



Darah & Limfatik

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Functions of Blood

1. Transportation

- O₂
- Nutrient
- Waste product
- Hormones
- Heat

2. Regulation

- pH
- body temperature
- water

3. Protection against :

- blood loss (hemostasis)
- foreign microbes and toxin

Karakteristik Fisika Darah

- Viscositas : 4,5 – 5,5
- Temperatur : 38°C
- pH : 7,35 – 7,45
- Salinitas : 0,9 %
- % ~ Berat Badan Total : 8%
- Volume : 5-6 L (pria)
4-5 L (wanita)

Components of Whole Blood

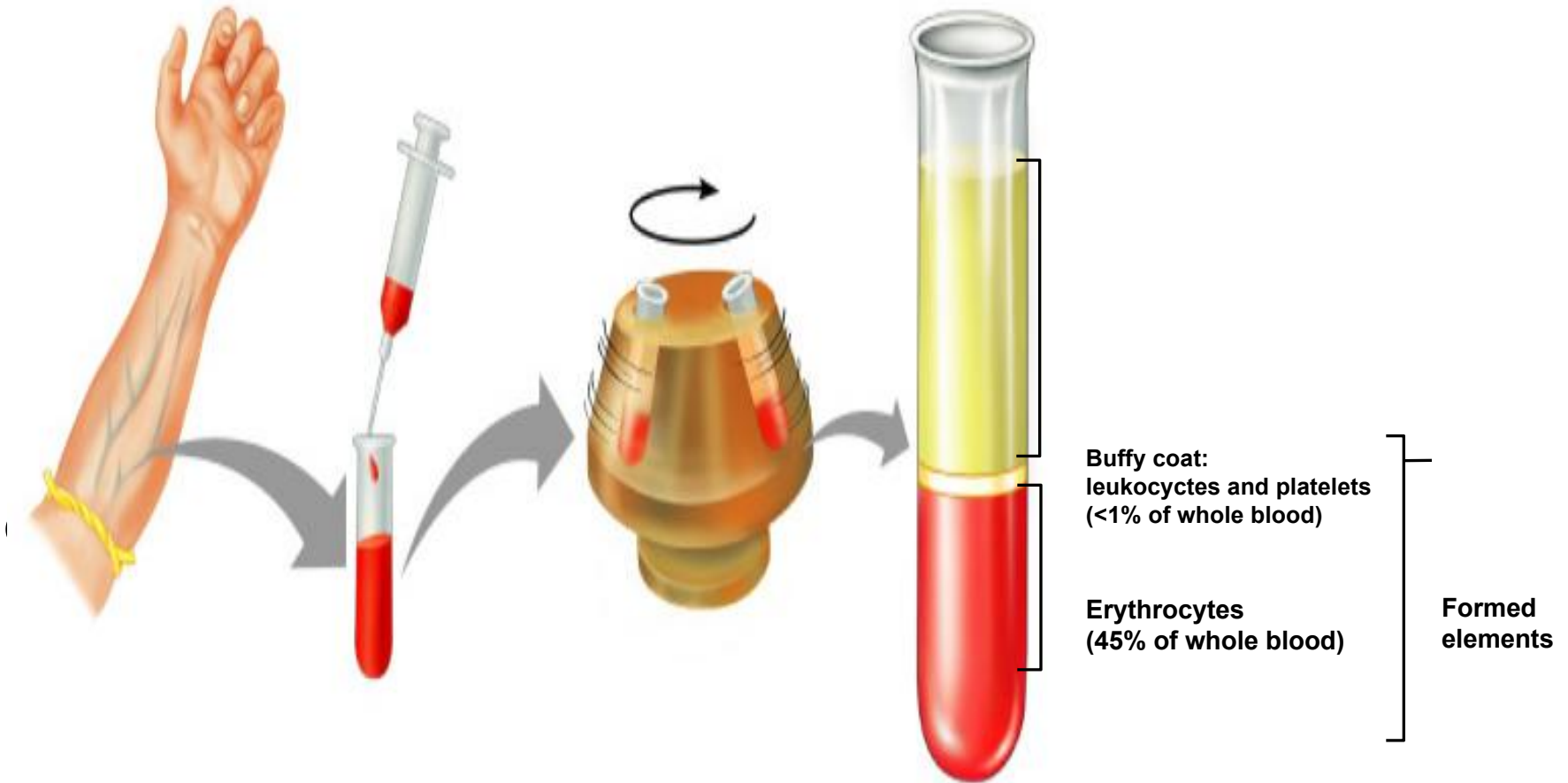


Figure 17.1

Components of Blood

I. Formed elements (45%)

1. Erythrocytes

2. Leucocytes : A. Granular: - Neutrophils

- Eosinophils

- Basophils

B. Agranular : - Monocytes

-

Lymphocytes

3. Thrombocytes (platelet)

II. Plasma (55%)

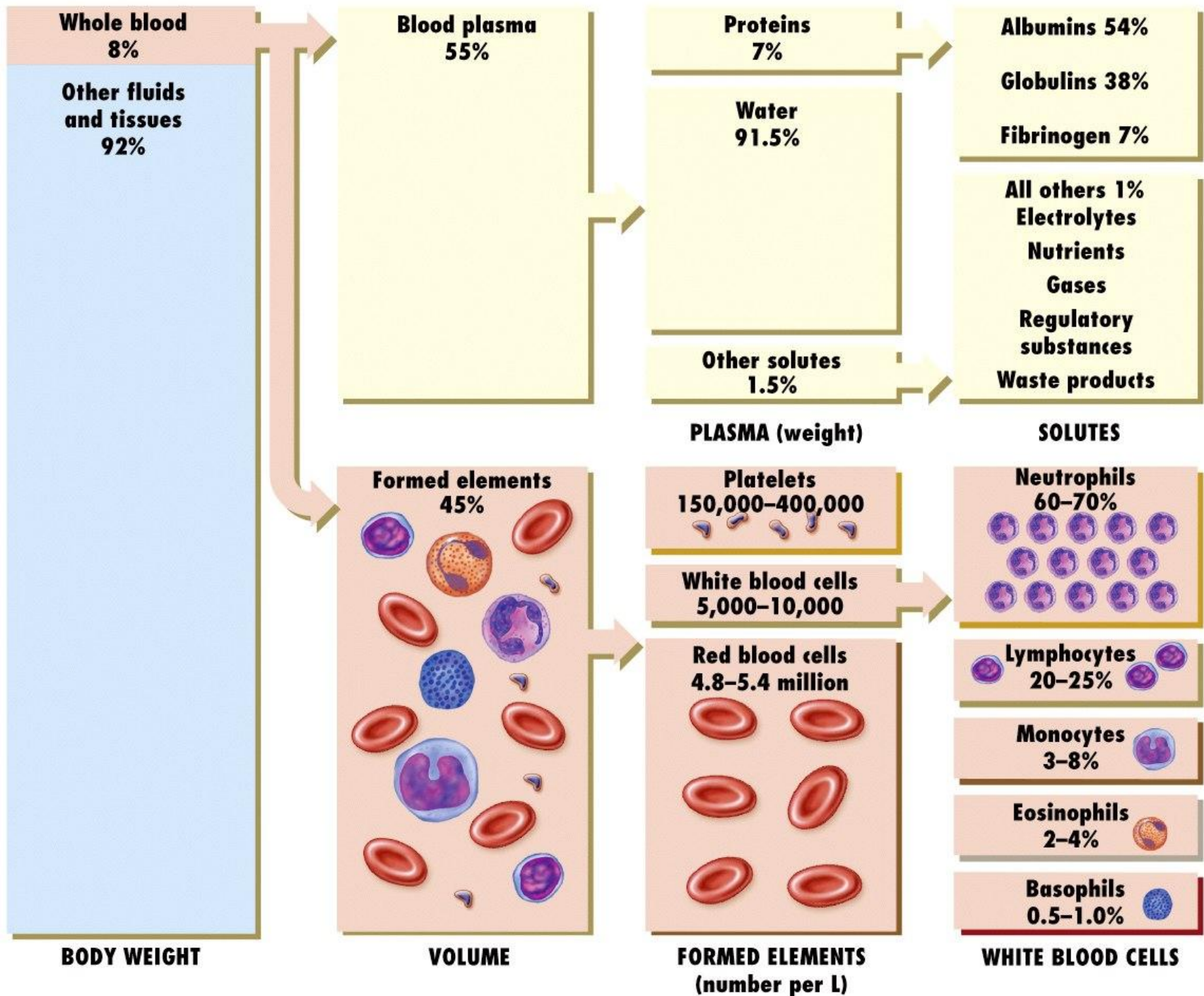
1. Protein 7 % : - Albumin (55%)

- Globulin (38 %)

- Fibrinogen (7%)

2. Water (91,5%)

3. Other solutes (1,5%)





Sample
of
whole
blood

consists
of

Plasma
(46–63%)

+

Formed
elements
(37–54%)

PLASMA COMPOSITION	
Plasma proteins	7%
Other solutes	1%
Water	92%
Transports organic and inorganic molecules, formed elements, and heat	

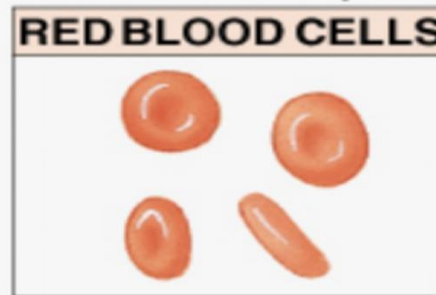
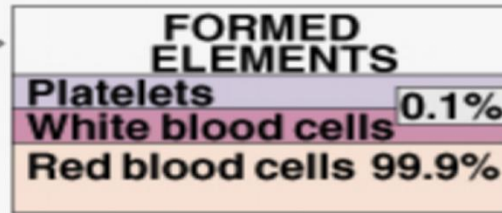
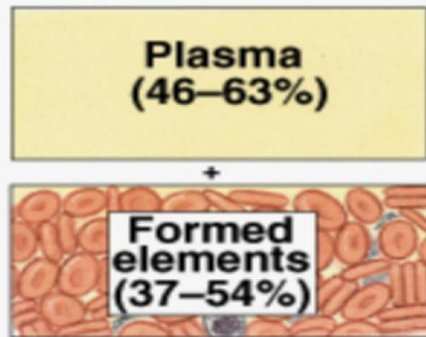
PLASMA PROTEINS	
Albumins (60%)	Major contributors to osmotic pressure of plasma; transport lipids, steroid hormones
Globulins (35%)	Transport ions, hormones, lipids; immune function
Fibrinogen (4%)	Essential component of clotting system; can be converted to insoluble fibrin
Regulatory proteins (<1%)	Enzymes, proenzymes, hormones
OTHER SOLUTES	
Electrolytes	Normal extracellular fluid ion composition for essential vital cellular activities. Ions contribute to osmotic pressure of body fluids. Major plasma electrolytes are Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Cl^- , HCO_3^- , HPO_4^{2-} , SO_4^{2-}
Organic nutrients	Used for ATP production, growth, and maintenance of cells; include lipids (fatty acids, cholesterol, glycerides), carbohydrates (primarily glucose), and amino acids
Organic wastes	Carried to sites of breakdown or excretion; include urea, uric acid, creatinine, bilirubin, ammonium ions

Table 11-1 Konstituen Darah dan Fungsinya
 Sherwood, Fisiologi Manusia dari Sel ke Sistem/Edisi 2 hal. 346

Konstituen	Fungsi
Plasma	
- Air	Media transportasi; mengangkut panas
- Elektrolit	Eksitabilitas membran, distribusi osmotik cairan antara cairan: intrasel dan ekstrasel ; menyangga perubahan pH
- Nutrient, zat sisa, gas, hormon	Diangkut dalam darah, gas CO ₂ darah berperan penting dalam keseimbangan asam basa
Protein plasma	Secara umum menimbulkan efek osmotik yang penting dalam distribusi cairan ekstrasel antara komponen vaskular dan interstinium, menyangga perubahan pH
- Albumin	Mengangkut banyak zat, memberi kontribusi terbesar pada tekanan osmotik koloid
- Globulin	
Alfa dan Beta	Mengangkut banyak zat, faktor pembekuan; molekul prekursor inaktif
Gama	Antibodi
- Fibrinogen	Prekursor inaktif untuk jaringan fibrin pada bekuan darah



↓ consists of



0 5 10 15
μm

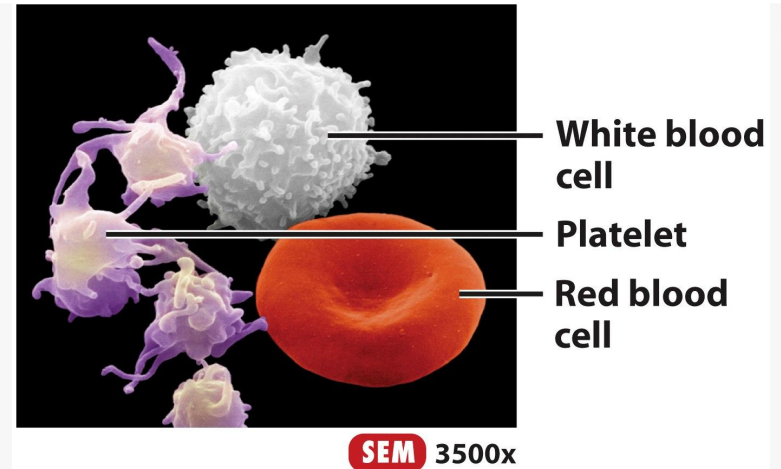


Figure 19-2a Principles of Anatomy and Physiology, 11/e

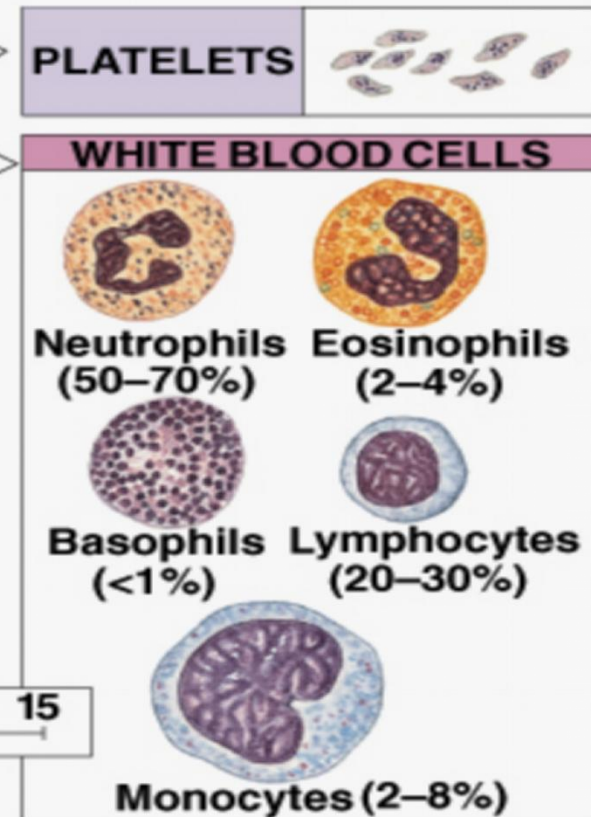


Table 11-1 Konstituen Darah dan Fungsinya (Lanjutan)
 Sherwood, Fisiologi Manusia dari Sel ke Sistem. Edisi 2 hal. 346

Konstituen	Fungsi
Unsur sel	
Eritrosit	Mengangkut O ₂ dan CO ₂
Leukosit	
-- Neutrofil	Fagosit yang memakan bakteri dan debris
-- Eosinofil	Menyerang cacing parasit; penting dalam reaksi alergi
-- Basofil	Mengeluarkan histamin yang penting dalam reaksi alergi dan heparin yang membantu membersihkan lemak dari darah dan mungkin berfungsi sebagai antikoagulan
-- Monosit	Dalam transit untuk menjadi makrofag jaringan
Limfosit	
-- Limfosit B	Pembentukan antibodi
-- Limfosit T	Respons imun seluler
Trombosit	Hemostasis

Hematopoiesis

A. Embryonic & fetal life

- yolk sac
- liver
- spleen
- thymus gland
- lymph nodes
- bone marrow

B. Adults

- proximal epiphyses of humerus & femur
- flat bones of cranium, sternum, ribs, vertebrae, pelvis
- lymphoid tissue (spleen, tonsils, thymus gland, lymph nodes)

Key:

- Progenitor cells
- Precursor cells or "blasts"
- Formed elements of circulating blood
- Tissue cells

Key:

- CFU-E Colony-forming unit-erythrocyte
- CFU-Meg Colony-forming unit-megakaryocyte
- CFU-GM Colony-forming unit-granulocyte macrophage

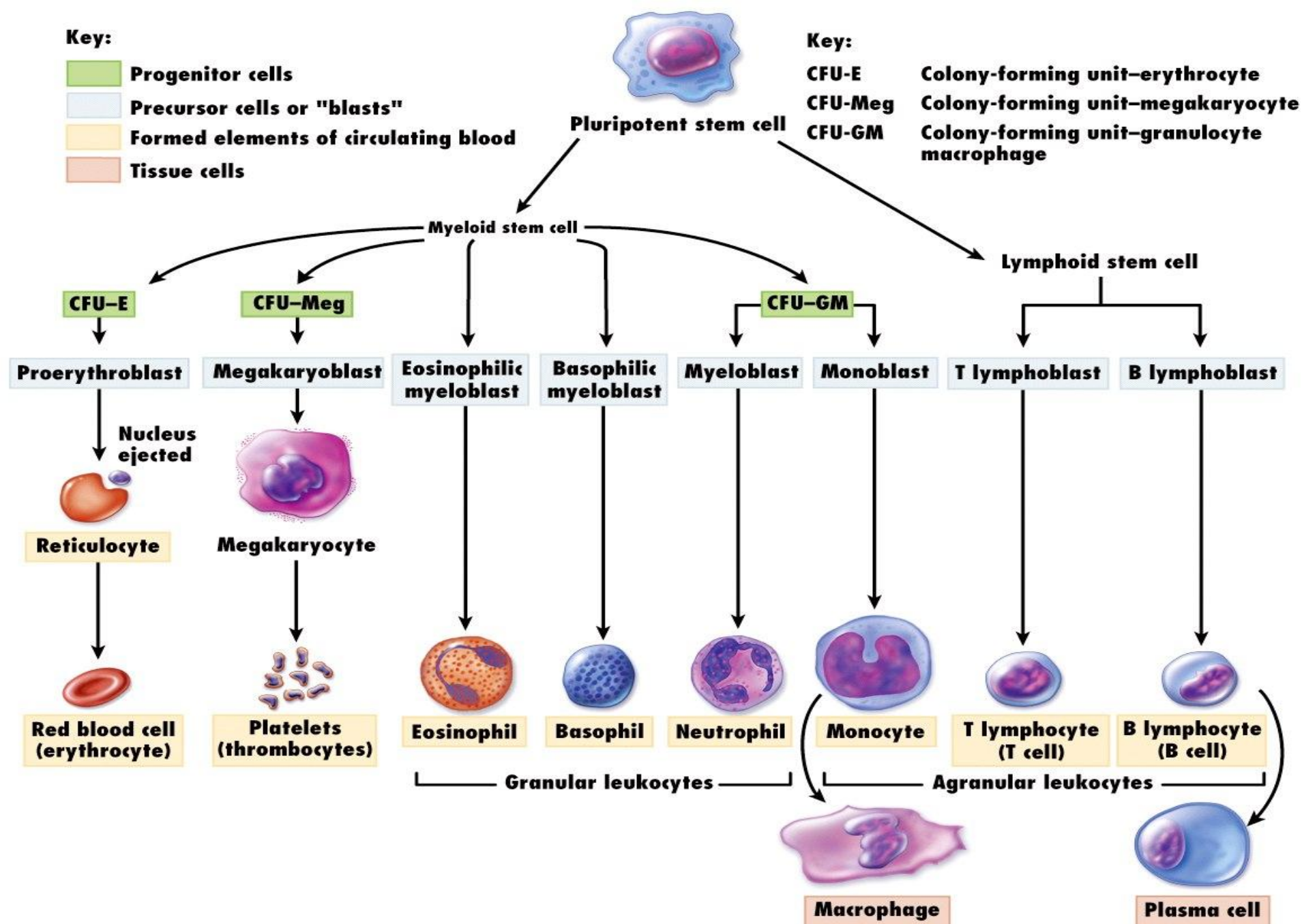
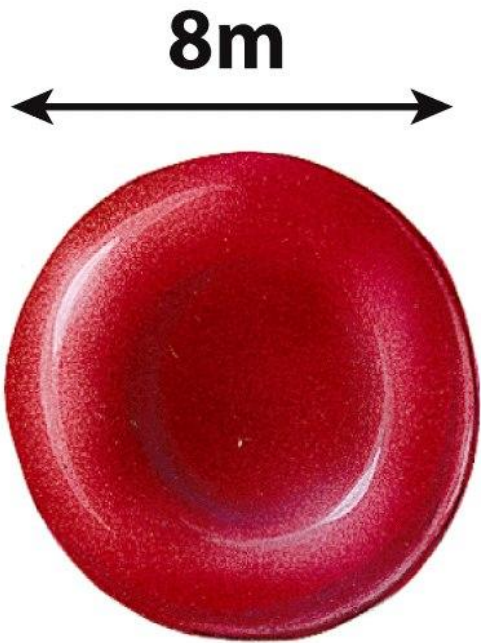


Figure 19-3 Principles of Anatomy and Physiology, 11/e
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Erythrocytes

- Biconcave discs, diameter 8 mikrometer
- Lack of nucleus
- Hb : pria 14 –16,5 G/dL
wanita 12 – 15 G/dL
- Number of eryt.
pria 5,4 jt/mm³ =
wanita 4,8 jt/mm³=
- Antigen pada permukaan eritrosit yaitu aglutinogen A dan B dan Rh
- Fungsi : transpor O₂ dan CO₂



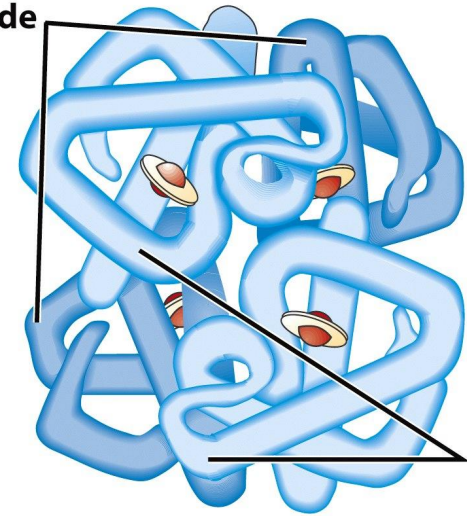
Surface view



Sectioned view

RBC shape

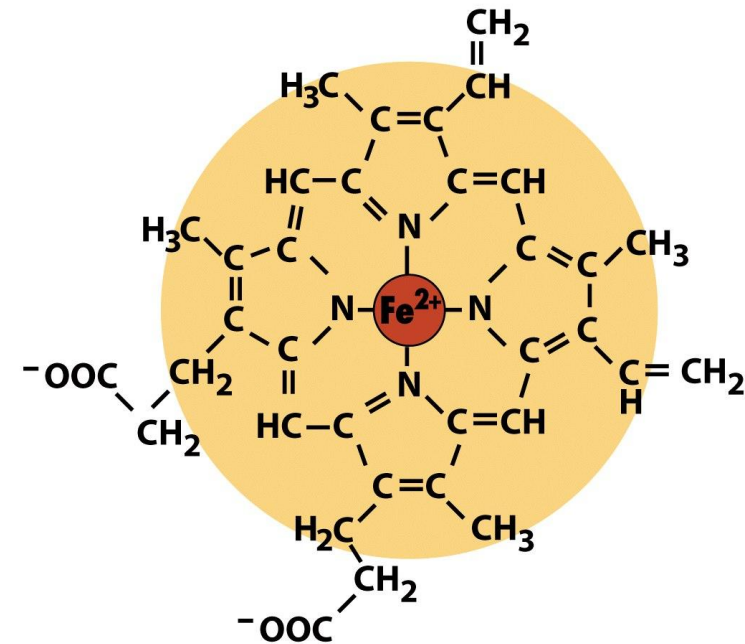
Beta polypeptide chains



Alpha polypeptide chains

Hemoglobin molecule

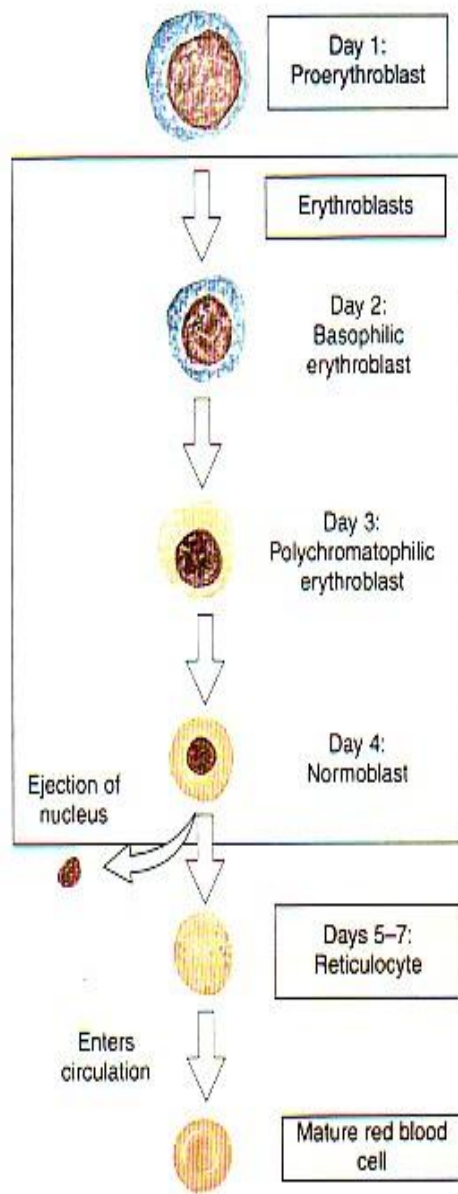
Figure 19-4b Principles of Anatomy and Physiology, 11/e
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Iron-containing heme

Figure 19-4c Principles of Anatomy and Physiology, 11/e
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Figure 19-4a Principles of Anatomy and Physiology, 11/e
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• **FIGURE 19-6 Stages of RBC Maturation.** Red blood cells are produced in the red bone marrow. The color density indicates the abundance of hemoglobin in the cytoplasm. Note the reduction in the size of the cell and the size of the nucleus before a reticulocyte is formed.

Eritropoiesis

- Dipercepat pada keadaan anemia / hipoksia
- Diatur oleh hormon eritropoietin yg dihasilkan oleh ginjal
- Bahan2 utk eritropoiesis :
 - vit. B12 dan asam folat (sintesa DNA)
 - protein, Fe, piridoksin, Cu, Co (pematangan normoblast)

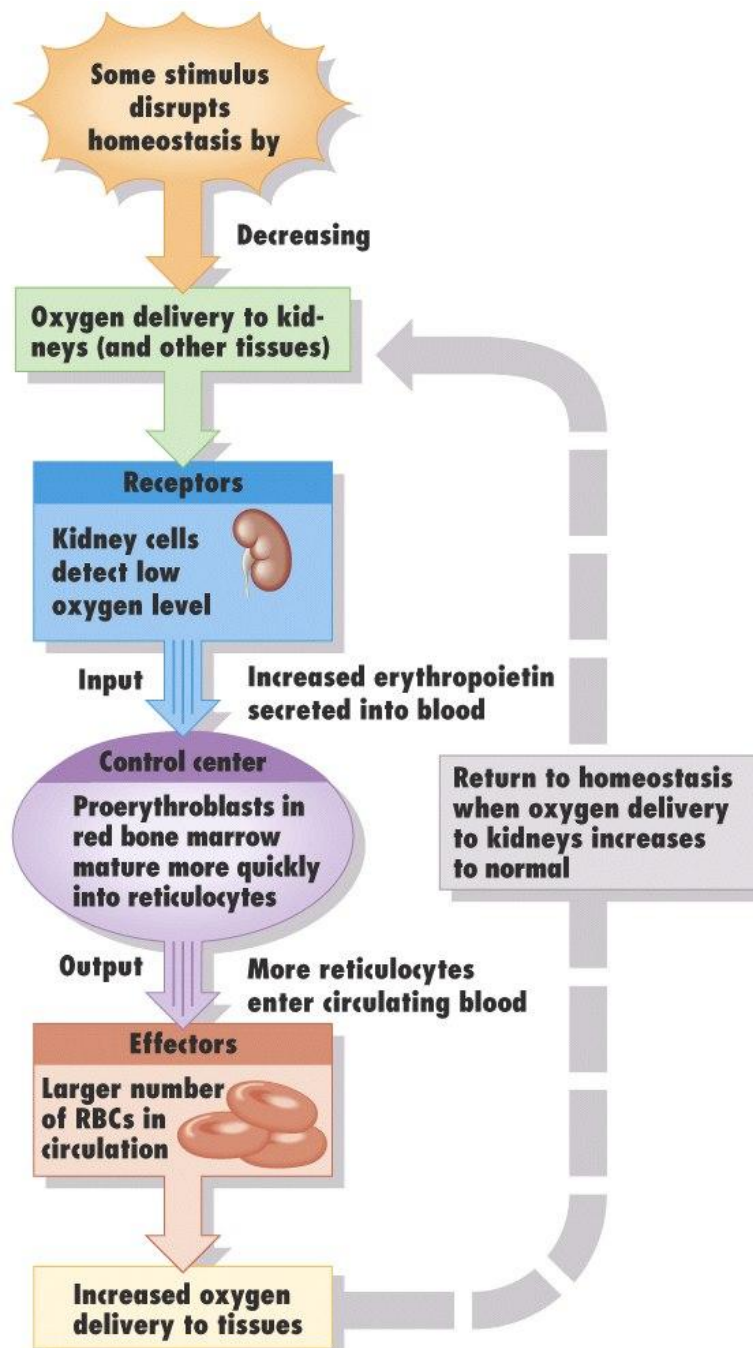
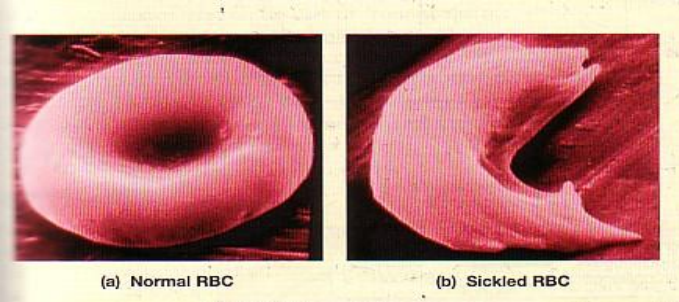


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Erythrocytes (continued)

- Life span : 120 days
- Removed from circulation by macrophages in spleen, liver and bone marrow
- Hb is broken down into :
Fe, bilirubin and globin

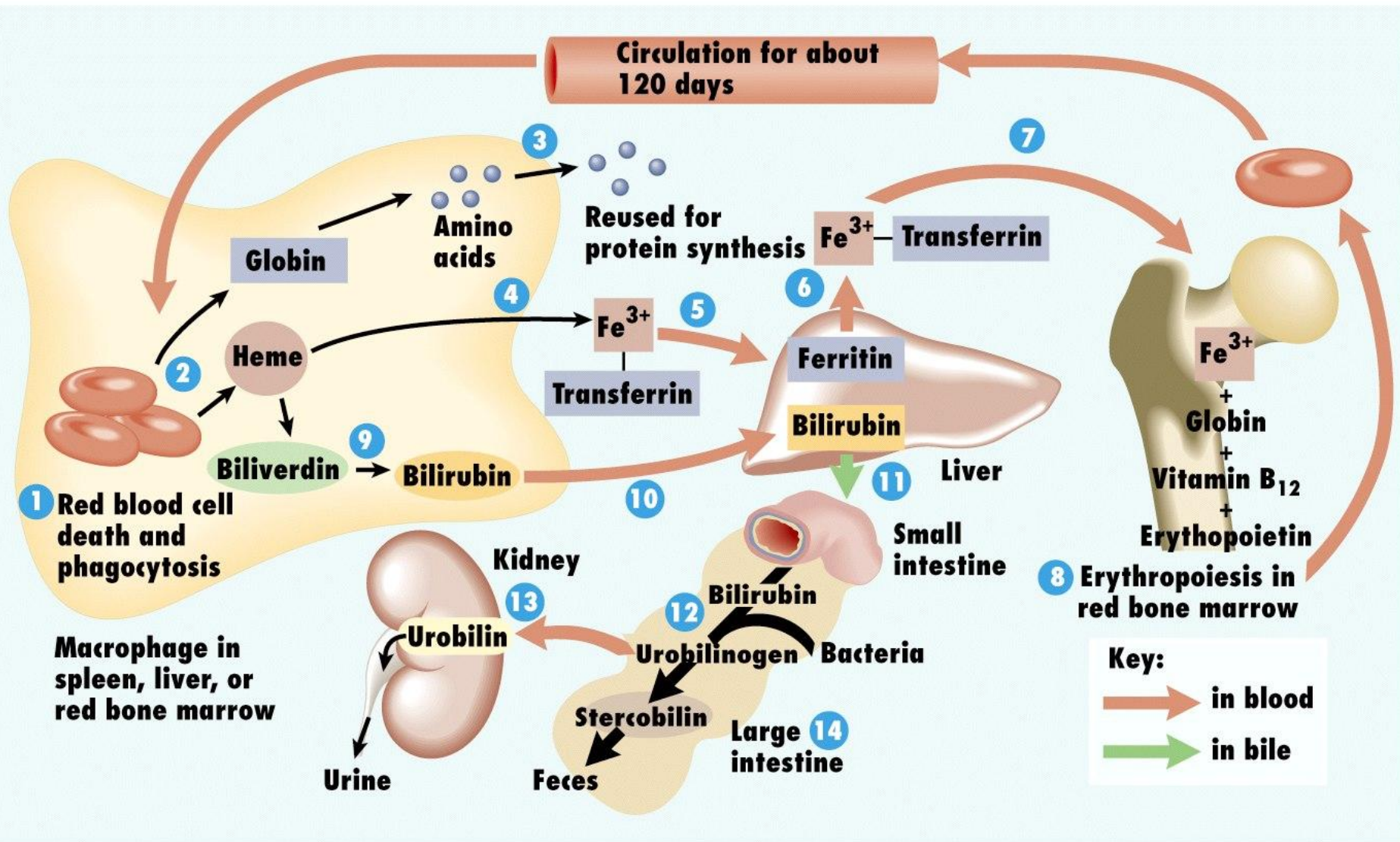
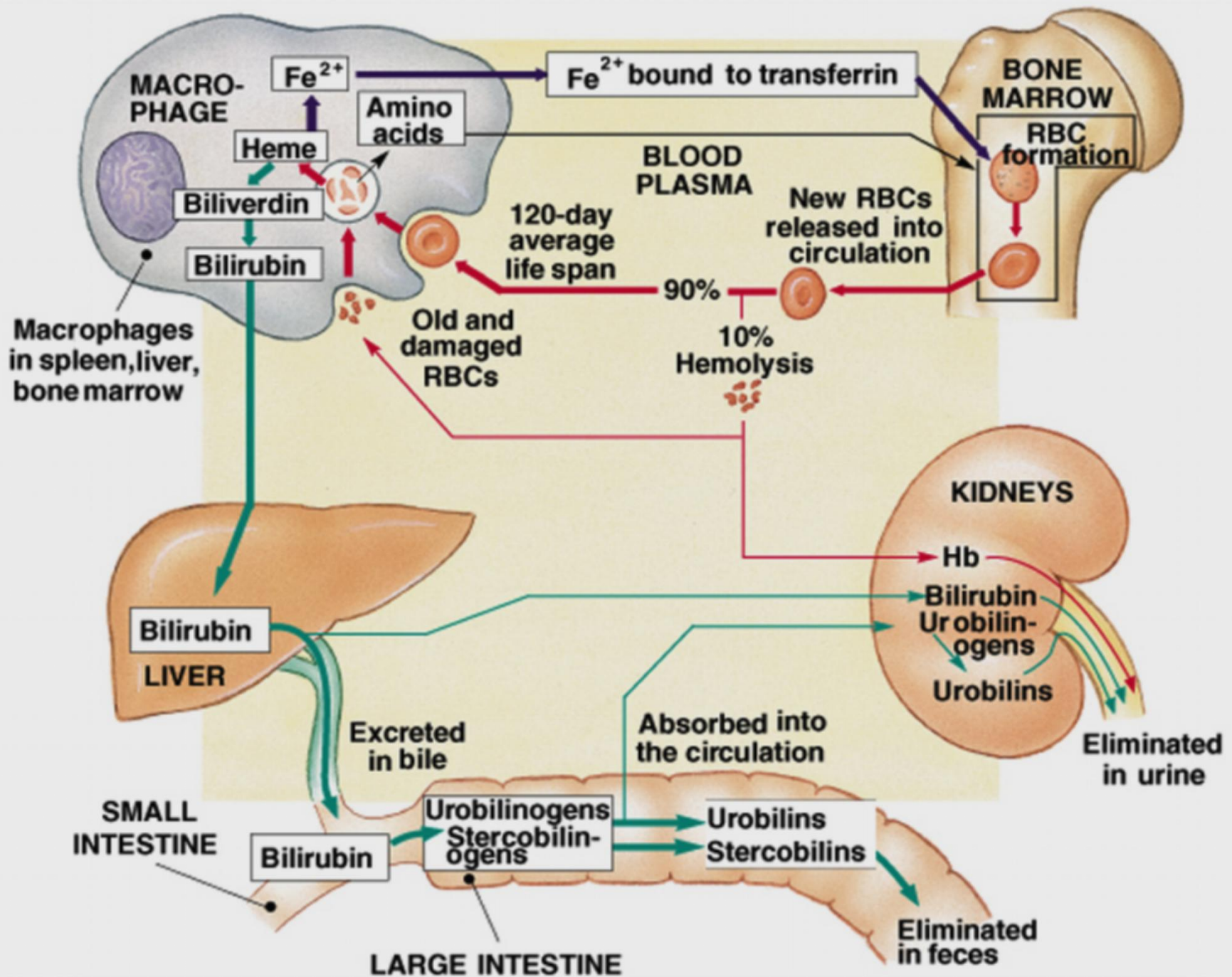


Figure 19-5 Principles of Anatomy and Physiology, 11/e
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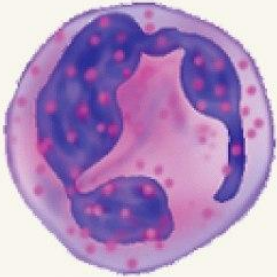


Leucocytes

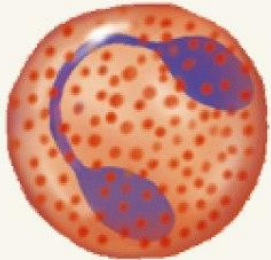
- Have nuclei
- No Hb
- Fall into 2 major groups :
 - Granular : neutrophils, eosinophils, basophils
 - Agranular : monocytes, lymphocytes
- HLA on the surface of leucocytes
- Number : 4000 – 11000 sel / mL darah
- >> : Leukosytosis, caused by : perdarahan, demam, kerja berat, kerusakan jaringan, byk makan protein, leukimia.
- << : leukopenia, caused by : malnutrisi, lapar, obat2 sulfonamid, defisiensi.

White Blood Cells (WBCs) or Leukocytes

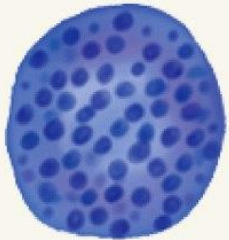
Granular leukocytes



Neutrophils



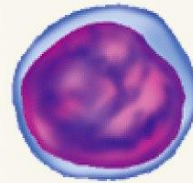
Eosinophils



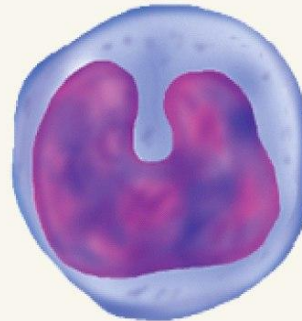
Basophils

White Blood Cells (WBCs) or Leukocytes

Agranular leukocytes



**Lymphocytes (T cells,
B cells, and natural
killer cells)**



Monocytes

Table 19-3 figure 3 Principles of Anatomy and Physiology, 11/e
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Table 19-3 figure 2 Principles of Anatomy and Physiology, 11/e
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Formation of Leukocytes

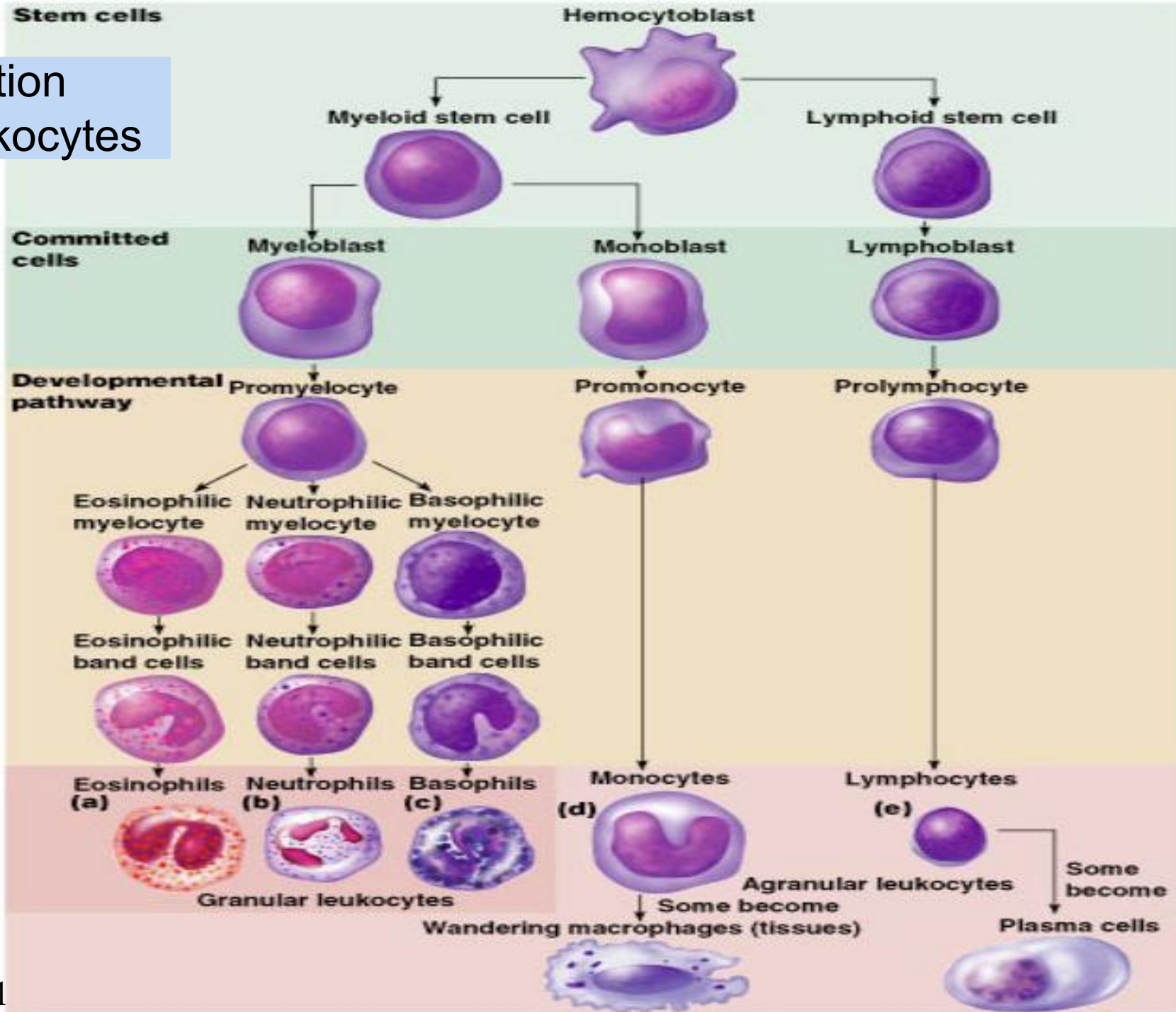


Figure 17.11

Pembuluh Darah (Vaskular)

- Arteri mempunyai dinding yang kuat dan tebal serta elastis
- Vena ; memiliki struktur yang khas yaitu memiliki katub yang dapat mencegah darah agar tidak kembali lagi (terutama pada vena kecil dan medium, sedangkan vena besar – misalnya vena kava – tidak memilikinya)
- Arteri dan Vena dapat mengecil (vasokonstriksi) dan melebar (vasodilatasi) oleh pengaruh saraf dari sistem saraf otonom.

Struktur Dinding Pembuluh Darah

- Tunika intima/interna: terdiri atas jaringan endotel dan merupakan lapisan terdalam.
- Tunika media: lapisan tengah dan terdiri atas jaringan otot polos sehingga dapat elastis.
- Tunika eksterna/adventitia: lapisan luar sekali yang terdiri atas jaringan ikat untuk menguatkan arteri.

Kapiler

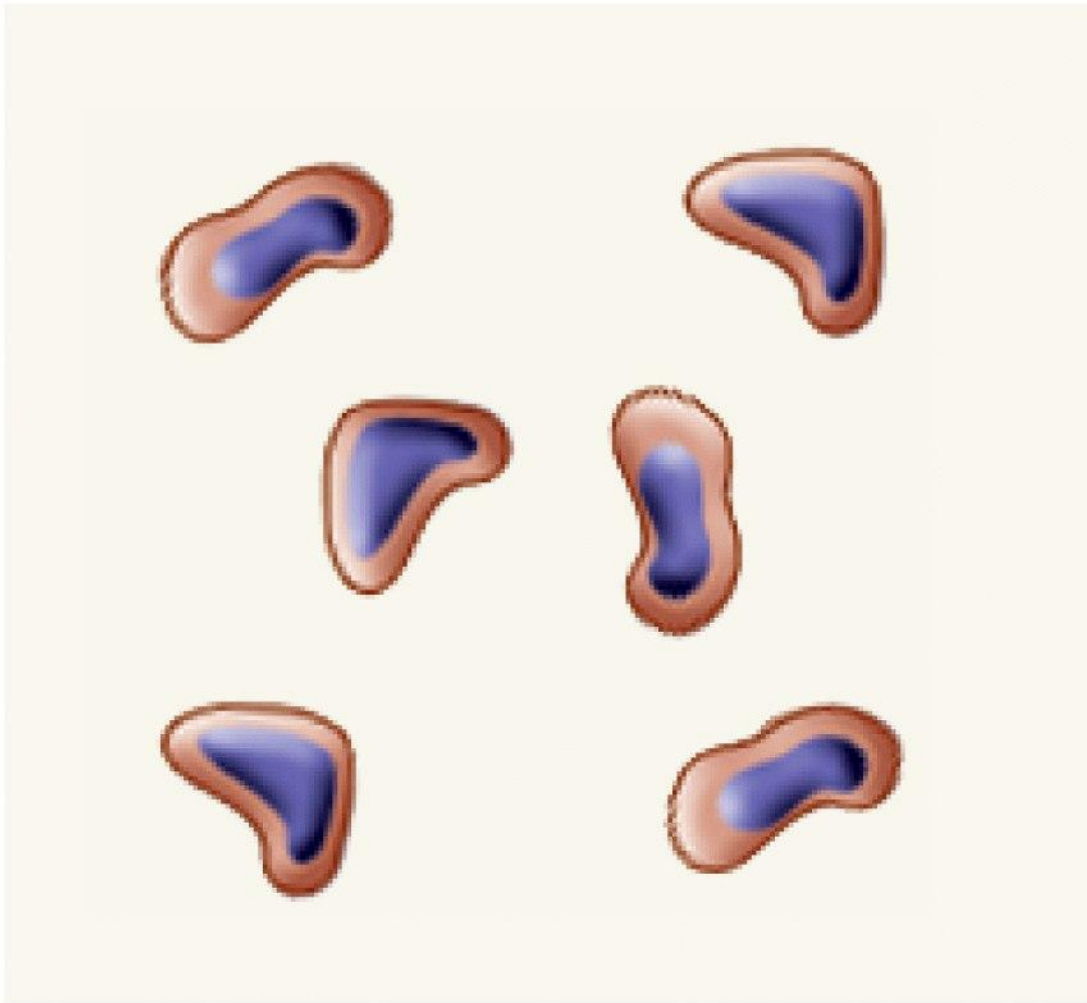
(=pembuluh darah rambut)

- Merupakan pembuluh darah yang sangat halus.
- Dindingnya terdiri atas satu lapisan endotel.
- Fungsi:
 1. Penghubung antara arteri dan vena
 2. Tempat terjadinya pertukaran zat-zat antara darah dan cairan jaringan
 3. Mengambil sekresi kelenjar
 4. Menyerap zat makanan di usus pada proses absorpsi.
 5. Menyaring (filtrasi) darah di ginjal.

Hemostasis

- Mekanisme tubuh untuk menghentikan darah secara spontan
- Sistem yang berperan:
 - Sistem vaskuler
 - Sistem trombosit
 - Pembekuan darah

Platelets (Thrombocytes)



Peran masing-masing sistem

- Sistem vaskuler → mencegah perdarahan; vasokonstriksi, aktivasi trombosit dan pembekuan darah
- Sistem trombosit
 - Pembentukan sumbat trombosit; adhesi, agregasi, pelepasan
 - Stabilisasi sumbat trombosit
- Sistem pembekuan darah → rangkaian reaksi enzimatik yang melibatkan: faktor pembekuan darah, fosfolipid dan ion kalsium.

Hemostasis

Hemostasis :

Pengendalian / regulasi pembekuan darah pada saat terjadi perdarahan akibat kerusakan pembuluh darah sehingga dapat mencegah terjadinya kekurangan volume darah

Tiga tahap proses hemostasis yang terjadi secara simultan :

1. Spasme/konstriksi pembuluh darah untuk mengurangi aliran darah ke tempat luka pada pembuluh darah
2. Pembentukan Sumbat Trombosit untuk menutup luka pembuluh darah
3. Terjadi Reaksi Pembekuan Darah secara lokal / regional pada daerah kerusakan pembuluh darah

Setelah proses repair (perbaikan) pembuluh darah terjadi maka proses berikutnya adalah Reaksi Lisis Bekuan Darah

1. Spasme Pembuluh Darah

- Jika pembuluh darah terluka, segera akan berkontraksi oleh adanya rangsangan simpatis dan zat kimia yg dilepaskan trombosit seperti serotonin dan tromboksan

2. Pembentukan Sumbat Trombosit

- Keadaan normal trombosit tdk melekat pd dinding pembuluh darah yang utuh
- Jika permukaan endotel pembuluh darah terluka, trombosit akan melekat pada pembuluh darah yg terluka
- Terjadi pengumpulan/aggregasi trombosit pd tempat luka → trombosit mengeluarkan ADP, untuk menarik trombosit lain untuk menempel

3. Pembekuan darah

- Proses transformasi darah yang cair menjadi bentuk agar-agar yang padat
- Pembentukan bekuan darah bertujuan memperkuat sumbatan trombosit

Aggregasi trombosit juga punya tiga peranan lain :

1. Aktin dan miosin di dlm trombosit yang menggumpal akan berkontraksi sehingga sumbat trombosit menjadi lebih padat dan kuat
2. Sumbat trombosit mengeluarkan serotonin, epinefrin dan tromboksan A₂ untuk kontraksi pembuluh darah
3. Sumbat trombosit akan melepaskan zat-zat pembekuan darah; mencegah pengeluaran darah

Mekanisme pembekuan terdiri dari beberapa tahap :

1. Pembentukan aktivator protrombin
2. Konversi protrombin menjadi trombin
3. Konversi fibrinogen menjadi fibrin yg berbentuk seperti benang dan menjaring sel-sel darah untuk membentuk bekuan darah

Faktor-faktor pembekuan darah tersebut umumnya dibentuk di hati

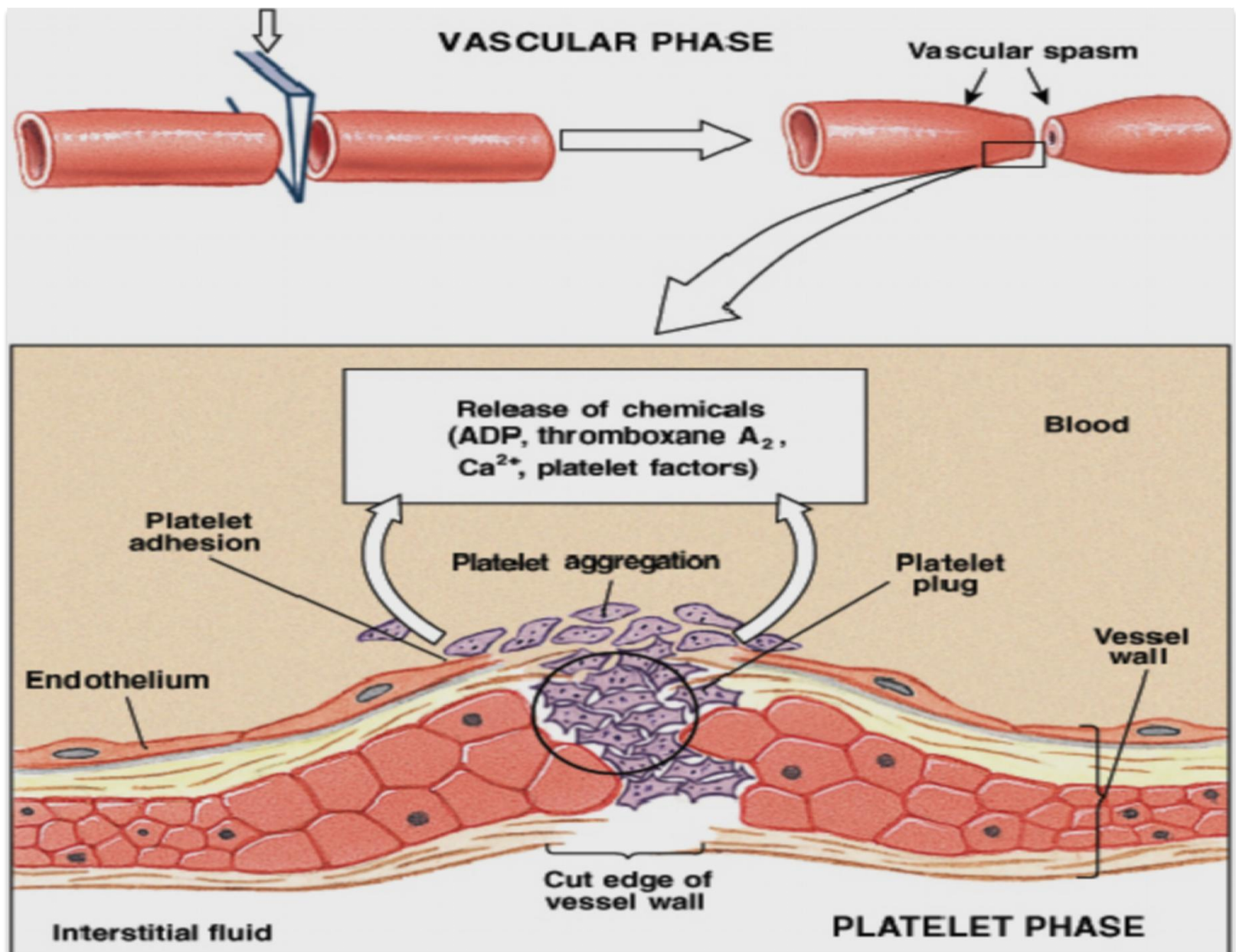
- Secara normal terdapat di dalam plasma dalam bentuk tidak aktif
- Sekali salah satu faktor diaktifkan akan terjadi reaksi pengaktifan faktor-faktor lainnya
- Reaksi pembekuan darah dapat dirangsang melalui jalur intrinsik dan ekstrinsik

Jalur intrinsik : semua faktor yg dibutuhkan untuk reaksi ini ada dalam pembuluh darah

Jalur ekstrinsik : membutuhkan kontak dengan faktor jaringan di luar pembuluh darah untuk memulai pembekuan darah

Bekuan darah yang terbentuk tidak menetap selamanya dalam pembuluh darah

- Bekuan darah yang tidak diperlukan lagi akan dilisiskan oleh plasmin
- Bentuk tidak aktif dari plasmin --> plasminogen
- Plasminogen $\xrightarrow{\text{Serin Protease}}$ plasmin

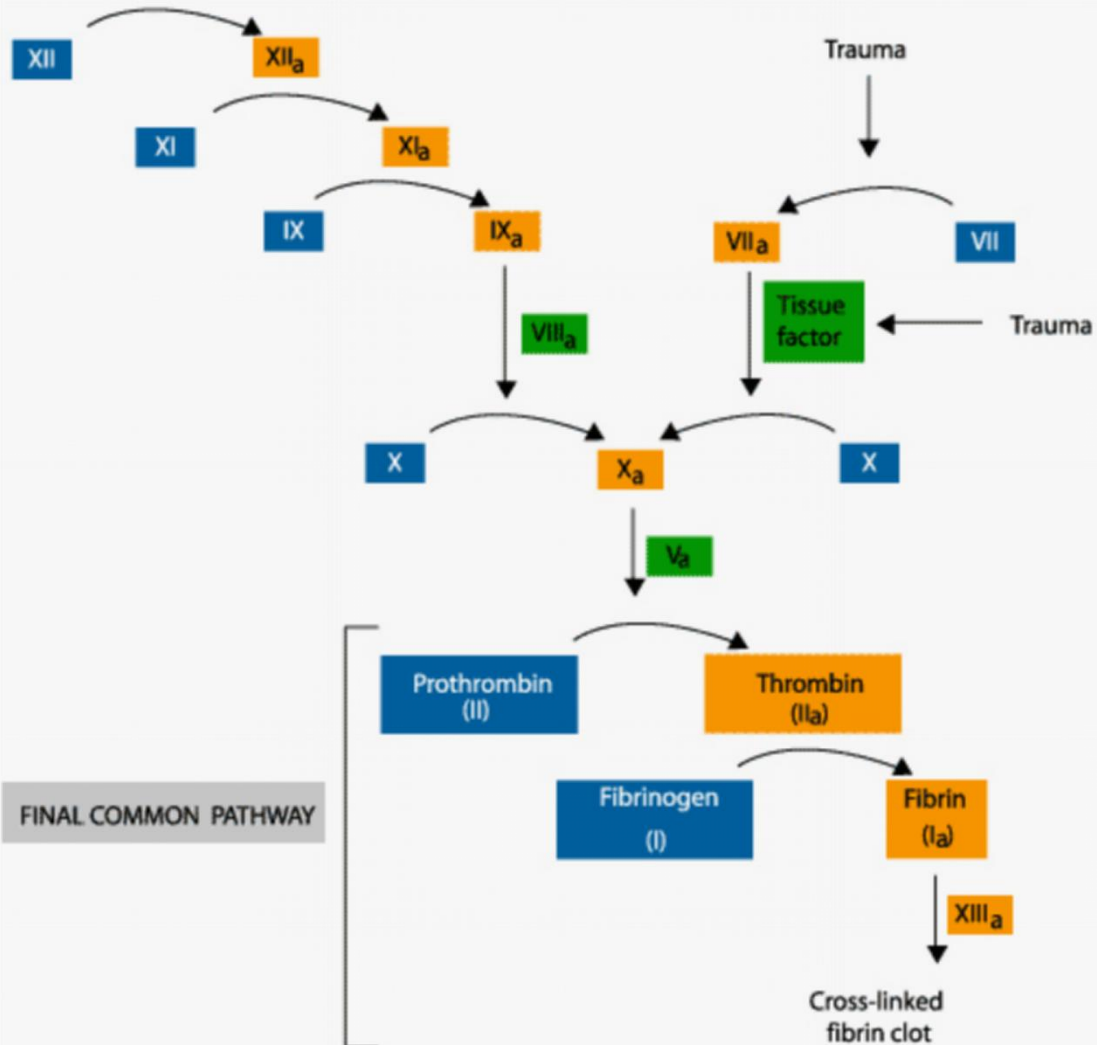


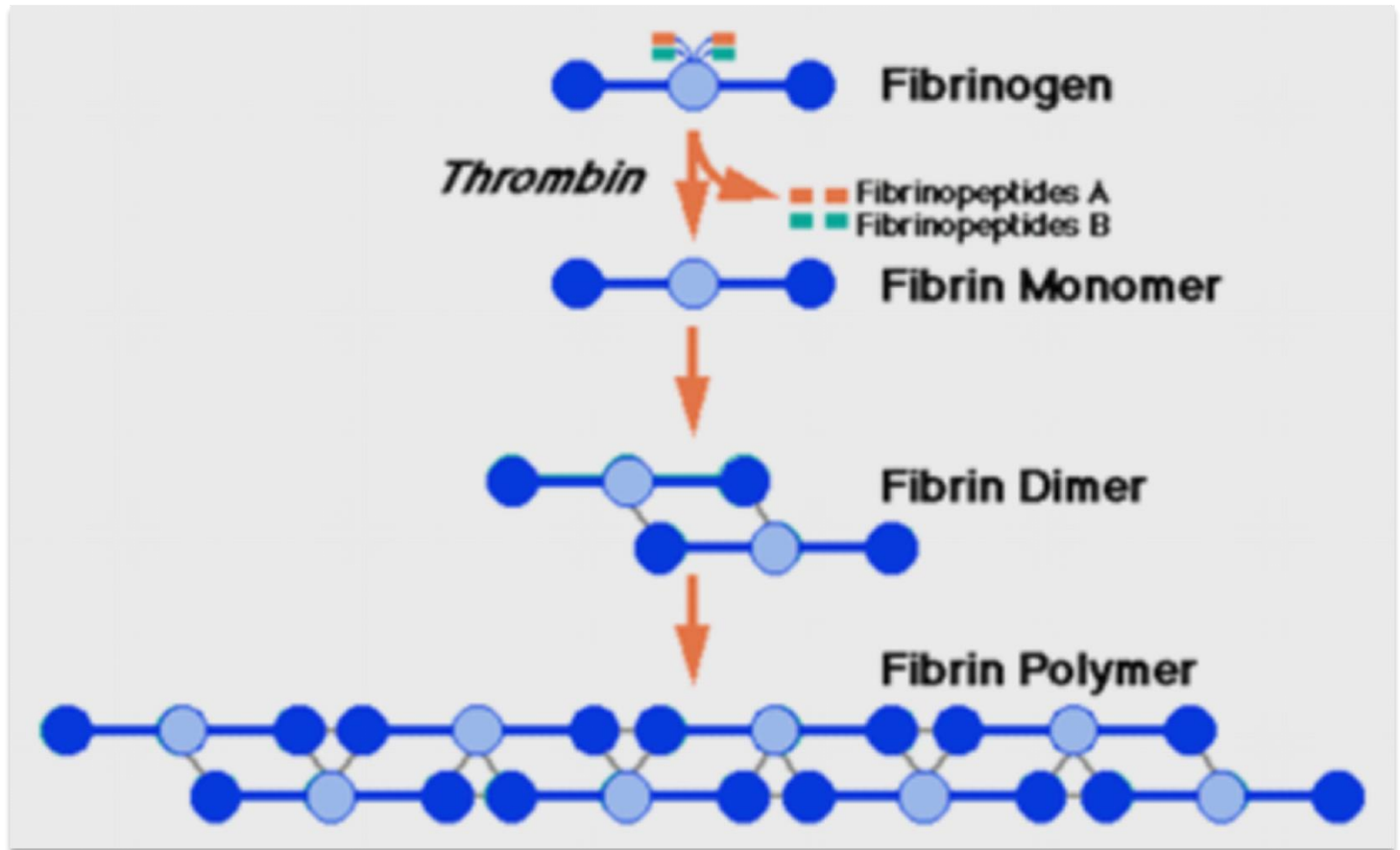
INTRINSIC PATHWAY

Damaged Surface



Kininogen
Kallikrein





Thrombin

Fibrin
polymers

Fibrin
monomers

Fibrinoge
n

Faktor-faktor pembekuan darah :

Faktor I	: Fibrinogen
II	: Protrombin
III	: Tromboplastin Jaringan
IV	: Kalsium
V	: Proakselerin (Labile Factor)
VII	: Prokonvertin (Stable Factor)
VIII	: Antihemofilik faktor A
IX	: Antihemofilik faktor B (christmas factor / PTC)
X	: Faktor stuart
XI	: Antihemofilik faktor C (PTA)
XII	: Faktor Hagemen
XIII	: Faktor stabilisasi fibrin

PTC = plasma tromboplastin component

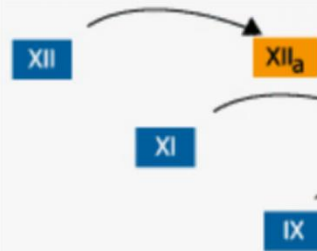
PTA = plasma tromboplastin antecedent

INTRINSIC PATHWAY

Damaged Surface



Kininogen
Kallikrein



VIII_a

X

Prothrombin
(II)

FINAL COMMON PATHWAY

Fibrinogen
(I)

EXTRINSIC PATHWAY

Trauma



Tissue
factor

Trauma

X_a

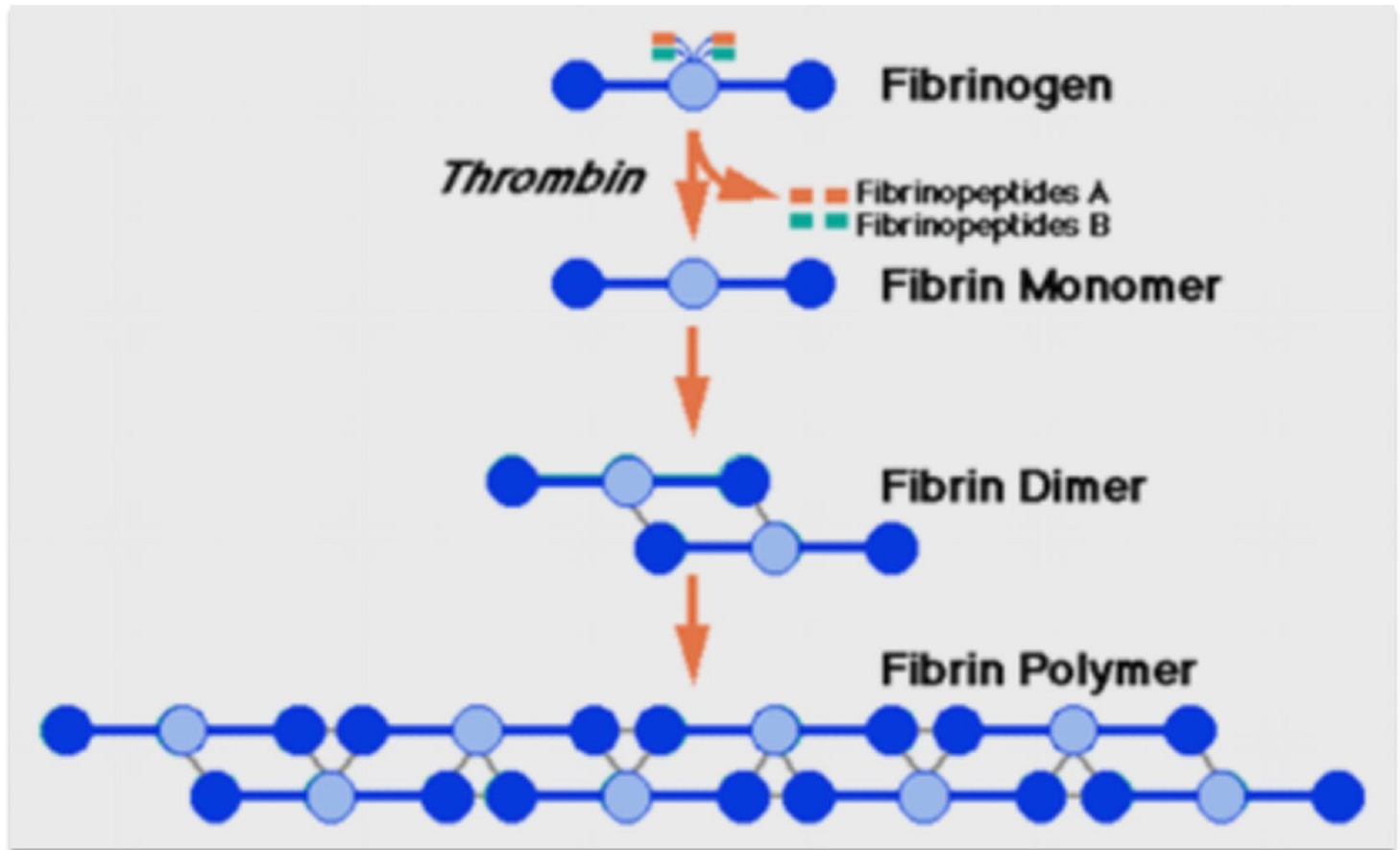
V_a

Thrombin
(II_a)

Fibrin
(I_a)

XIII_a

Cross-linked
fibrin clot

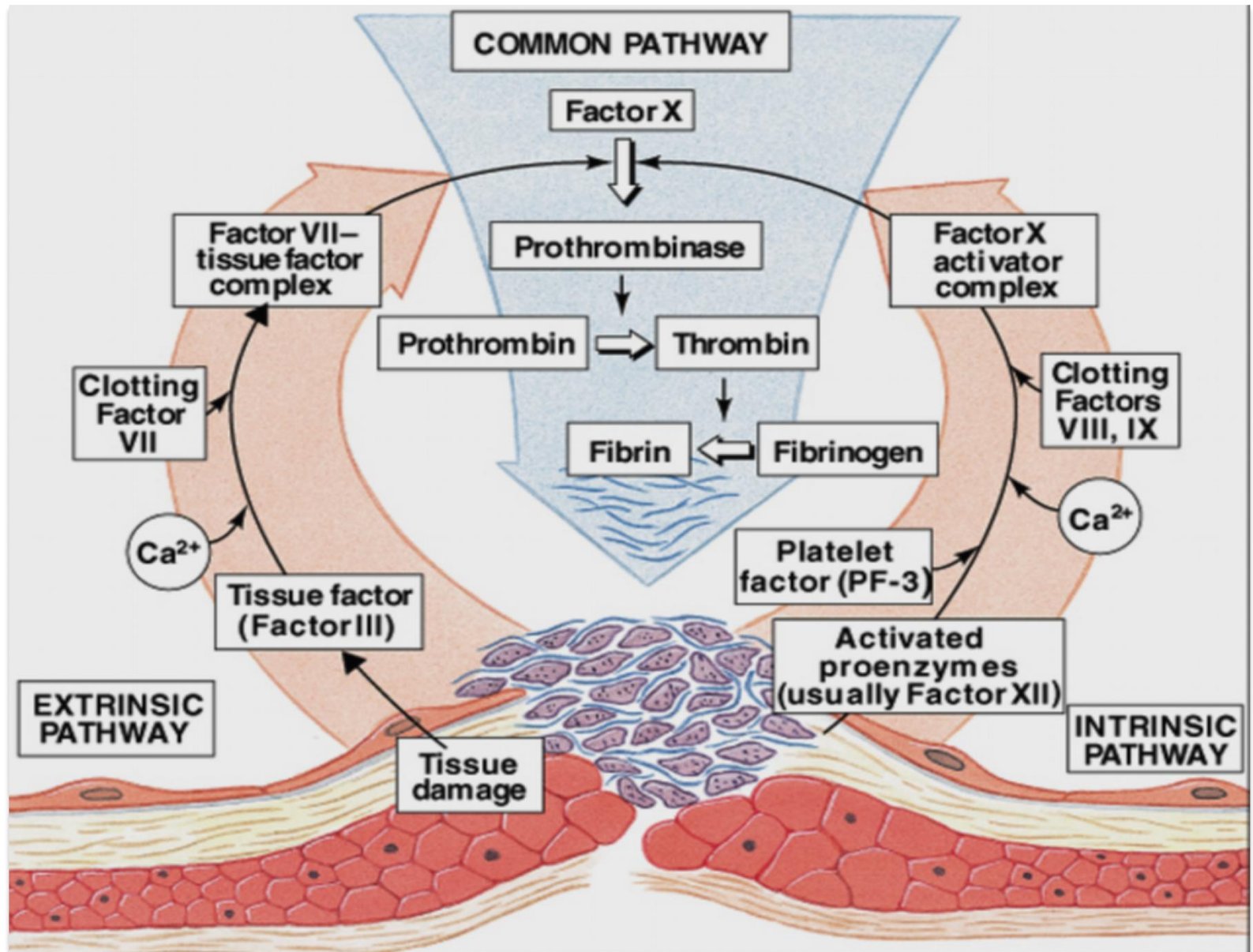


Thrombin

Fibrin
polymers

Fibrin
monomers

Fibrinoge
n



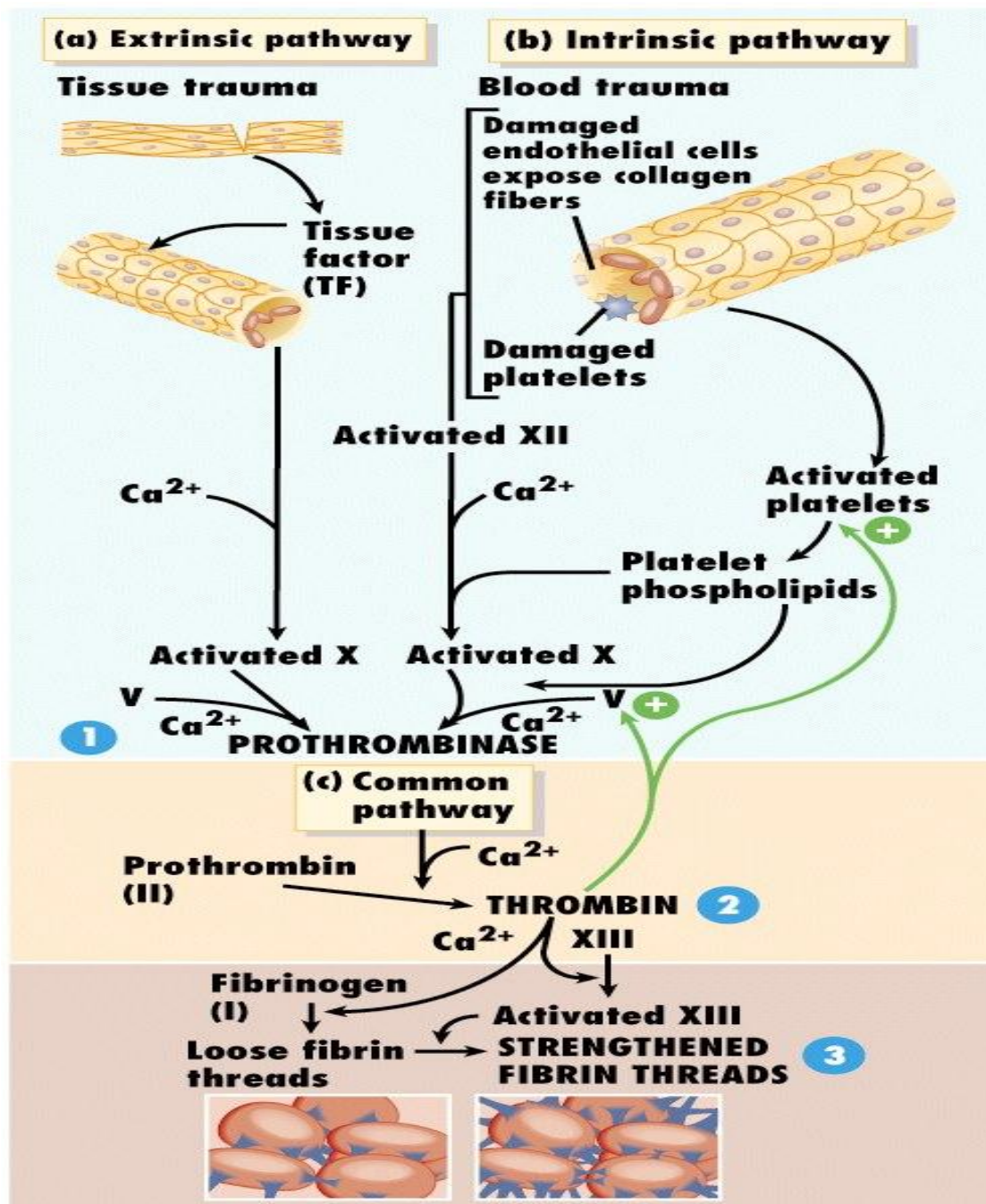
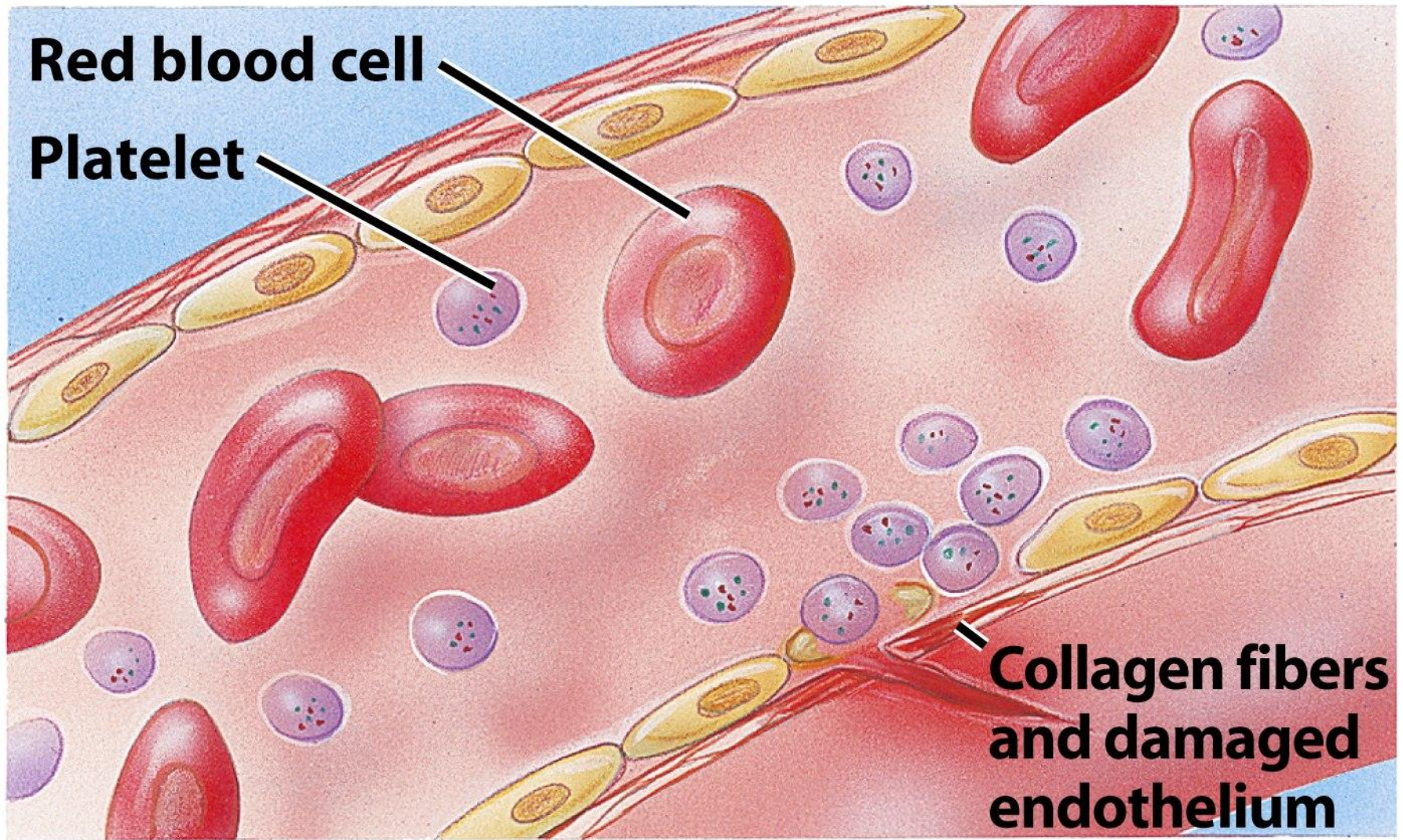
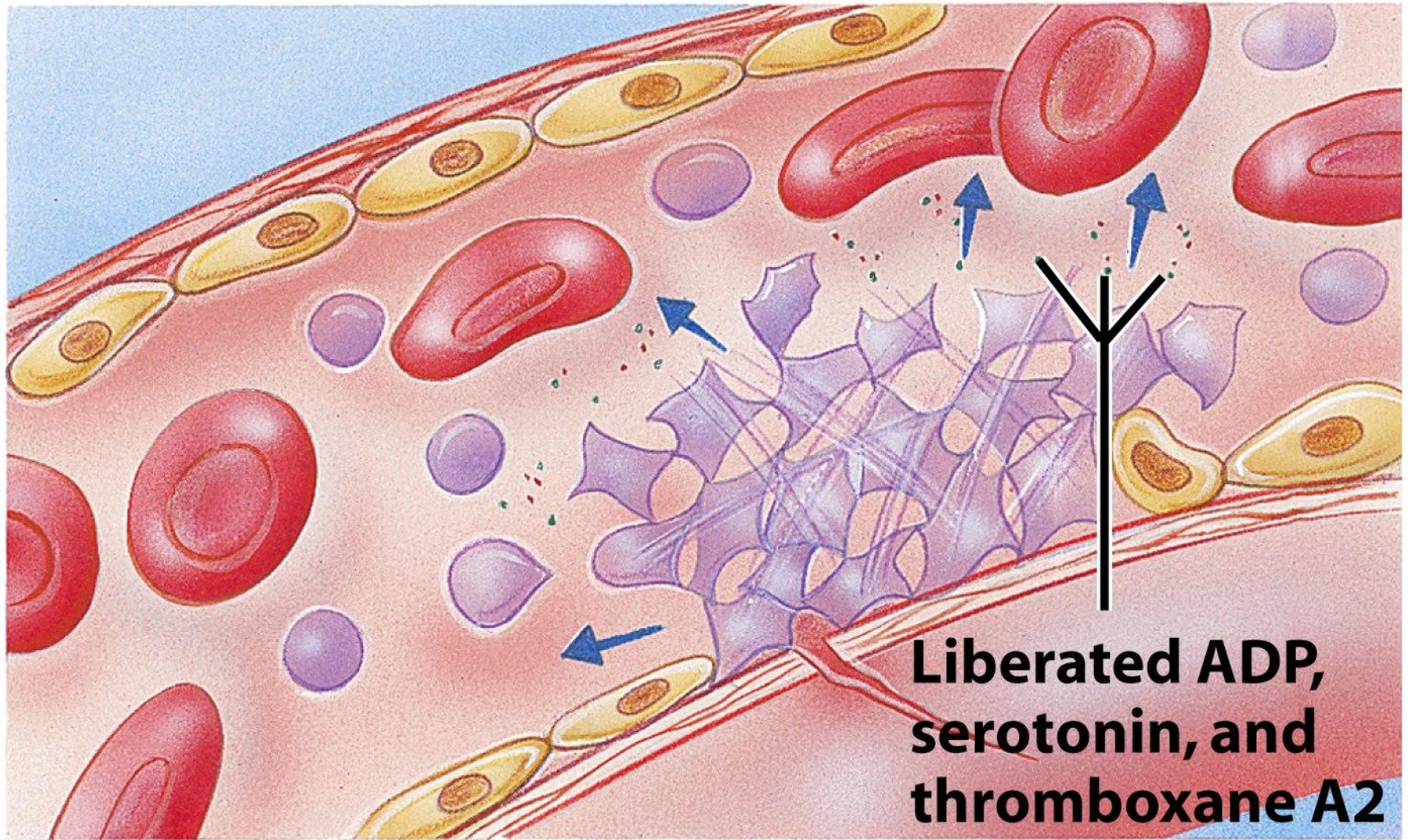


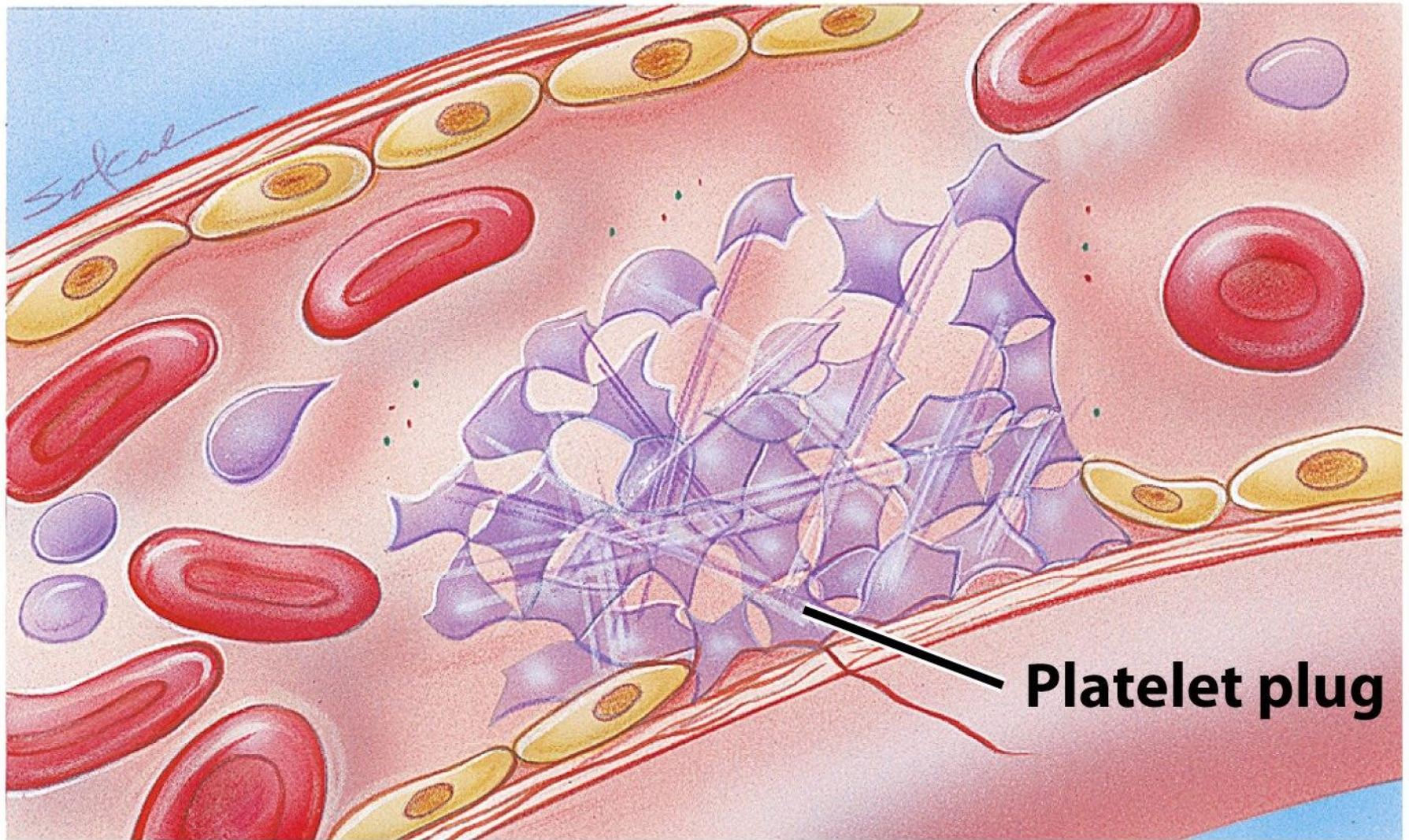
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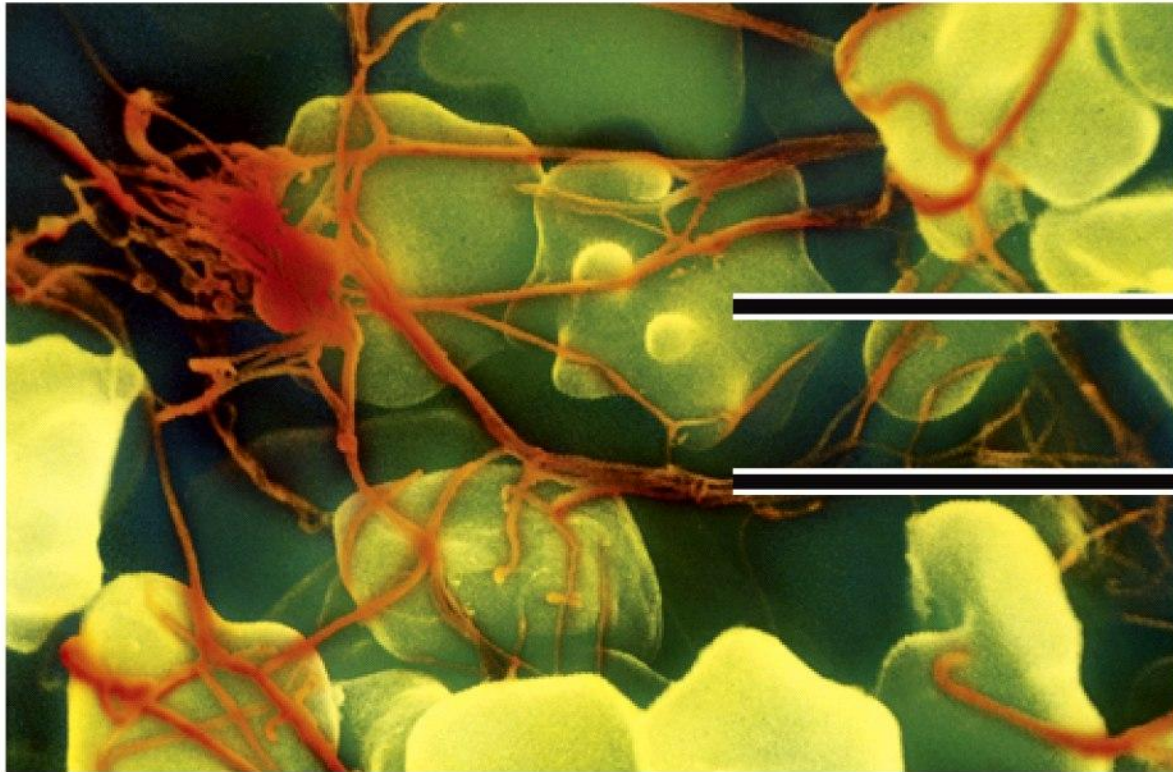
1 Platelet adhesion



2 Platelet release reaction



3 Platelet aggregation



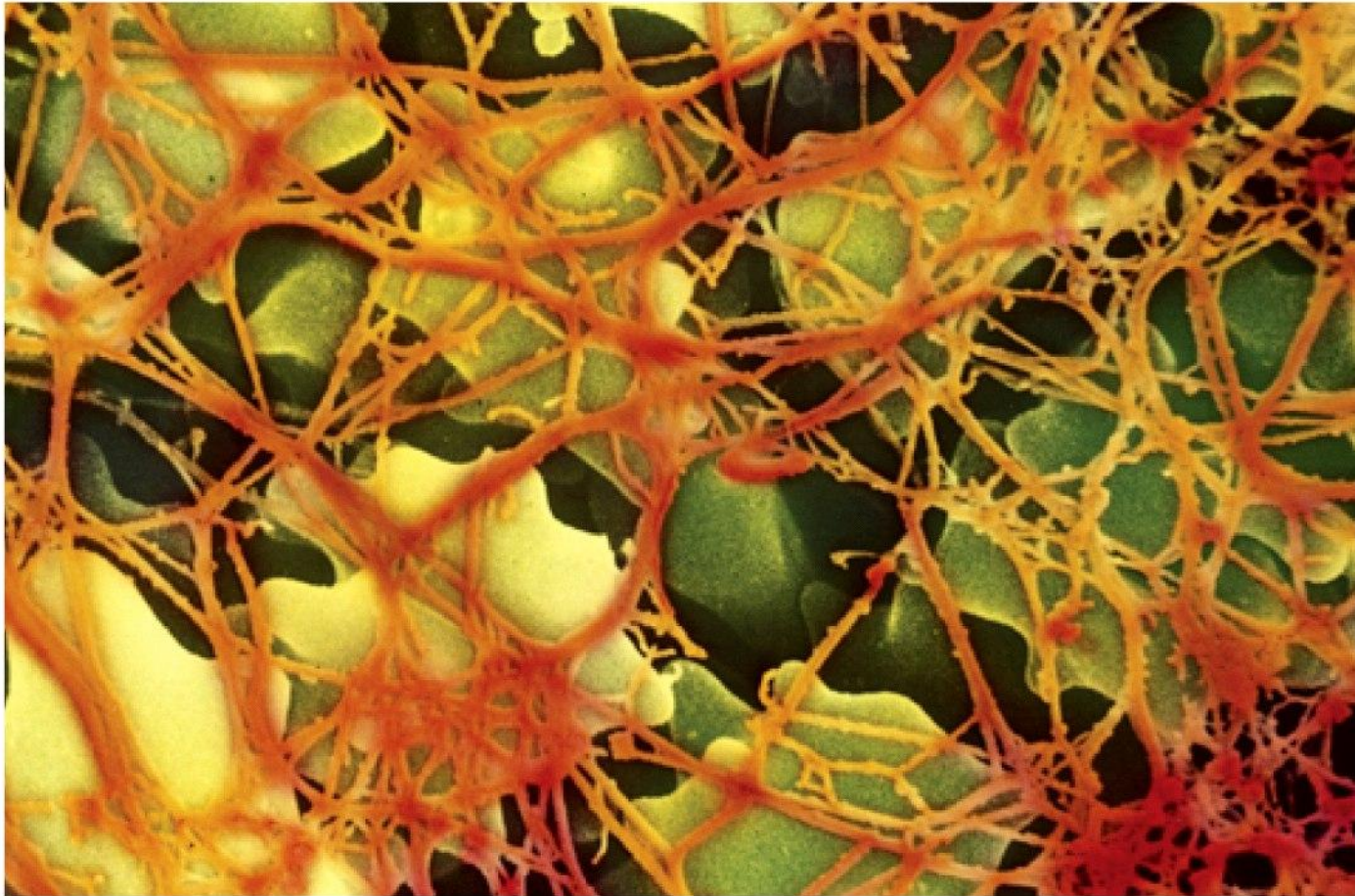
Platelet

**Fibrin
threads**

SEM 900x

Early stage

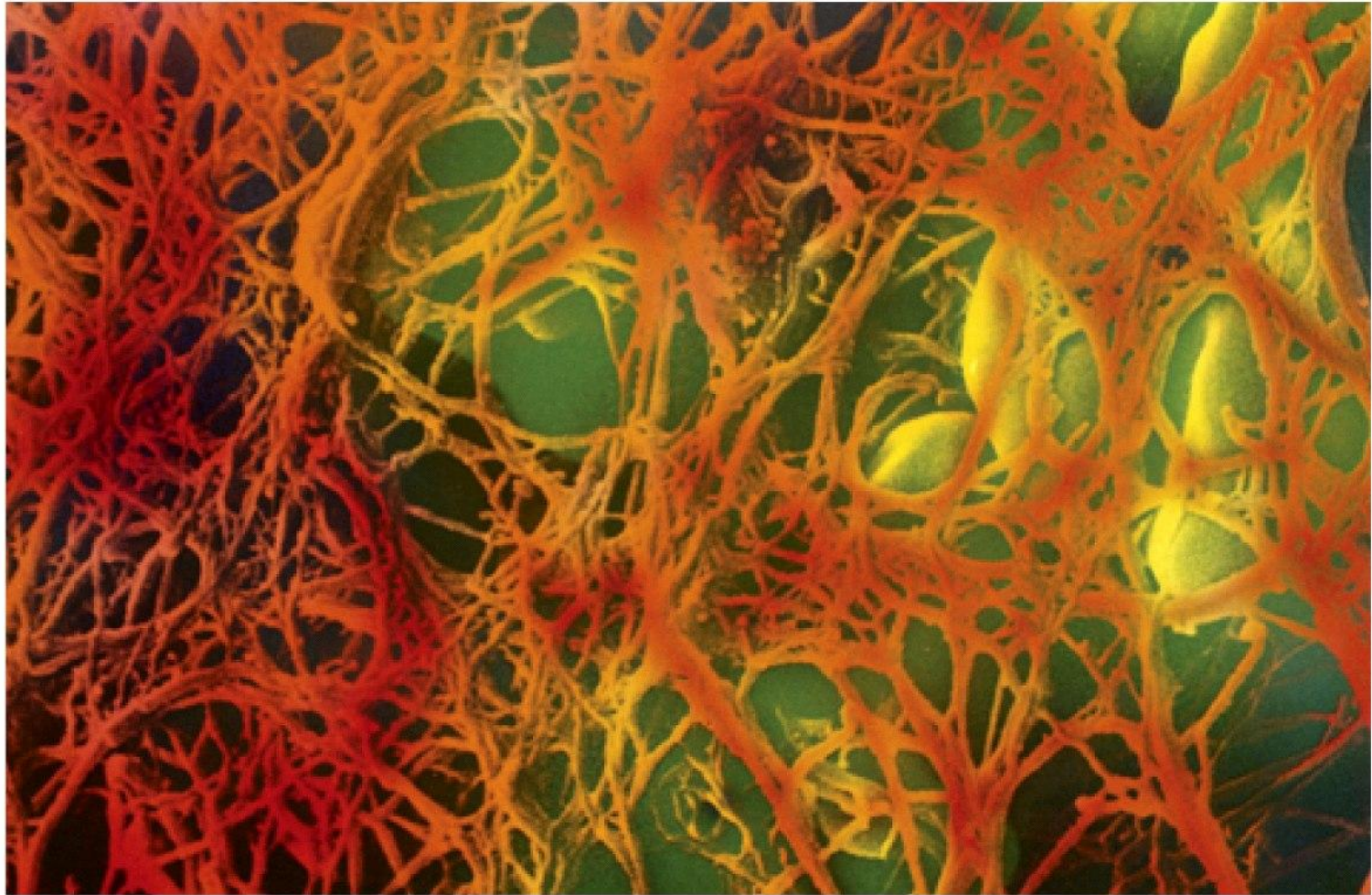
Figure 19-10a Principles of Anatomy and Physiology, 11/e



SEM 900x

Intermediate stage

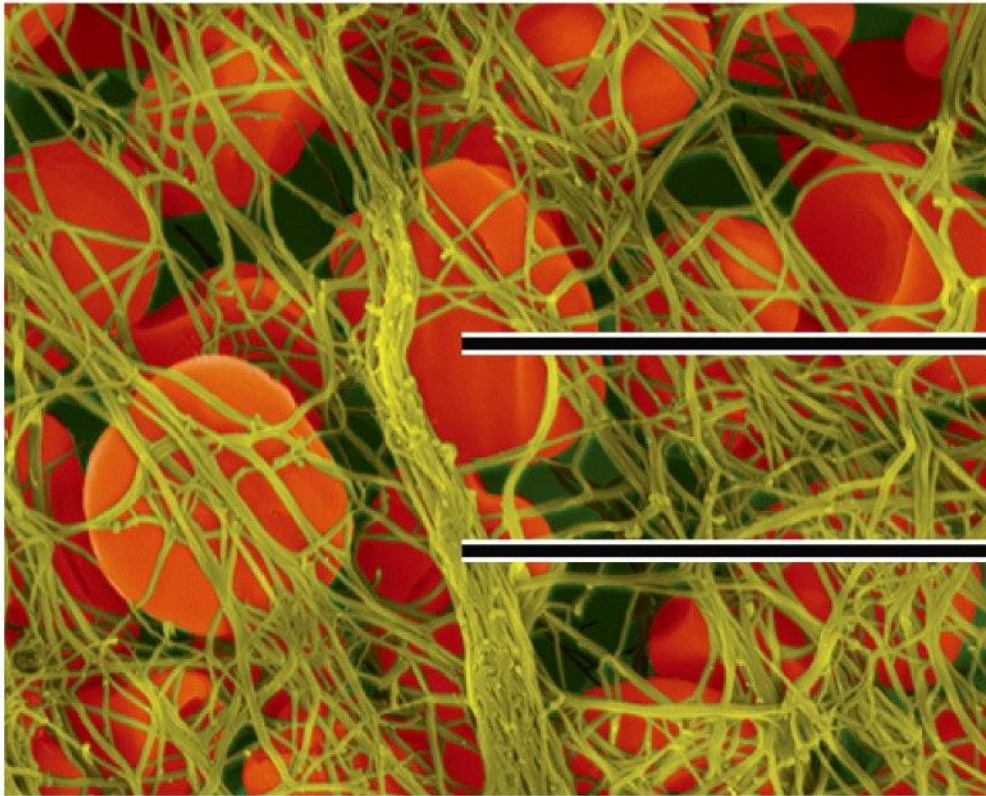
Figure 19-10b Principles of Anatomy and Physiology, 11/e



SEM 900x

Late stage

Figure 19-10c Principles of Anatomy and Physiology, 11/e



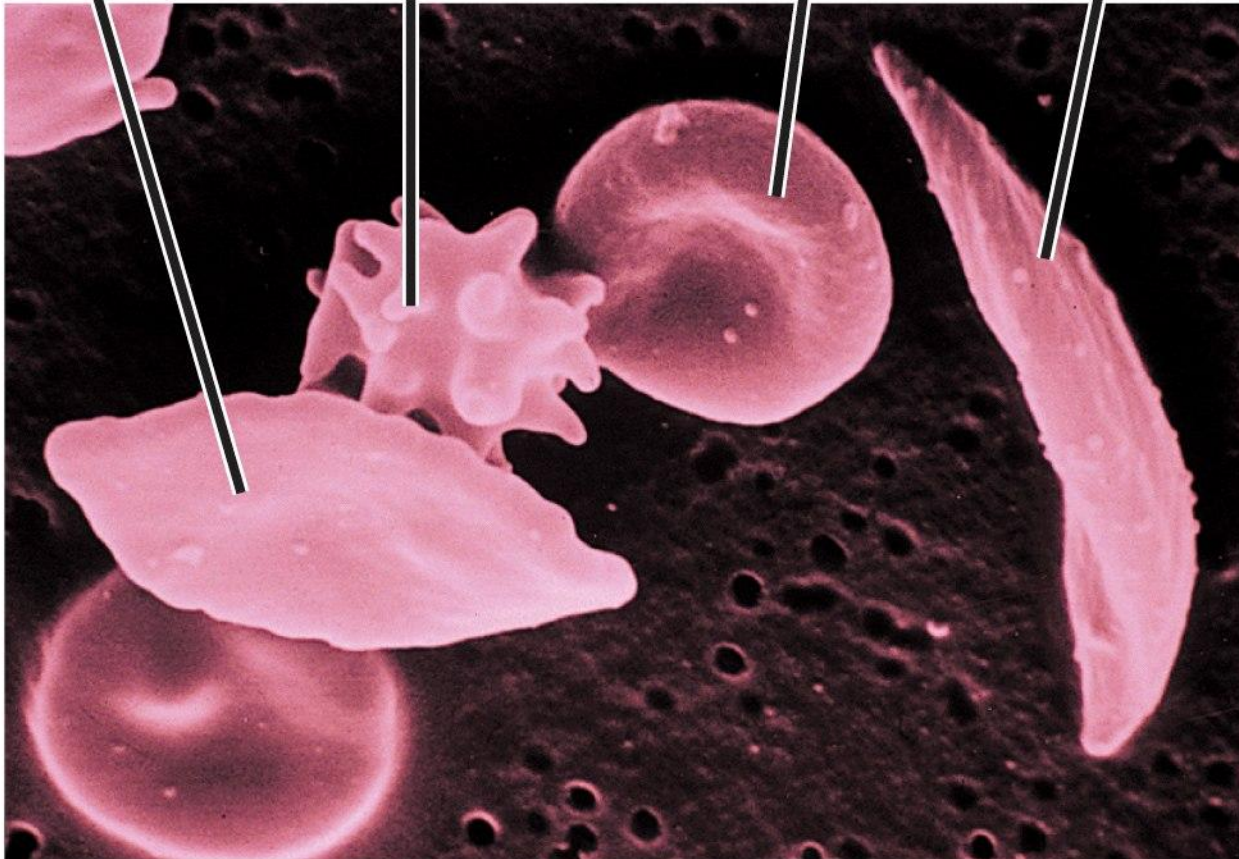
Red blood cell

Fibrin threads

SEM 1600x

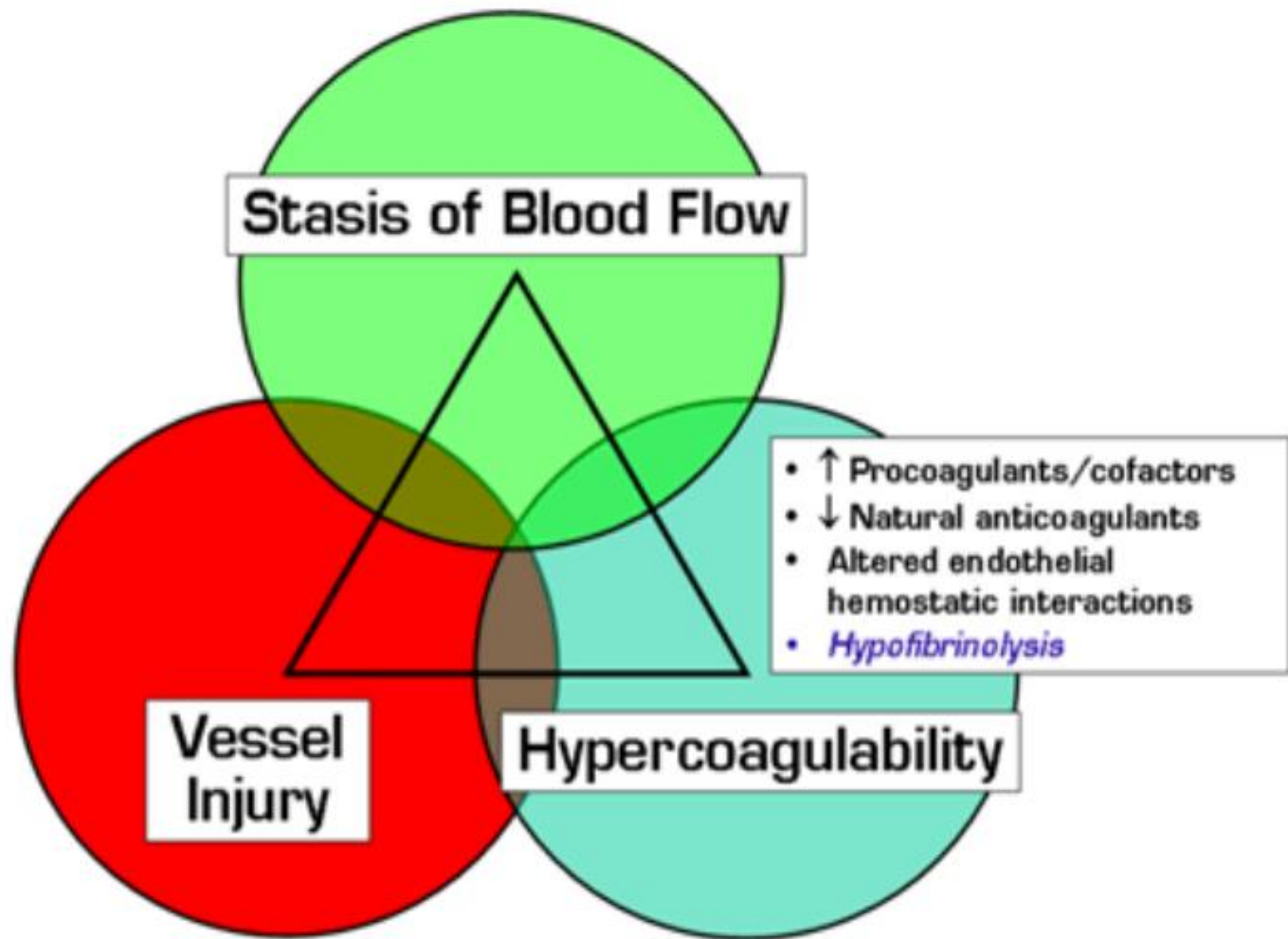
Red blood cells trapped in fibrin threads

Beginning to sickle Crenated Normal Sickled

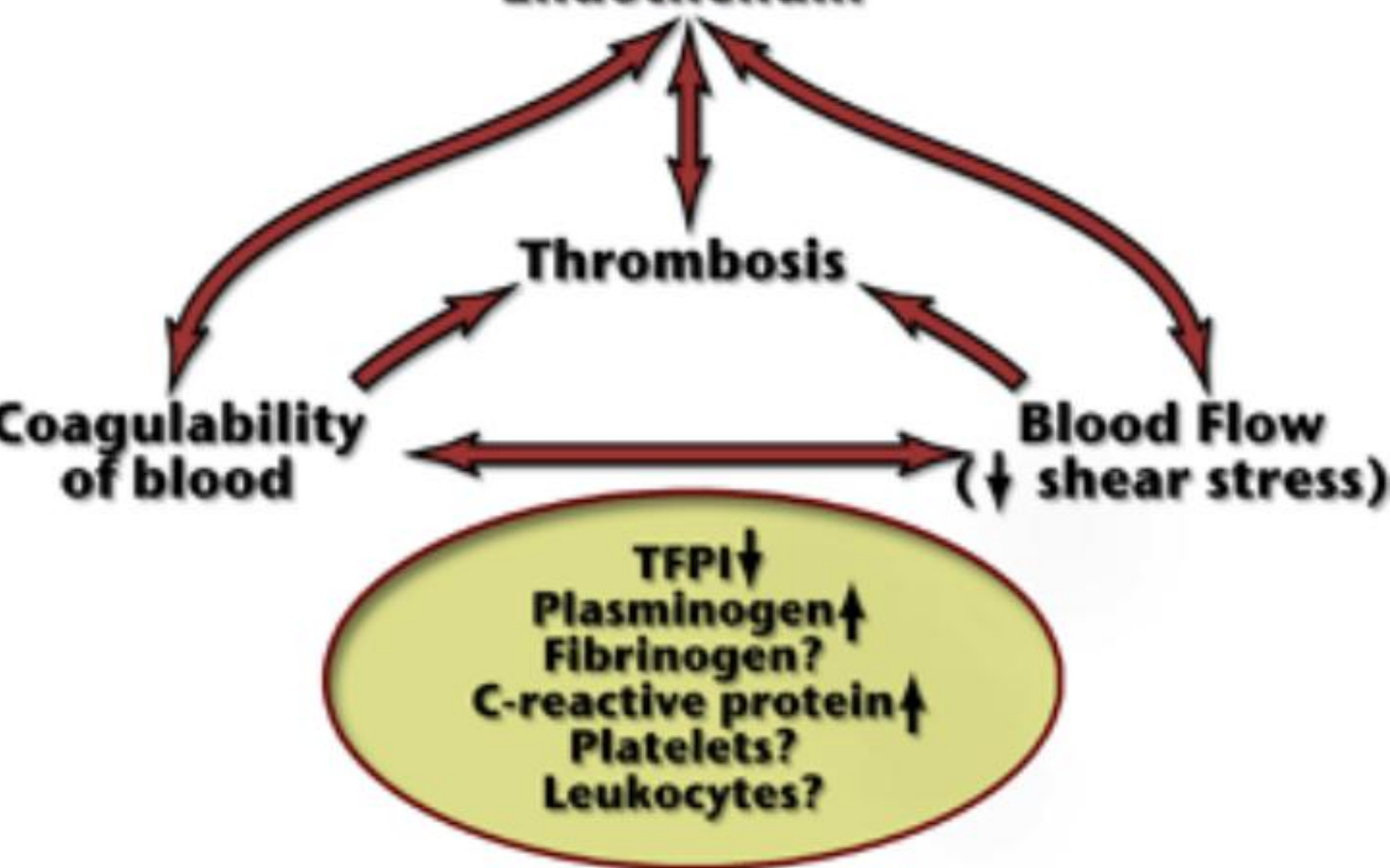


SEM 3310x

Red blood cells



Anatomy of venous wall
Smooth Muscle
Endothelium



Trombosis

- Pembentukan suatu massa abnormal di dalam sistem peredaran darah makhluk hidup yang berasal dari komponen darah.
- Massa ini disebut trombus bila terlepas dari dinding pembuluh darah disebut embolus.
- Bekuan darah in vitro, atau di dalam rongga tubuh atau yang terbentuk post mortem $\neq$ trombus

Berdasarkan komposisinya;
trombus dibagi atas 3 jenis:

1. *White thrombus*: terdapat di arteri, terdiri atas trombosit
2. *Red thrombus*; terdapat pada vena, terdiri atas fibrin dan eritrosit
3. *Mixed thrombus*: gabungan antara white dan *red thrombus*.

Faktor resiko untuk trombosis

Trombosis arteri

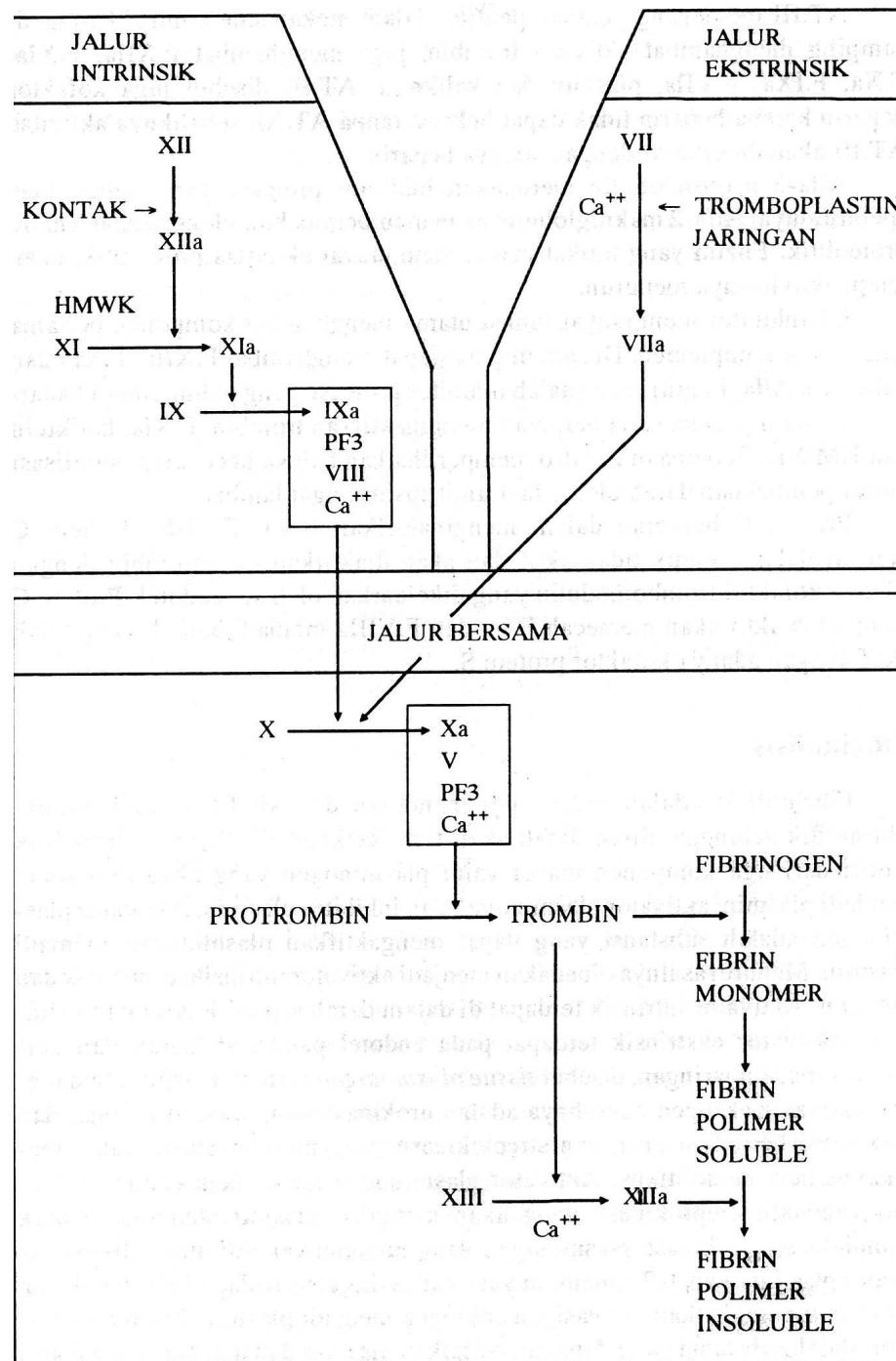
1. Hipertensi
2. Hiperkolesterolemia
3. Hiperlipoproteinemia
4. Kebiasaan merokok
5. Diabetes melitus
6. Homosistenemia
7. Trombositosis
8. Polisitemia

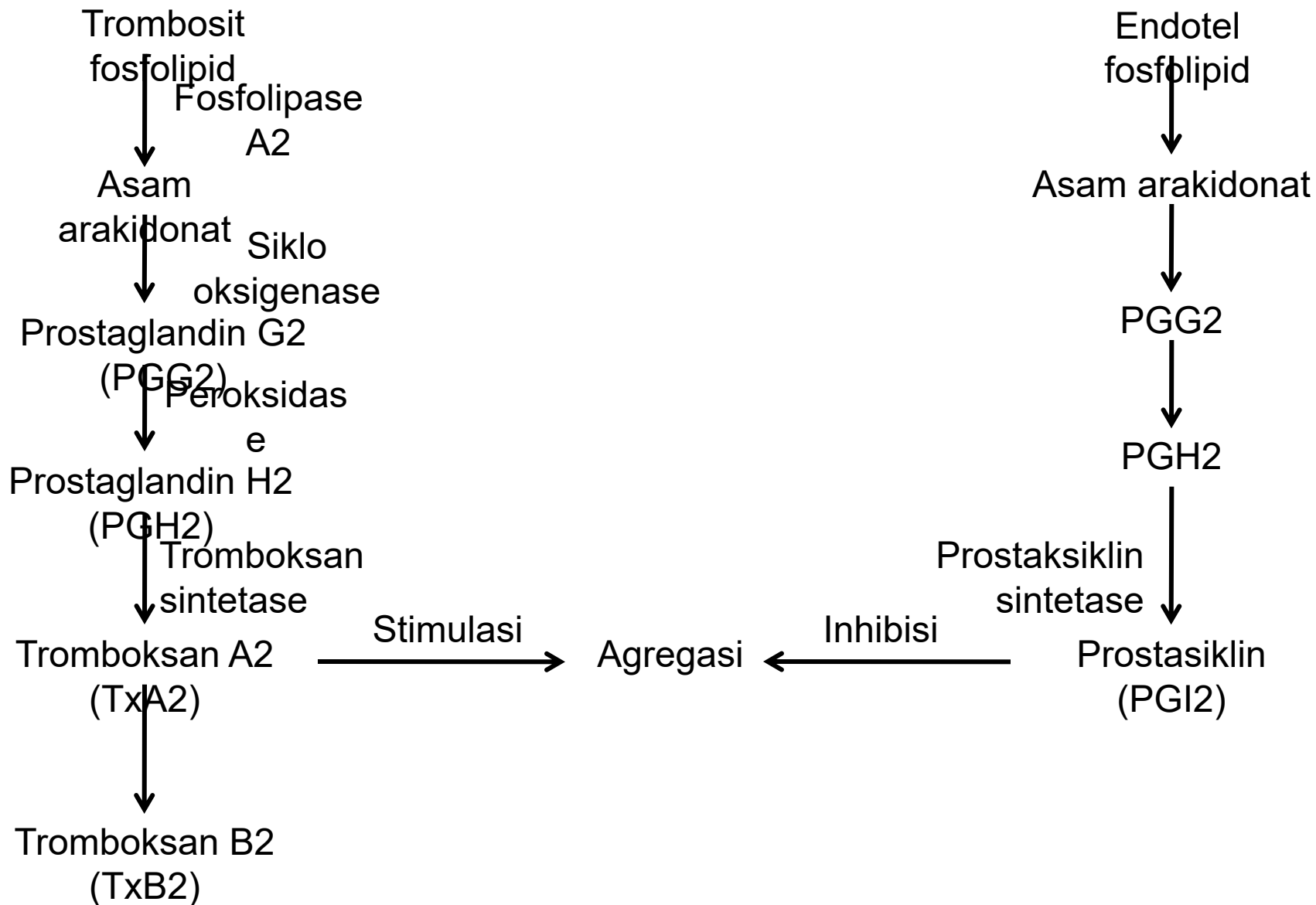
Trombosis vena

1. Immobilisasi
2. Operasi
3. Trauma jaringan yang luas
4. Keganasan
5. Kehamilan
6. Pil kontrasepsi
7. Defisiensi Antitrombin III
8. Defisiensi Protein C, Protein S, F XII
9. Struktur molekul plasminogen abnormal
10. Paroxymal noctural hemoglobinuria

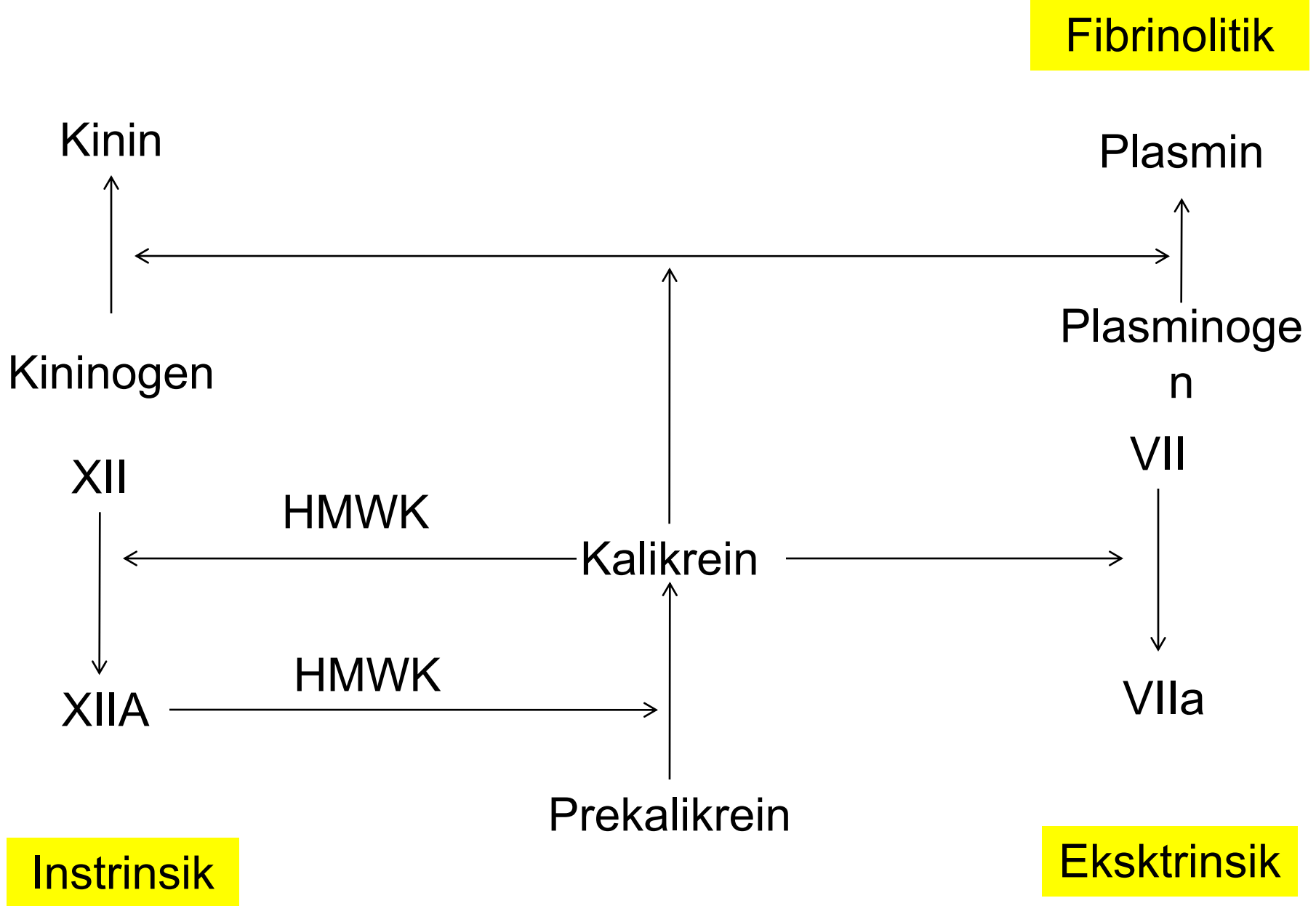
Tabel 1. Nomenklatur faktor pembekuan darah

Fakto	Nama	Sinonim
I ^r	Fibrinogen	-----
II	Protrombin	-----
III	Tissue factor	Tissue Thromboplastin
IV	Ion kalsium	-----
V	Procelerin	Labile factor
VI	-----	----
VII	Proconvertin	Stabile factor
VIII	Antihemophilic factor (AHF)	Antihemophilic globulin (AHG)
IX	Plasma Thromboplastin Component	Christmas factor
X	(PTC) Stuart factor	Prower factor
XI	Plasma Thromboplastin Antecedent	Antihemophilic factor C
XII	(PTA) Hageman factor	Contact factor
XIII	Fibrin Stabilizing factor (FSF)	Fibrinase
----	High Molecular Weight Kininogen	Fitzgerald factor
-----	(HMK) Pre Kalikrein (PK)	Fletcher factor





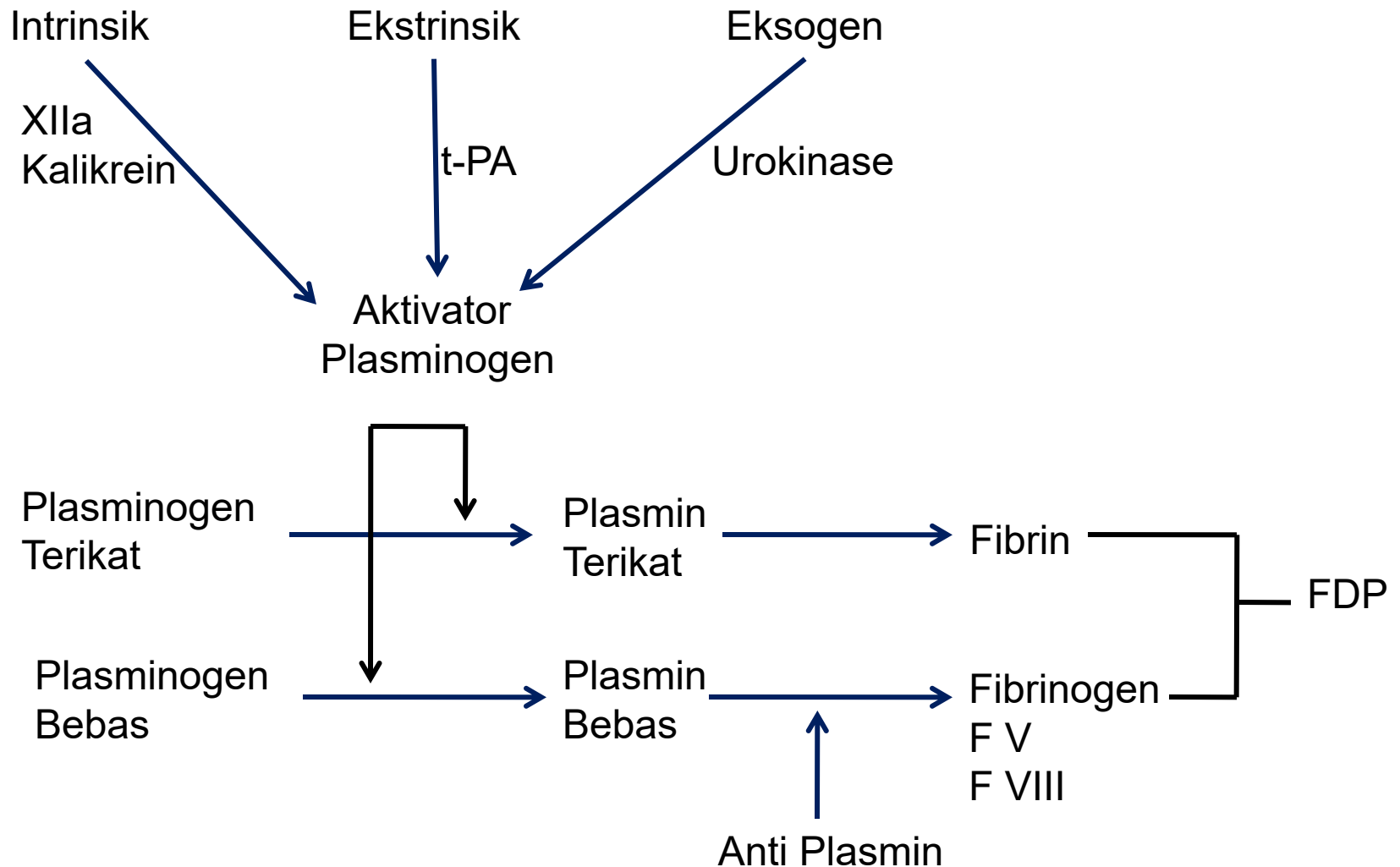
Gambar 1. Sintesis prostaglandin



Gambar 2. Hubungan antara sistem koagulasi, fibrinolotik & kinin

Fibrinolisis

- Proses penghancuran deposit fibrin oleh sistem fibrinolitik sehingga aliran darah akan terbuka kembali.
- Sistem fibrinolitik terdiri atas:
 - a. Plasminogen yang akan diaktifkan jadi plasmin
 - b. Aktivator plasminogen; substansi yang mengaktifkan plasminogen menjadi plasmin
 - c. Inhibitor plasmin



Gambar 4. Skema Fibrinolisis

FDP; Fibrin degradation products; t-PA; tissue plasminogen aktivator; urokinase ; dibentuk di ginjal & diekskresi melalui urin.

Inhibitor plasmin=anti plasmin= substansi yang dapat menetralkan plasmin

Contoh antiplasmin dalam plasma

- Alfa-2 plasmin inhibitor → bekerja paling cepat
- Alfa-2 makroglobulin
- Alfa-1 antitripsin
- ATIII

Lymphatic system

Tim Anfisman FFUP

Functions of the Lymphatic System

- Fluid balance
 - Excess interstitial fluid enters lymphatic capillaries and becomes lymph
- Fat absorption
 - Absorption of fat and other substances from digestive tract
- Defense
 - Microorganisms and other foreign substances are filtered from lymph by lymph nodes and from blood by spleen

Saluran Limfatik
(Sirkulasi
Limfatik)

Kelenjar Limfe
(Sistem Imun)

Sistem
Imun dan
Limfatik

```
graph TD; A[Saluran Limfatik (Sirkulasi Limfatik)] --> C((Sistem Imun dan Limfatik)); B[Kelenjar Limfe (Sistem Imun)] --> C;
```

The diagram illustrates the relationship between the lymphatic system and the immune system. It features a central black circle labeled 'Sistem Imun dan Limfatik'. Two arrows point towards this central circle: a red arrow from the top-left box labeled 'Saluran Limfatik (Sirkulasi Limfatik)' and a brown arrow from the top-right box labeled 'Kelenjar Limfe (Sistem Imun)'.

Regional lymph nodes:

Cervical nodes

Axillary nodes

Inguinal nodes

Entrance of right lymphatic duct into right subclavian vein

Internal jugular vein

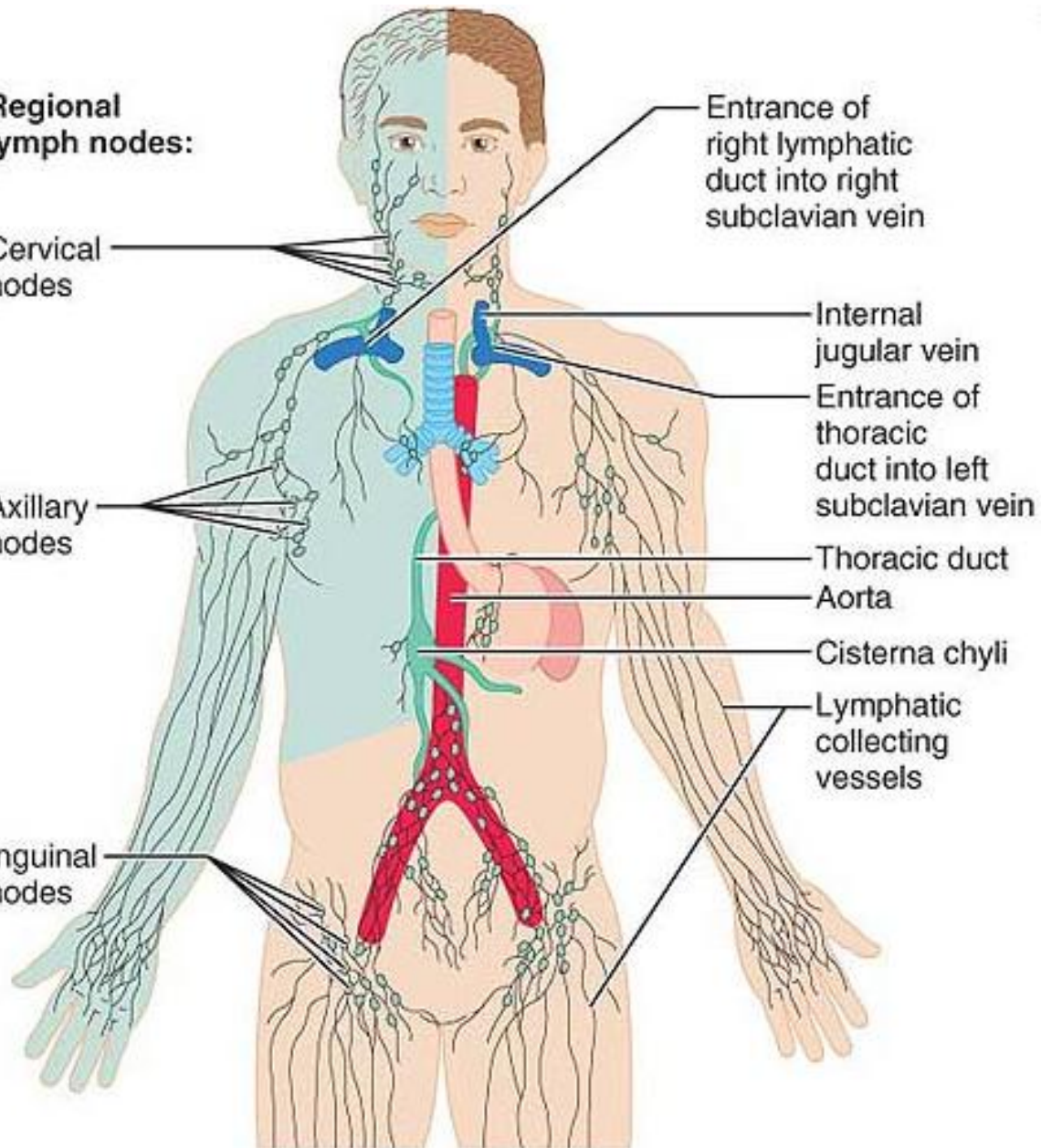
Entrance of thoracic duct into left subclavian vein

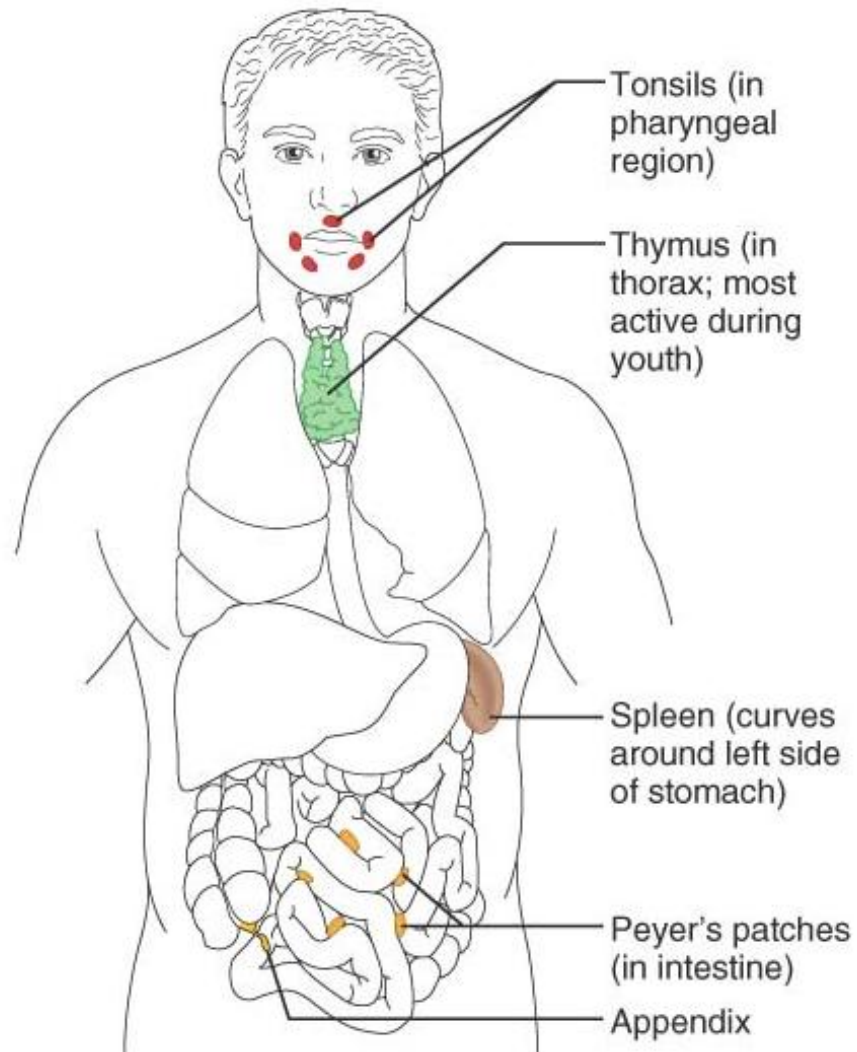
Thoracic duct

Aorta

Cisterna chyli

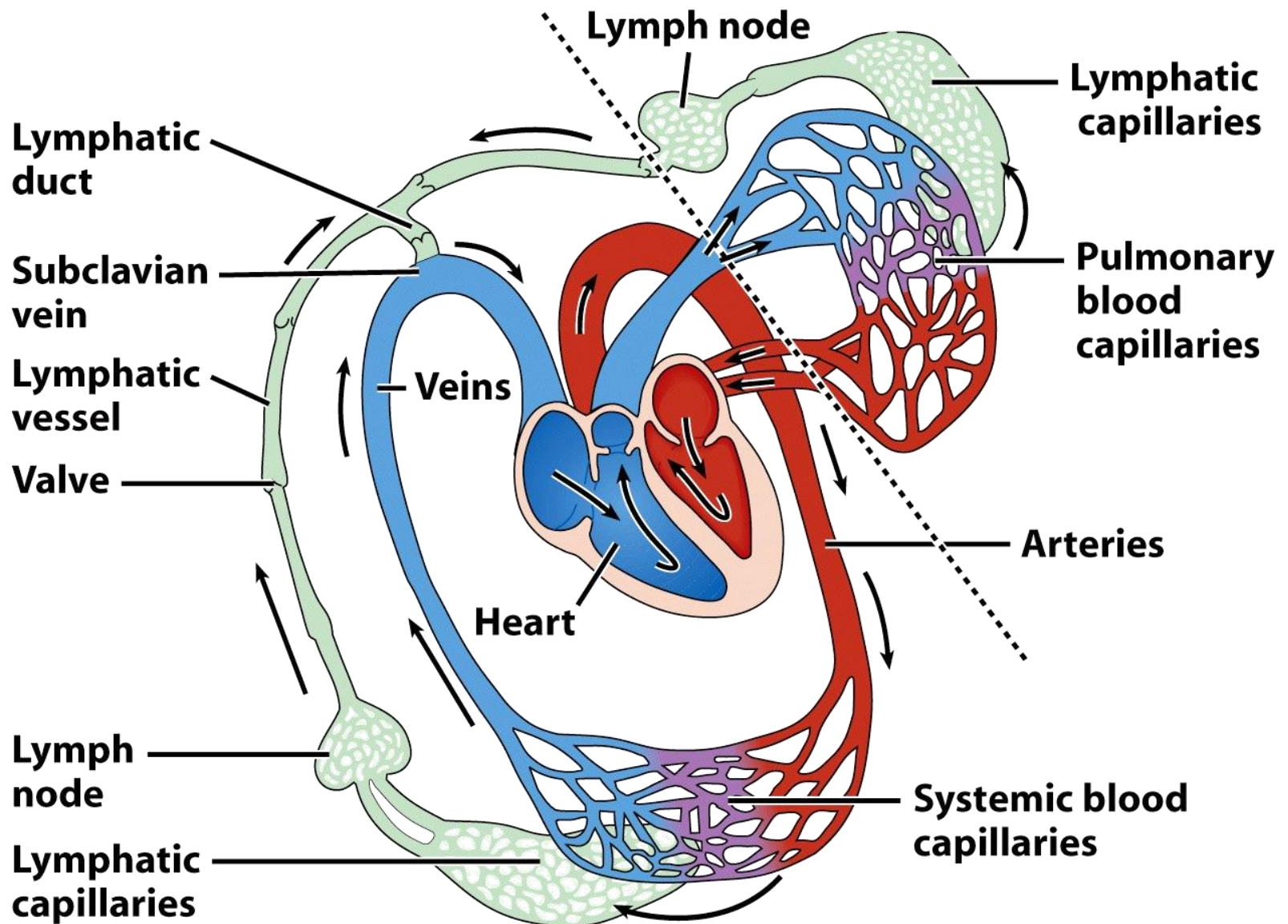
Lymphatic collecting vessels





SYSTEMIC CIRCULATION

PULMONARY CIRCULATION



Lymphatic capillary



Lymph node



Lymphatic vessel



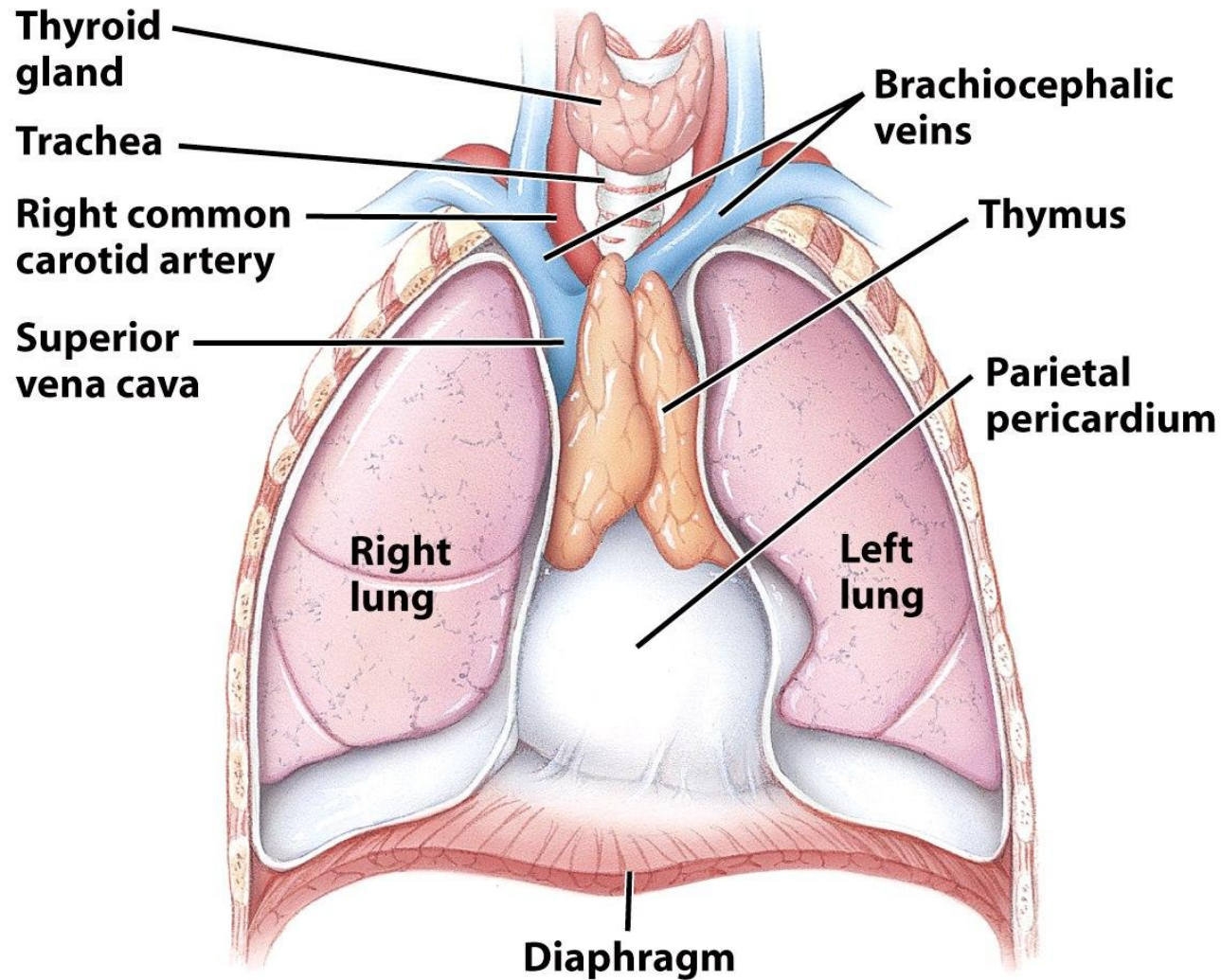
Lymphatic trunk



Collecting duct



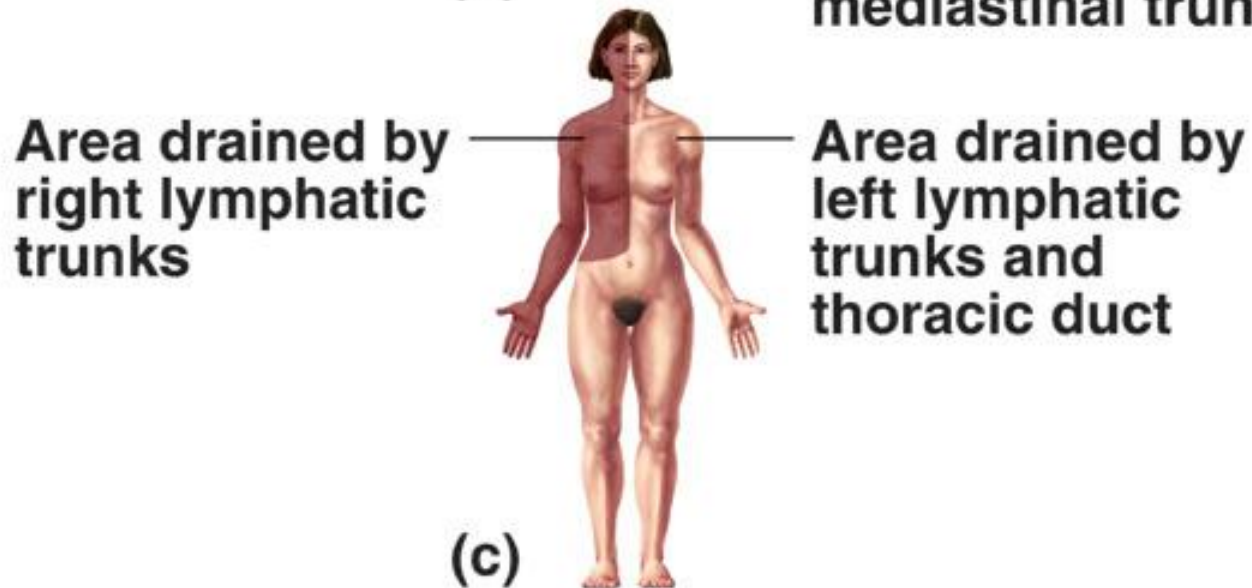
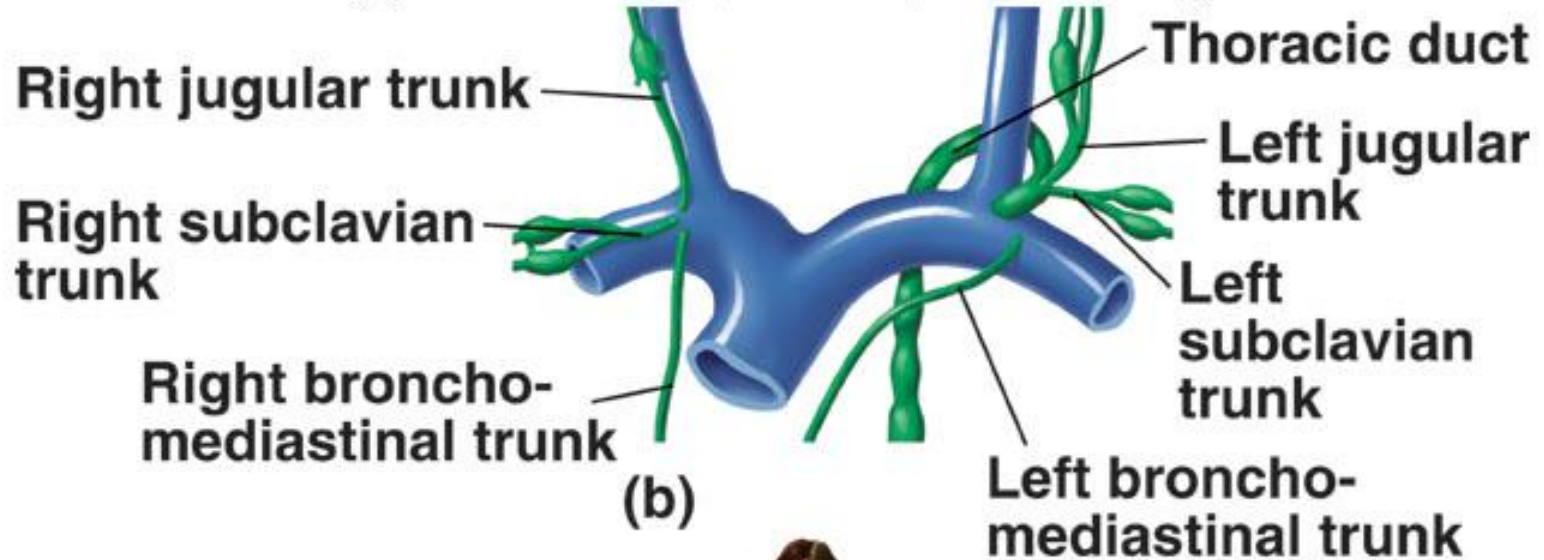
Subclavian vein

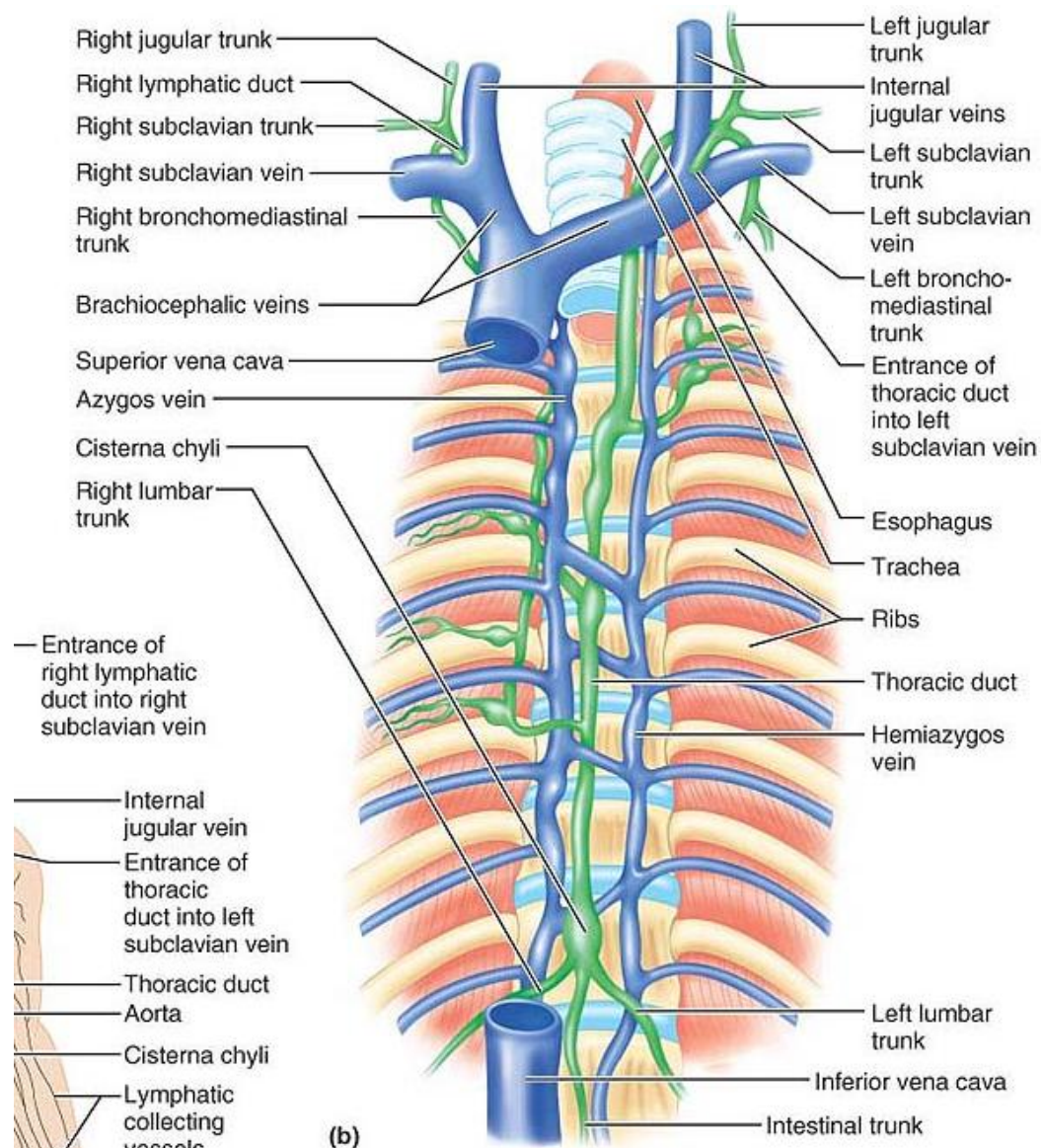


Thymus of adolescent

Lymphatic System and Immunity:

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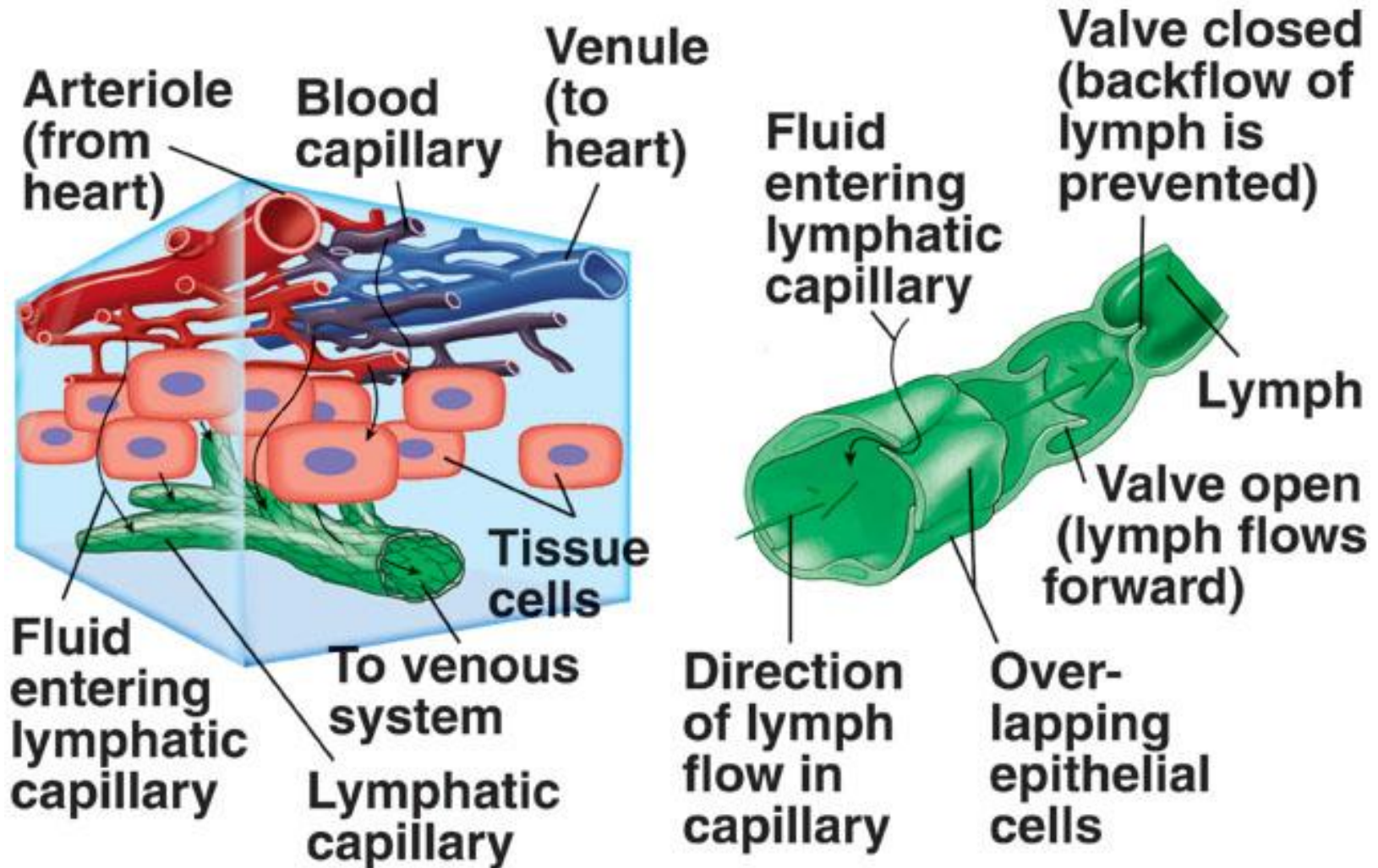


Lymphatic Vessels

- Lymphatic capillaries join to form
- Lymphatic vessels
 - Have valves that ensure one-way flow
- Lymph nodes: Distributed along vessels and filter lymph
- Lymphatic trunks: Jugular, subclavian, bronchomediastinal, intestinal, lumbar
- Lymphatic ducts: Right and thoracic which connect to large veins

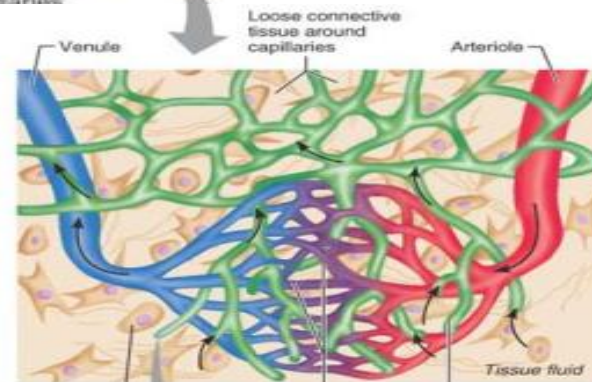
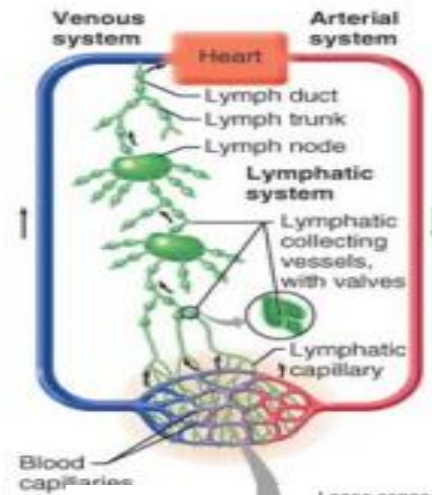
Lymph Drainage Into Veins

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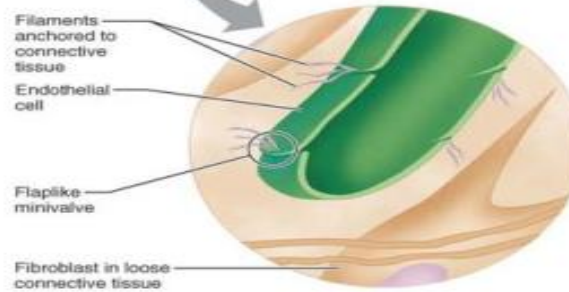


(a)

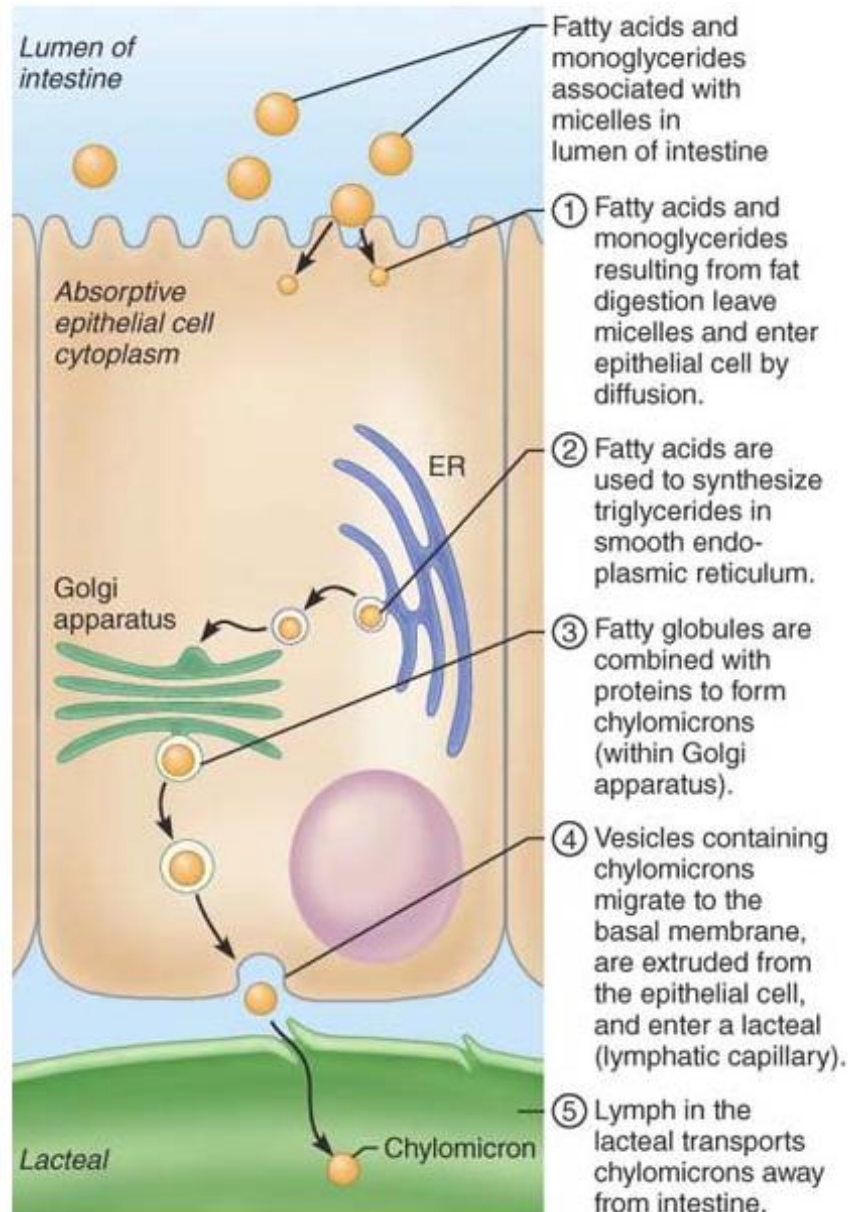
(b)

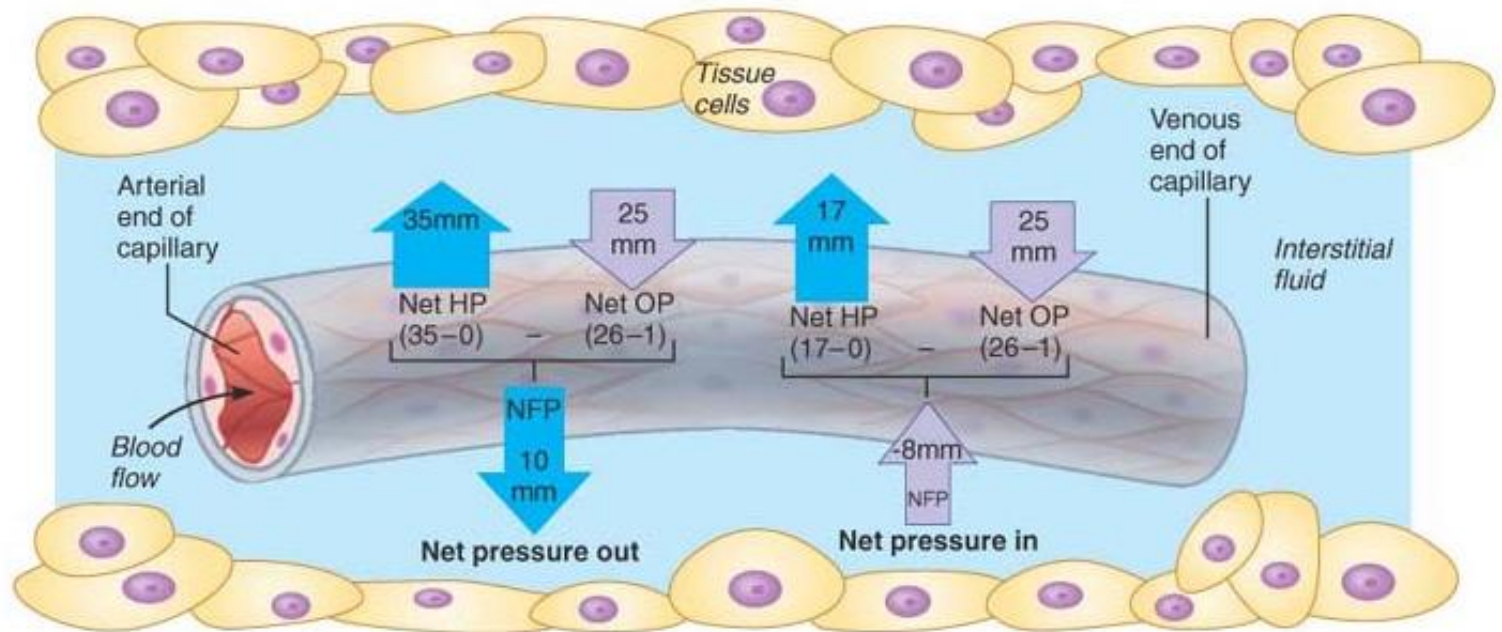


(a)



(b)



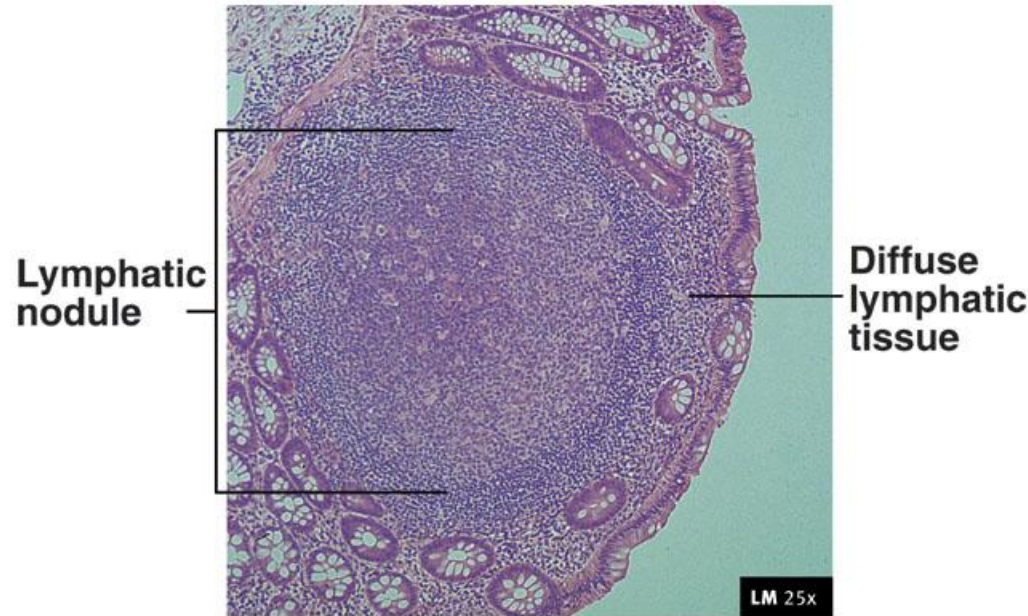


Key to pressure values:

HP_c at arterial end = 35 mm Hg $HP_{if} = 0$ mm Hg $OP_{if} = 1$ mm Hg
 HP_c at venous end = 17 mm Hg $OP_c = 26$ mm Hg

Lymphatic Tissue and Nodules

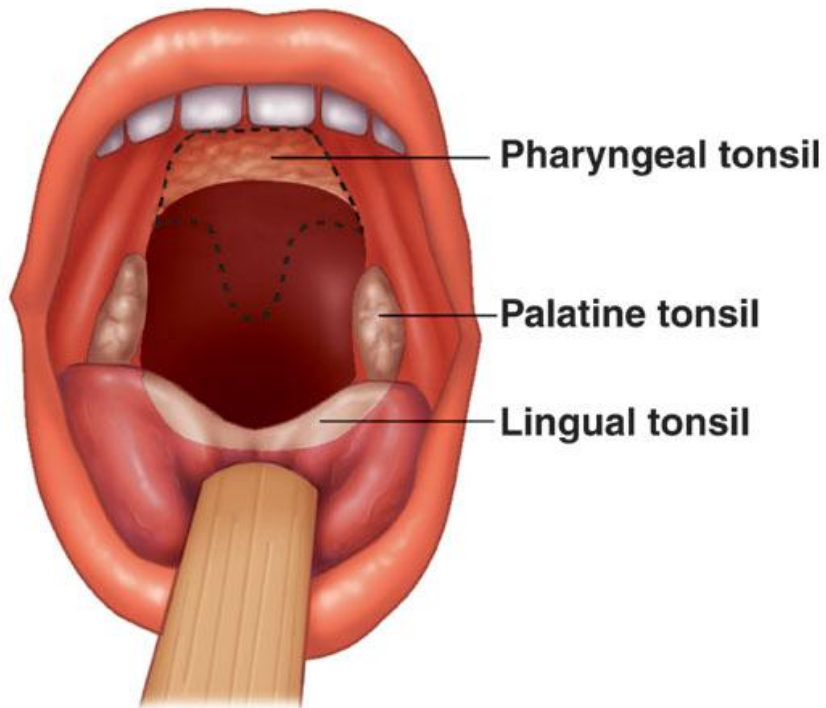
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- Lymphatic tissue
 - Consists mainly of lymphocytes
 - Encapsulated or not
- Lymphatic nodules
 - Numerous in loose connective tissue of digestive (Peyer's patches), respiratory, urinary, reproductive systems

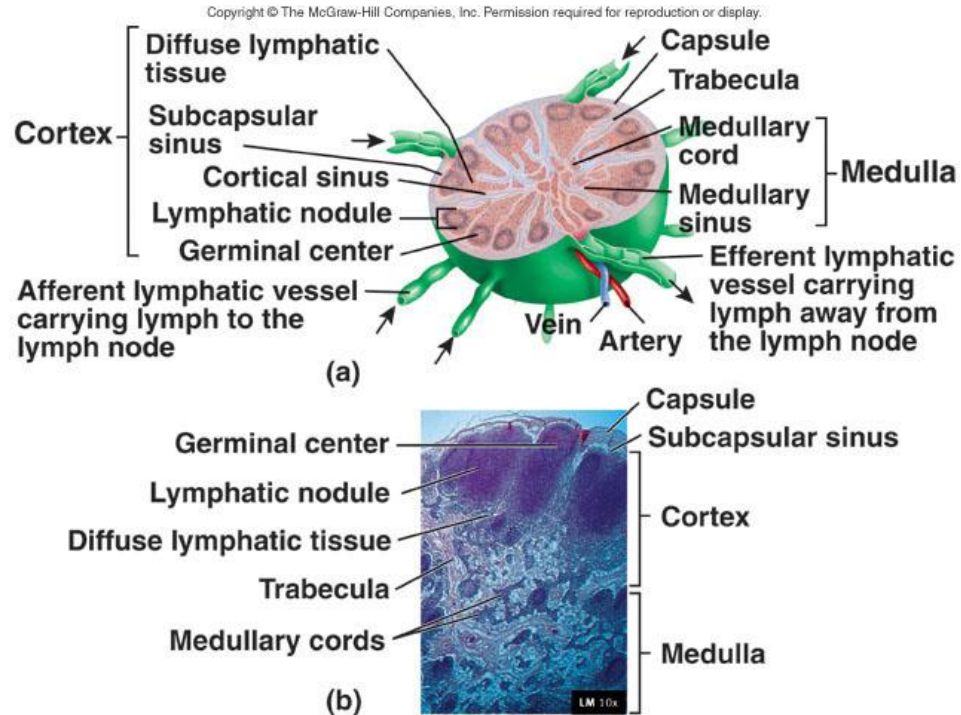
Tonsils

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- Large groups of lymphatic nodules in nasopharynx and oral cavity
- Provide protection against bacteria and other harmful material
- Groups
 - Palatine
 - Pharyngeal
 - Lingual

Lymph Nodes



- Organized in cortex and medulla
- Substances removed by phagocytosis or stimulate lymphocytes or both
- Only structures to filter lymph
 - Afferent and efferent vessels

Spleen

- Located in left superior side of abdomen
 - Can be ruptured in traumatic abdominal injuries resulting in bleeding, shock, death
- Blood flows through at 3 different rates
 - Fast (most), slow, intermediate
- Functions
 - Destroys defective RBCs
 - Detects and responds to foreign substances
 - Limited reservoir for blood

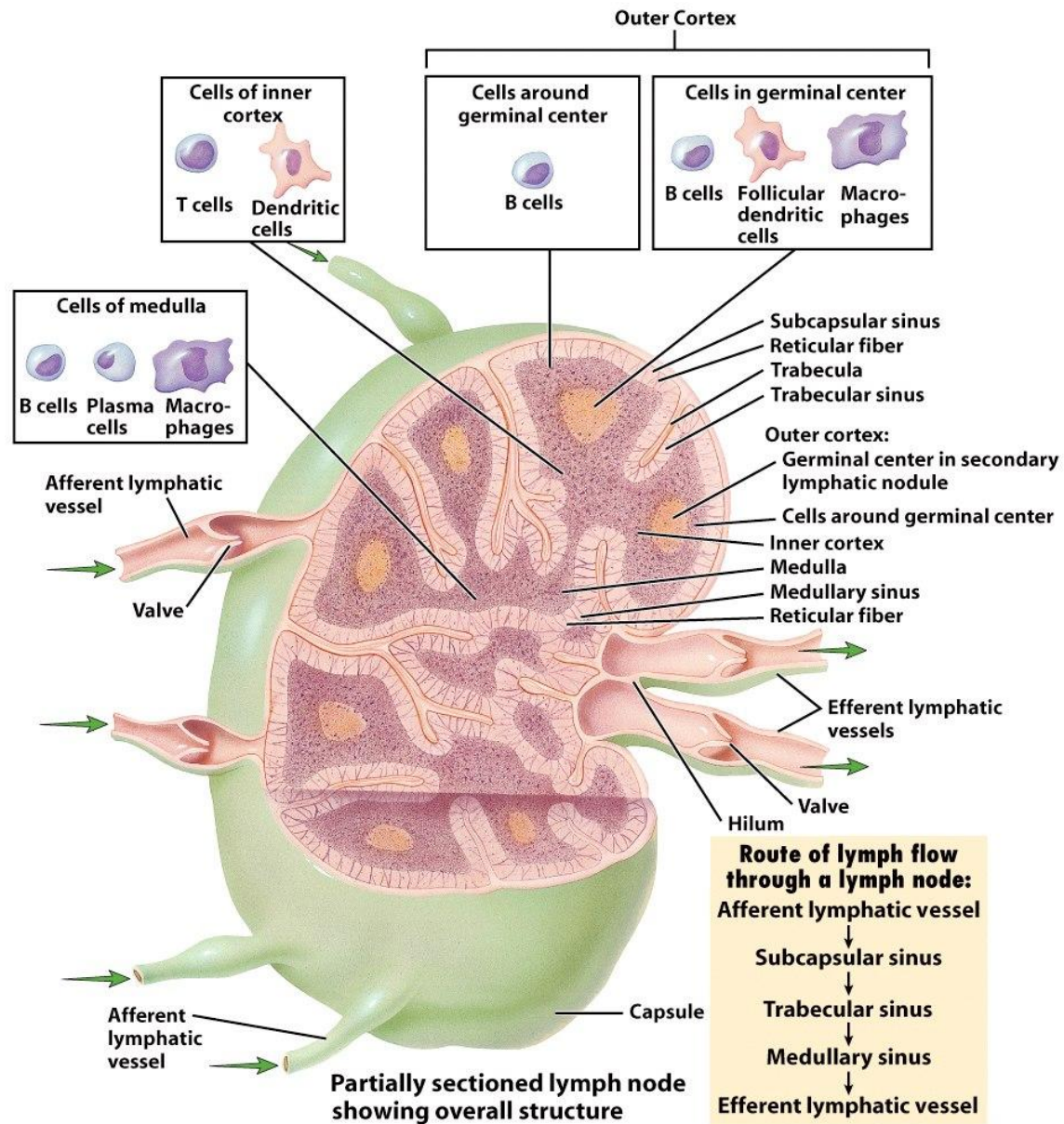
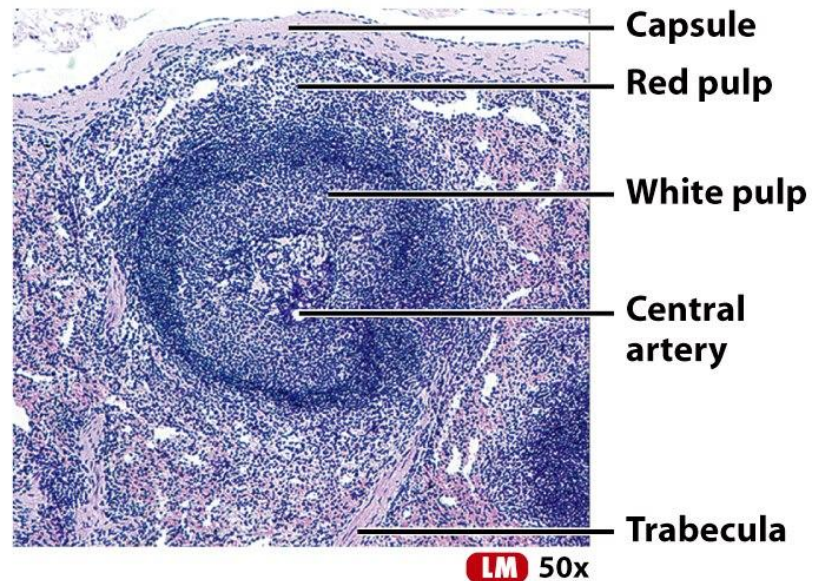
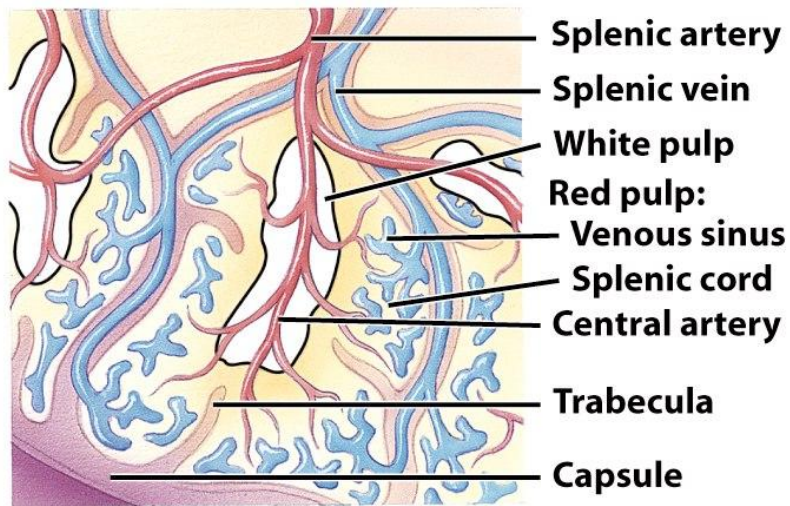
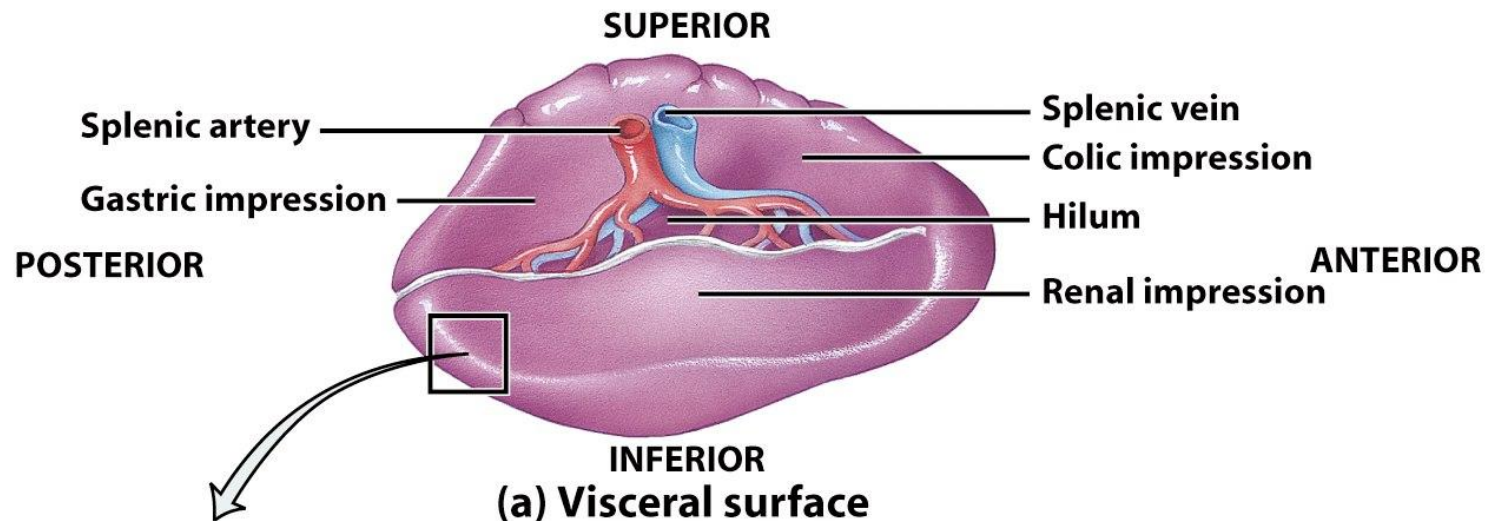
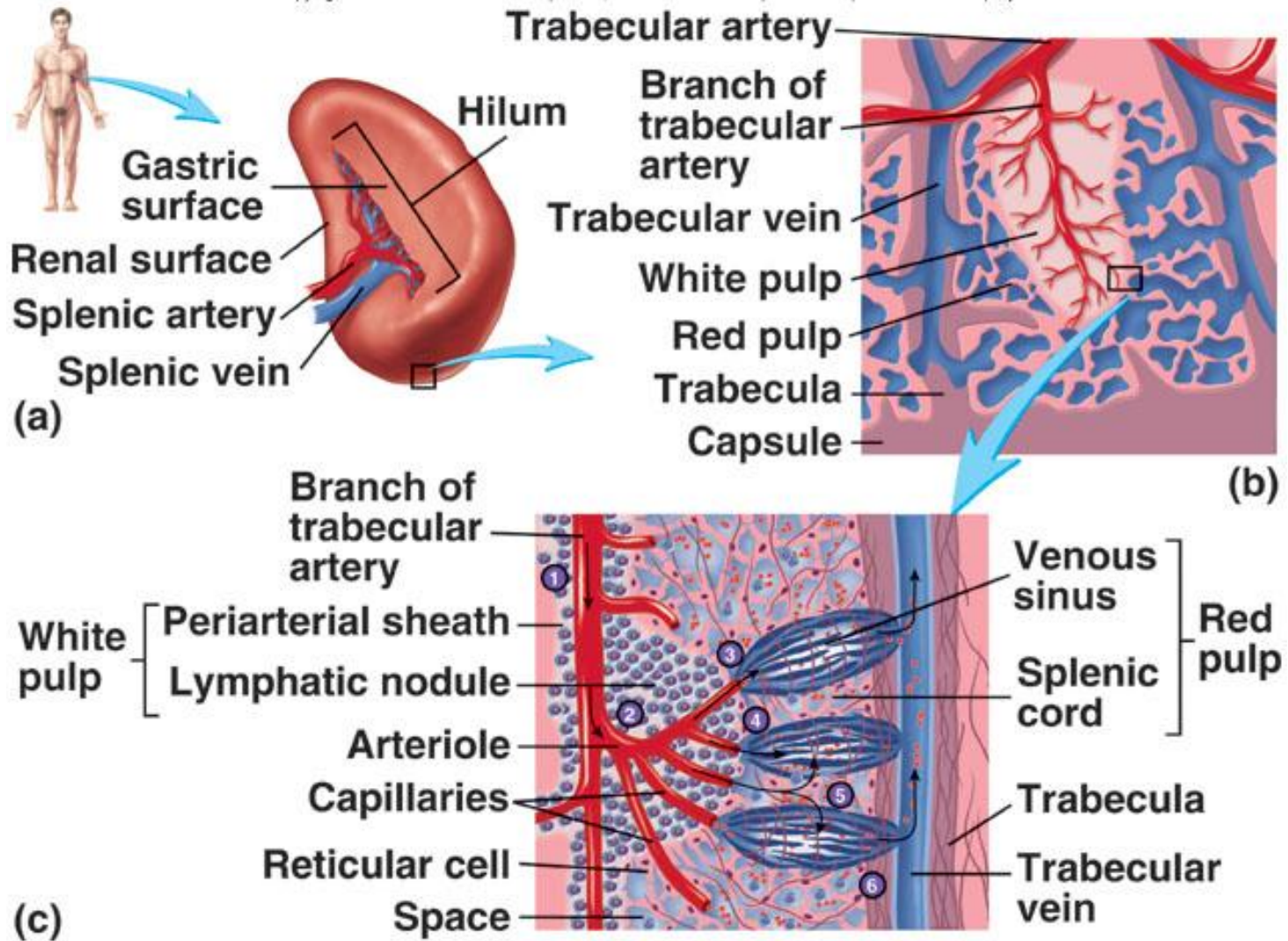


Figure 22-6a Principles of Anatomy and Physiology, 11/e
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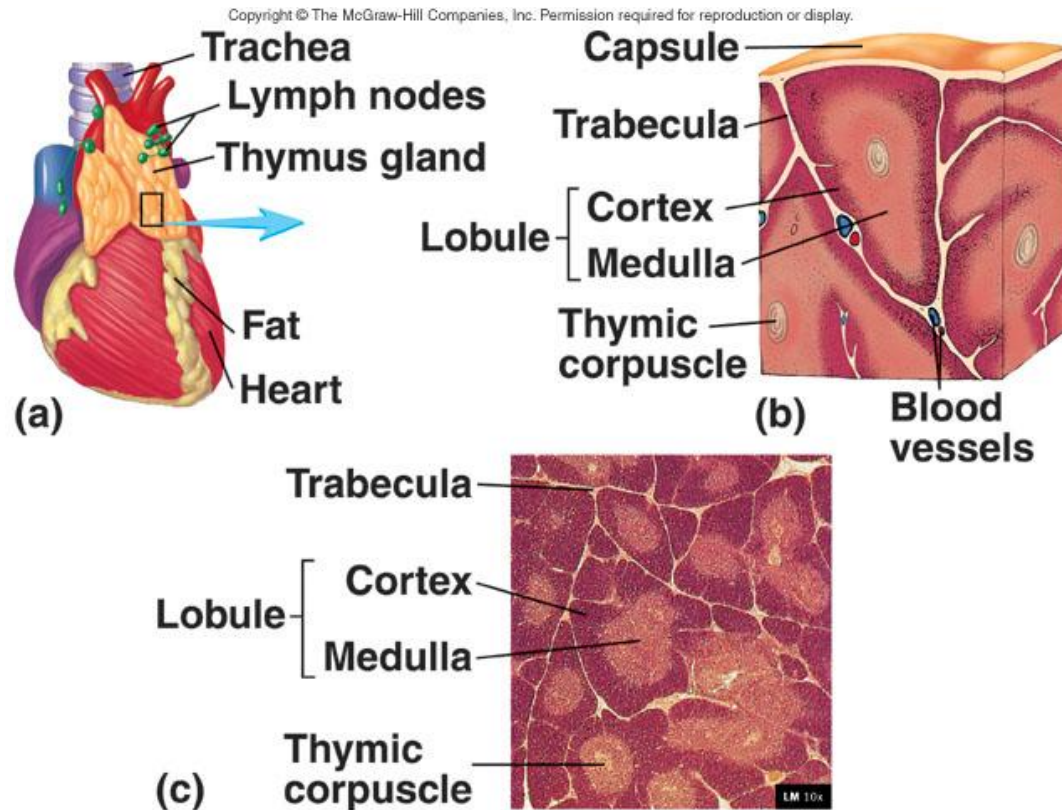


Spleen

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Thymus



- Located in superior mediastinum
- Divisions: Cortex and medulla
- Site of maturation of T cells