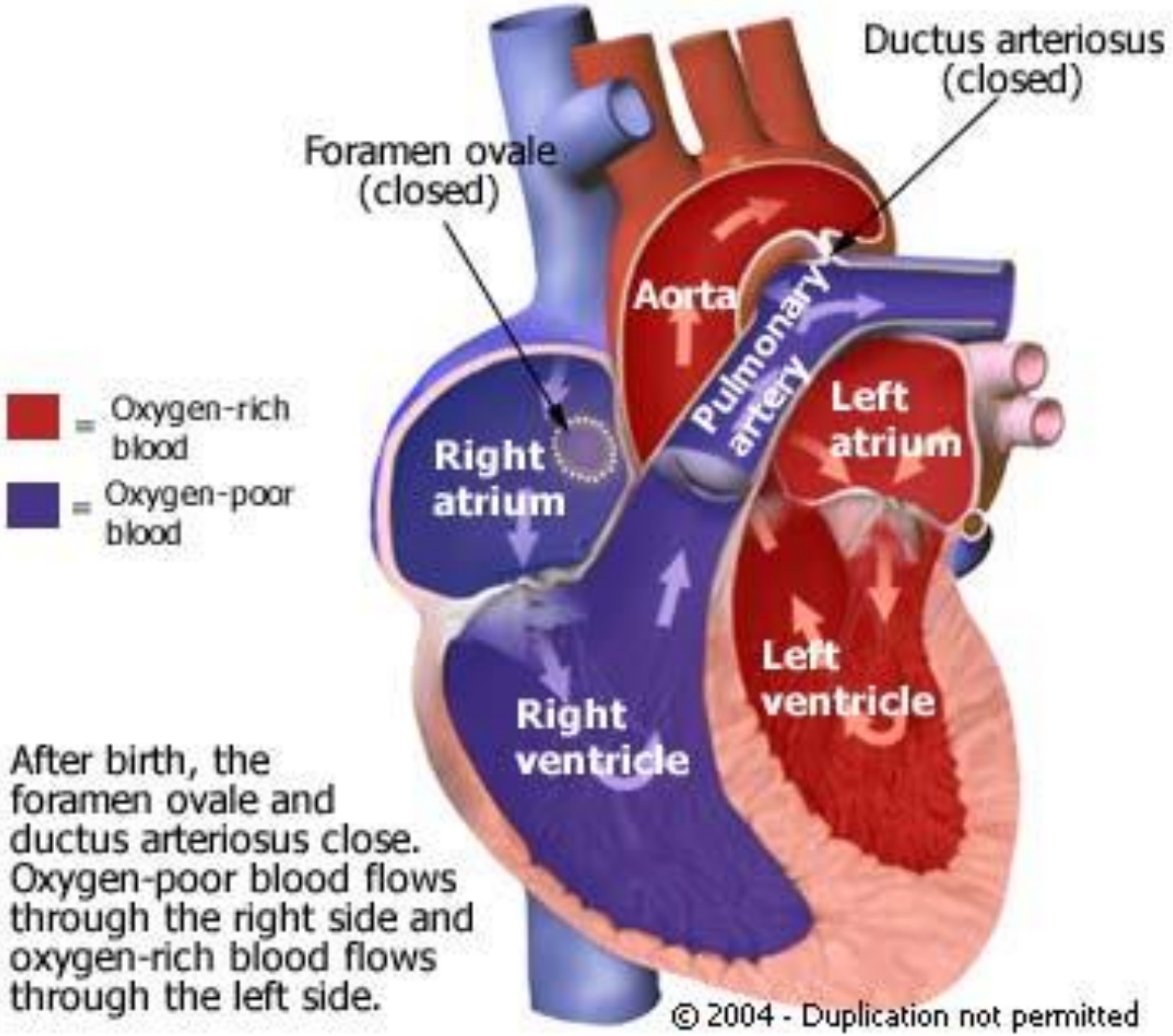


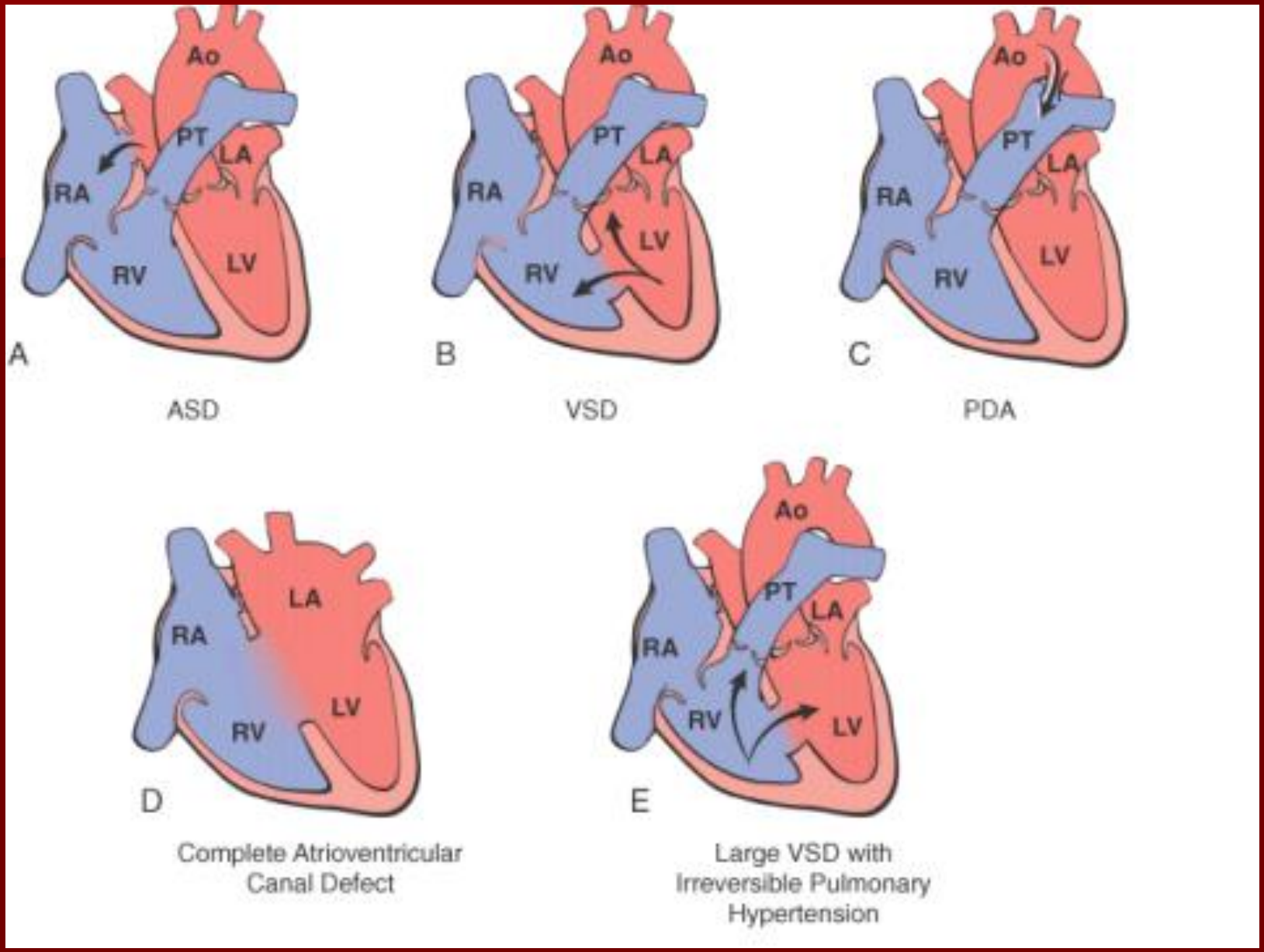
FIGURE 21-20 Veins of the thorax, abdomen, and pelvis in anterior view.

Sirkulasi Fetus

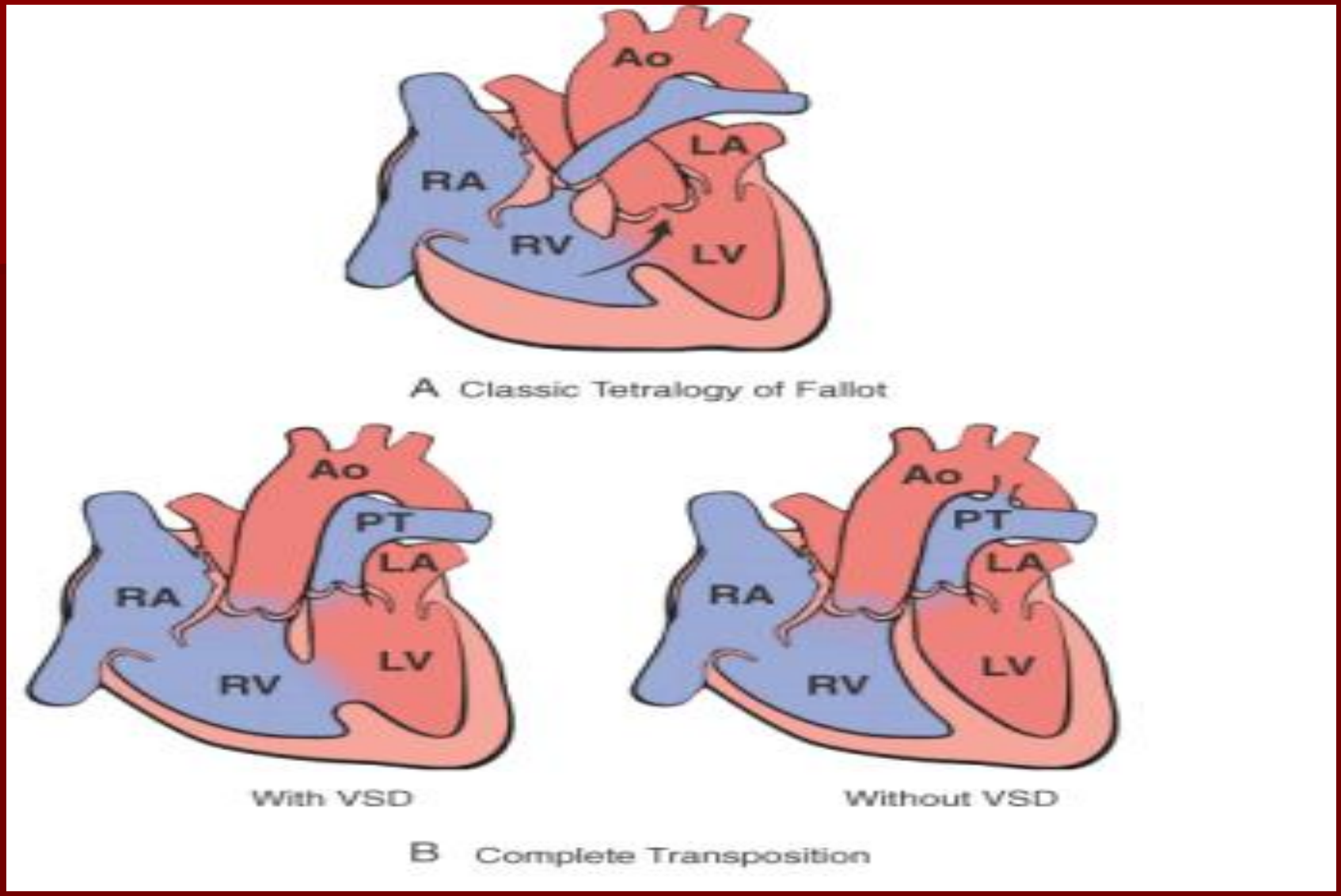


Normal Neonatal (Newborn) Circulation



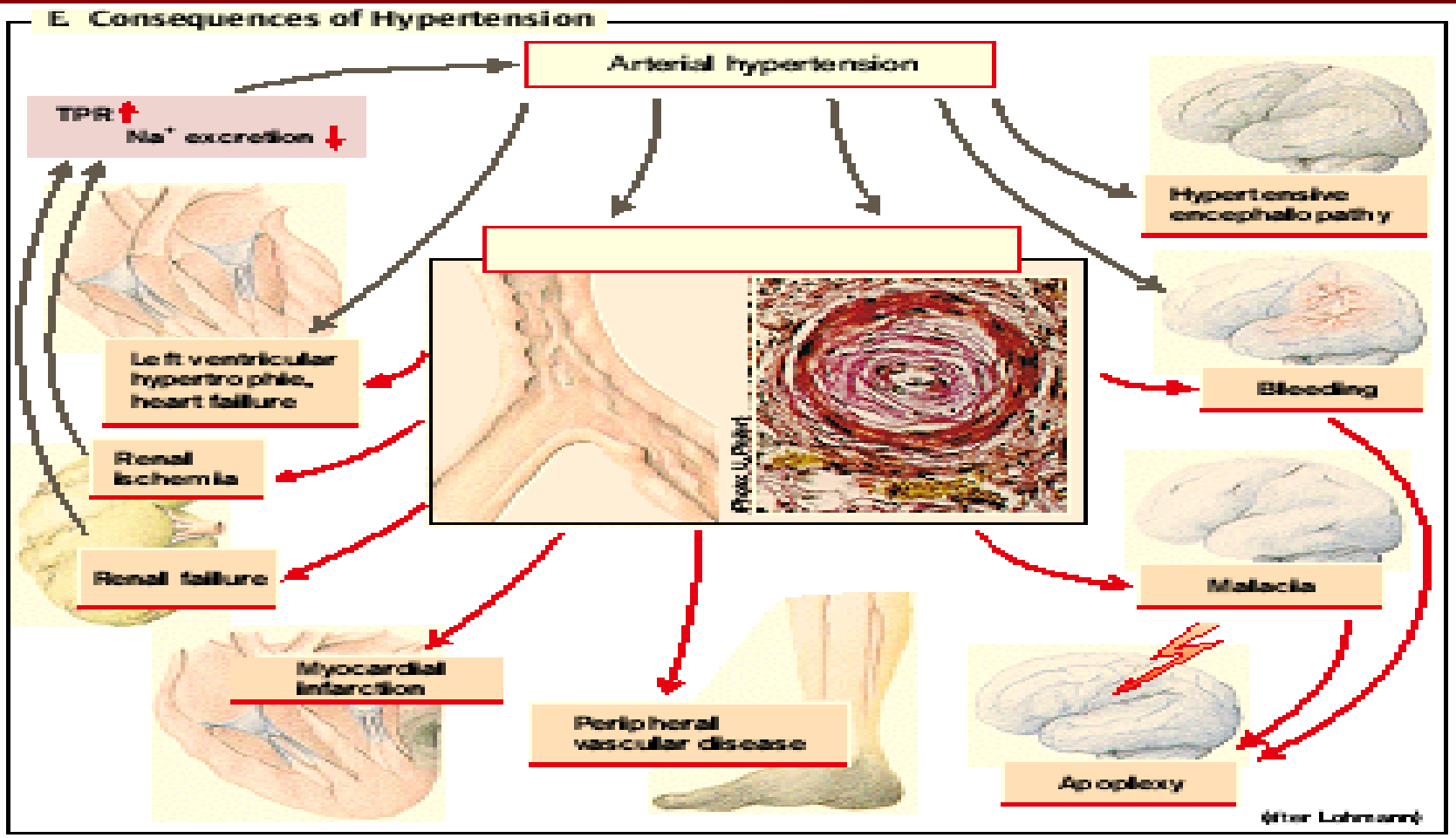


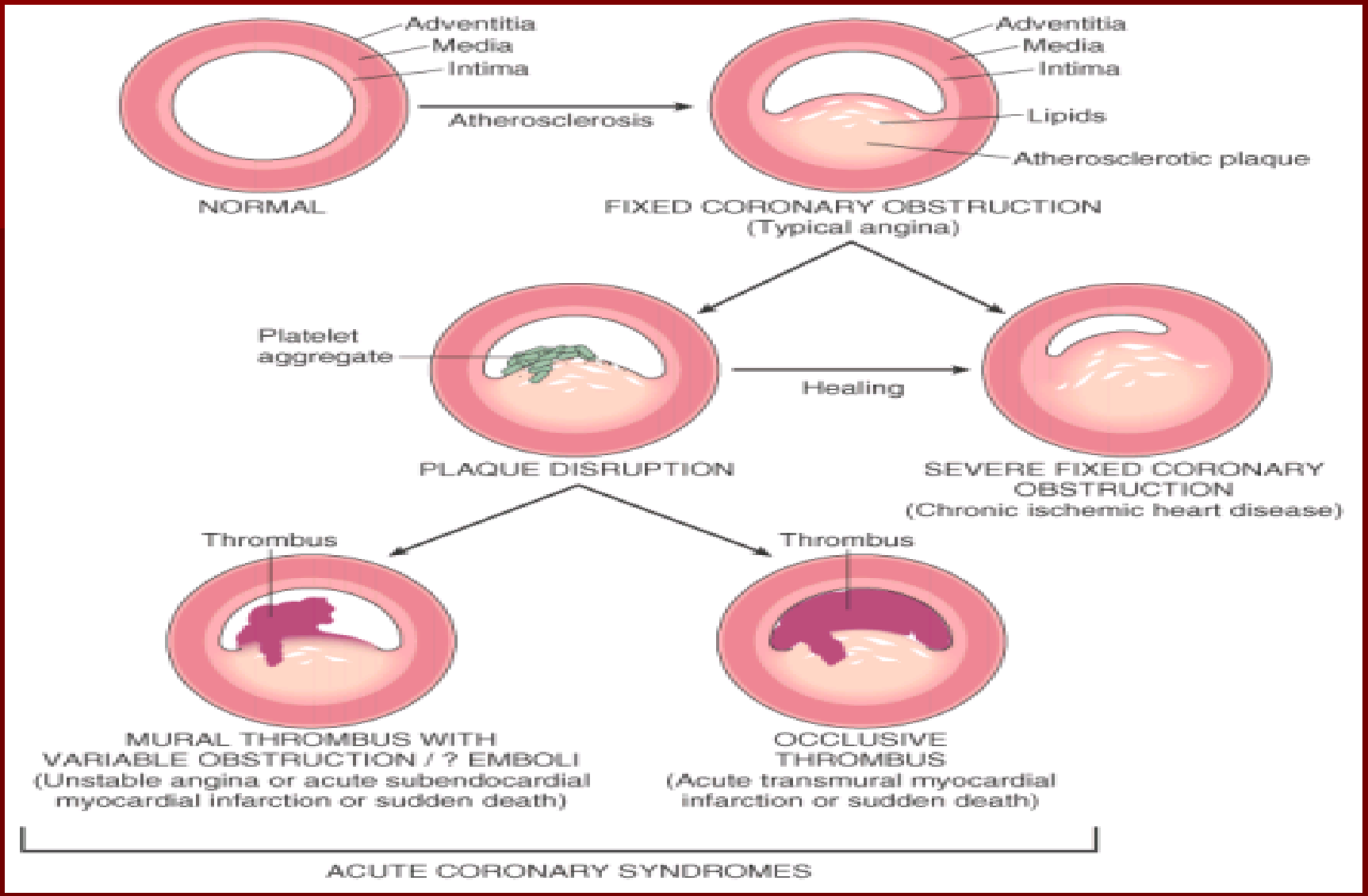
Gangguan dgn shunt kiri ke kanan : janin sianosis???



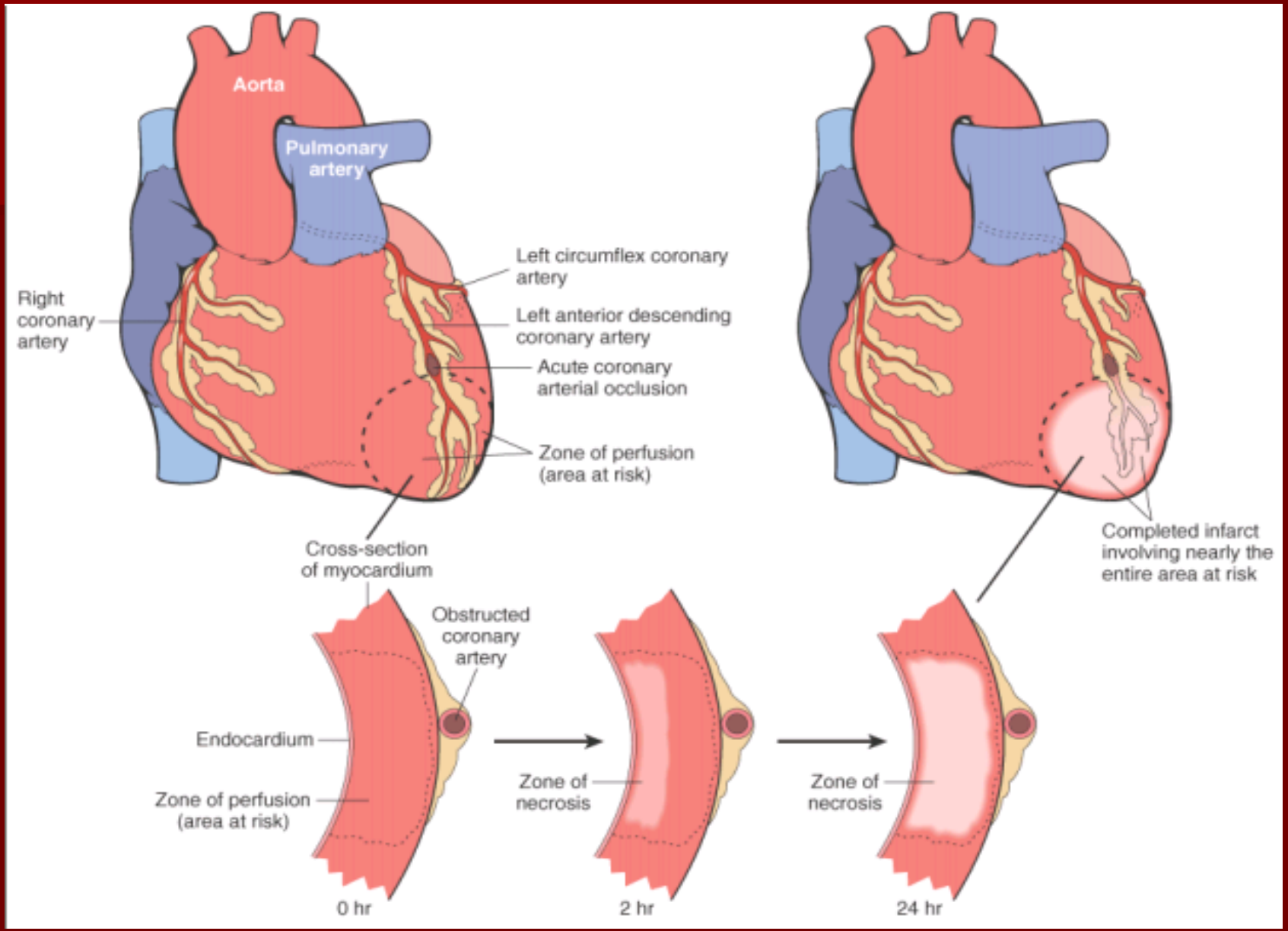
Gangguan dgn shunt kanan ke kiri : janin sianosis >>>

Hipertensi





Terjadinya oklusi pada a.coronaria


Aorta
Pulmonary artery
Right coronary artery
Left circumflex coronary artery
Left anterior descending coronary artery
Acute coronary arterial occlusion
Zone of perfusion (area at risk)
Completed infarct involving nearly the entire area at risk
Cross-section of myocardium
Obstructed coronary artery
Endocardium
Zone of perfusion (area at risk)
Zone of necrosis
Zone of necrosis
0 hr
2 hr
24 hr