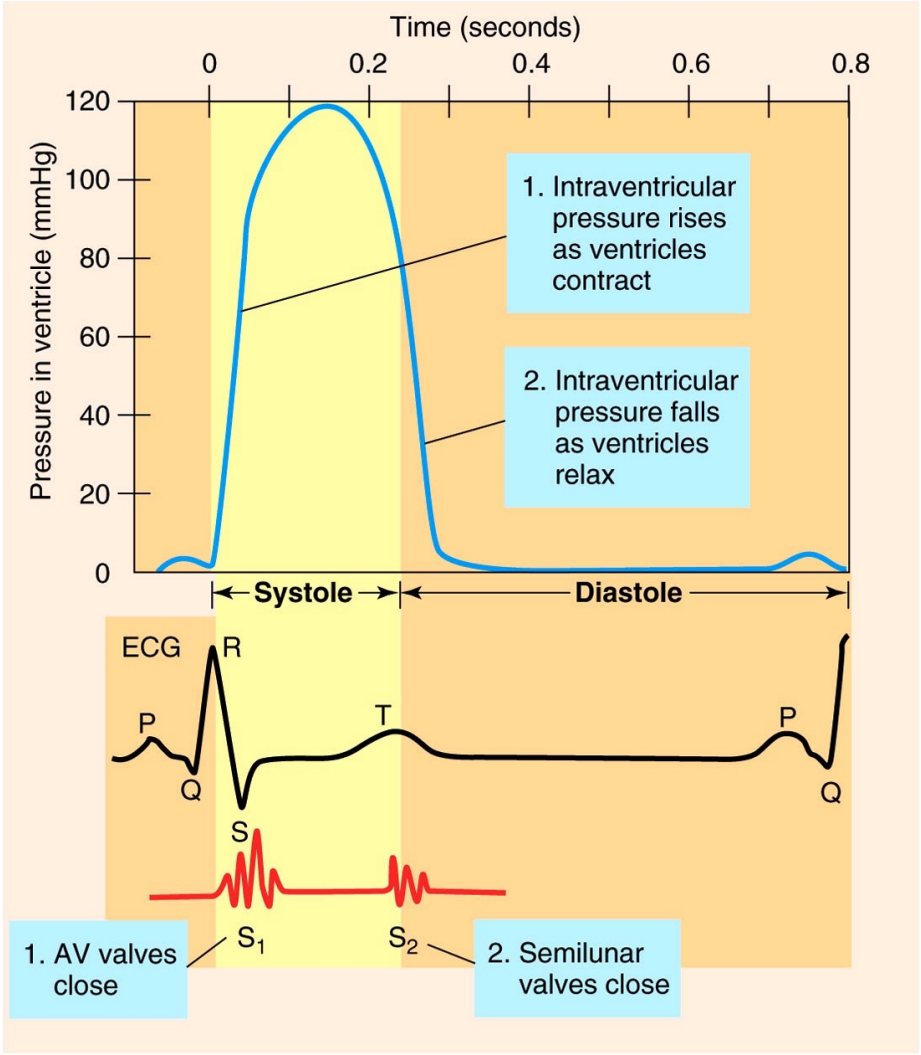
PCB4701

Heart 2
Fox Chapter 13 part 2

Figure 13.25


Time (seconds)
0
0.2
0.4
0.6
0.8
120
100
80
60
40
20
0
Pressure in ventricle (mmHg)
1. Intraventricular pressure rises as ventricles contract
2. Intraventricular pressure falls as ventricles relax
Systole
Diastole
ECG
R
P
T
P
Q
Q
S
S_1
S_2
1. AV valves close
2. Semilunar valves close

Events of the Cardiac Cycle

Electrical	ECG	Atria	AV Valves	Ventricles	Semi-Lunar Valves	Blood Flow
between beats		diastole	open	diastrole	closed	into atria (from vena cava, lungs)
SA node fires, spreads to AV node	P	systole	open	diastole	closed	into ventricles
spreads down bundle of His to Apex		systole	open	diastole	closed	
			"lub"			
spreads thru Purkinje fibers	QRS	diastole	closed	systole	open	into lungs, aorta
					"dub"	
between beats	T	diastole	open	diastrole	closed	into atria (from vena cava, lungs)

diastole = relaxed, systole = contracting

Arrhythmias and the ECG

Sinus bradycardia & tachycardia: changes in heart rate due to changes in SA Node pacemaker, e.g. by sympathetic stimulation of HCN channels -> tachycardia during "fight or flight"

Ectopic pacemakers outside of the SA node, e.g. ectopic pacemakers in ventricles -> ventricular tachycardia -> ventricular fibrillation

Circus rhythms: continuous recycling of AP around ventricles when refractory periods of myocardial cells become desynchronized. Circus rhythms can arise after damage to heart leading to disconnected portions of ventricle, or by electrical shock in middle of T wave.

Defibrillator: electrical shock depolarizes all of the myocardial cells at the same time, and syncrhonize in refractory state so SA node can restart contraction.

AV node block: damage to AV node slows or blocks atrial pacemaker signal. Can observe P-waves (of atrial contraction) without QRS wave (of ventricular contraction).

bradycardia = slow heart beat; tachycardia = rapid heart beat
fibrillation = "quivering" of myocardium; uncoordinated contraction
arrhythmia = loss of rhythm

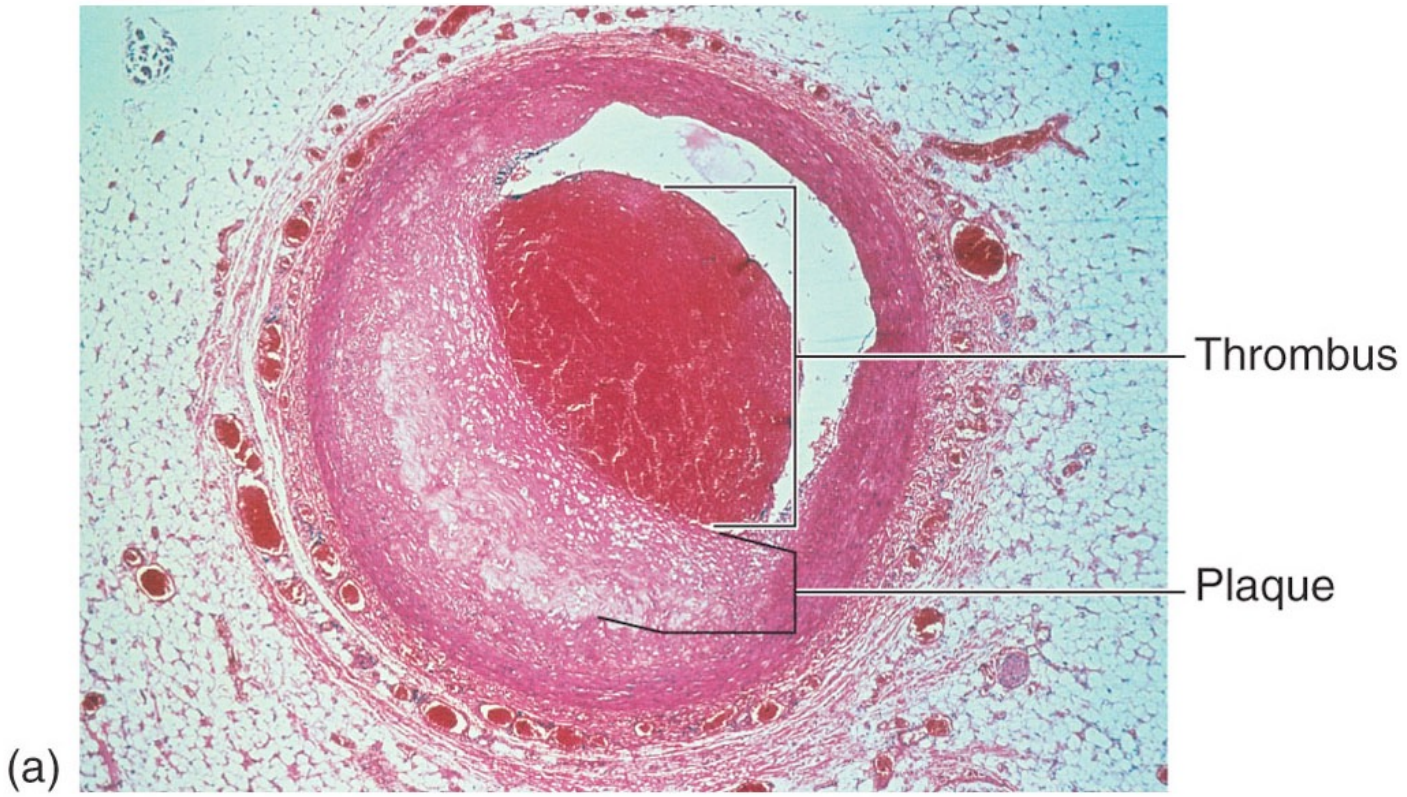


Figure 13.31a

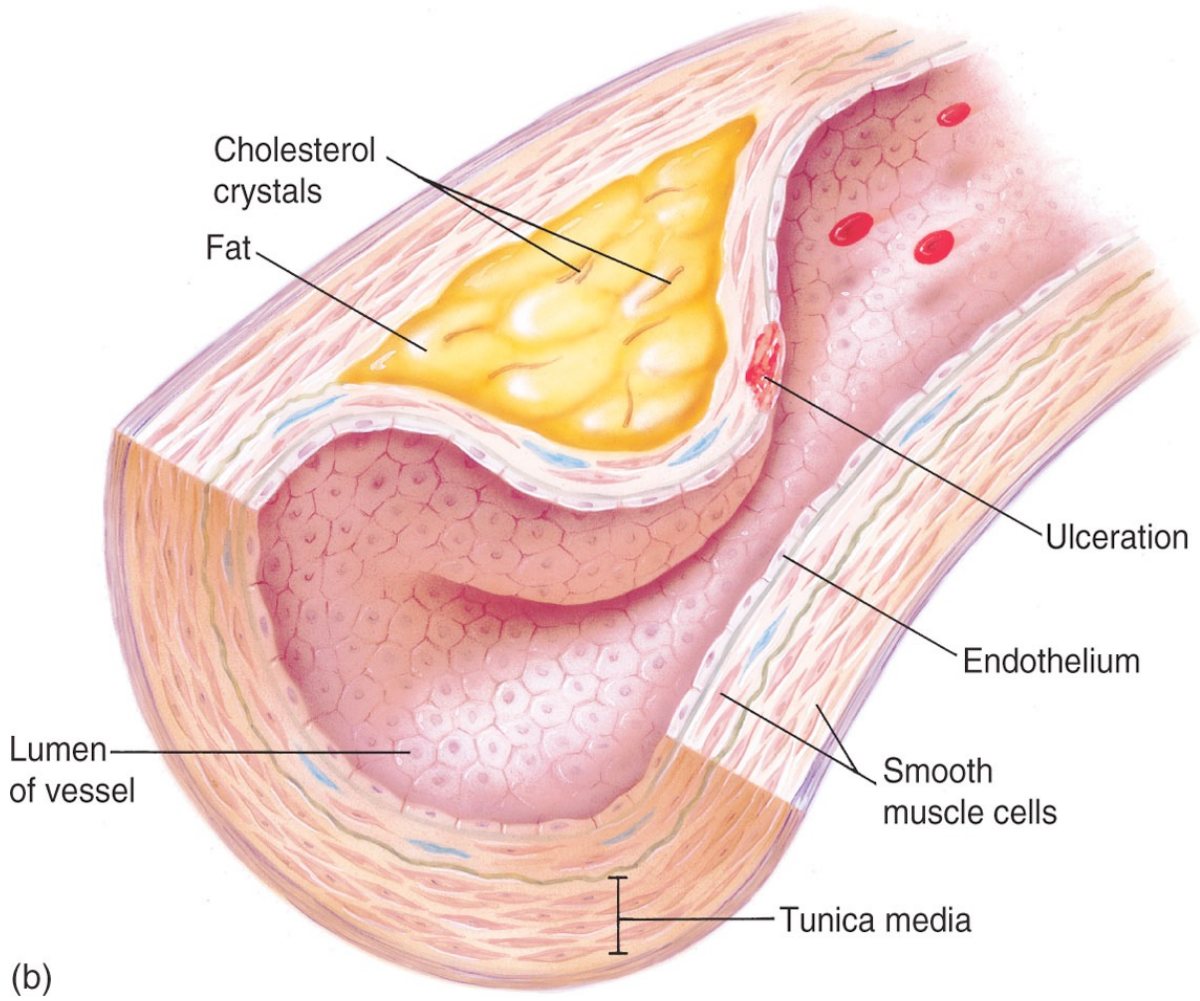
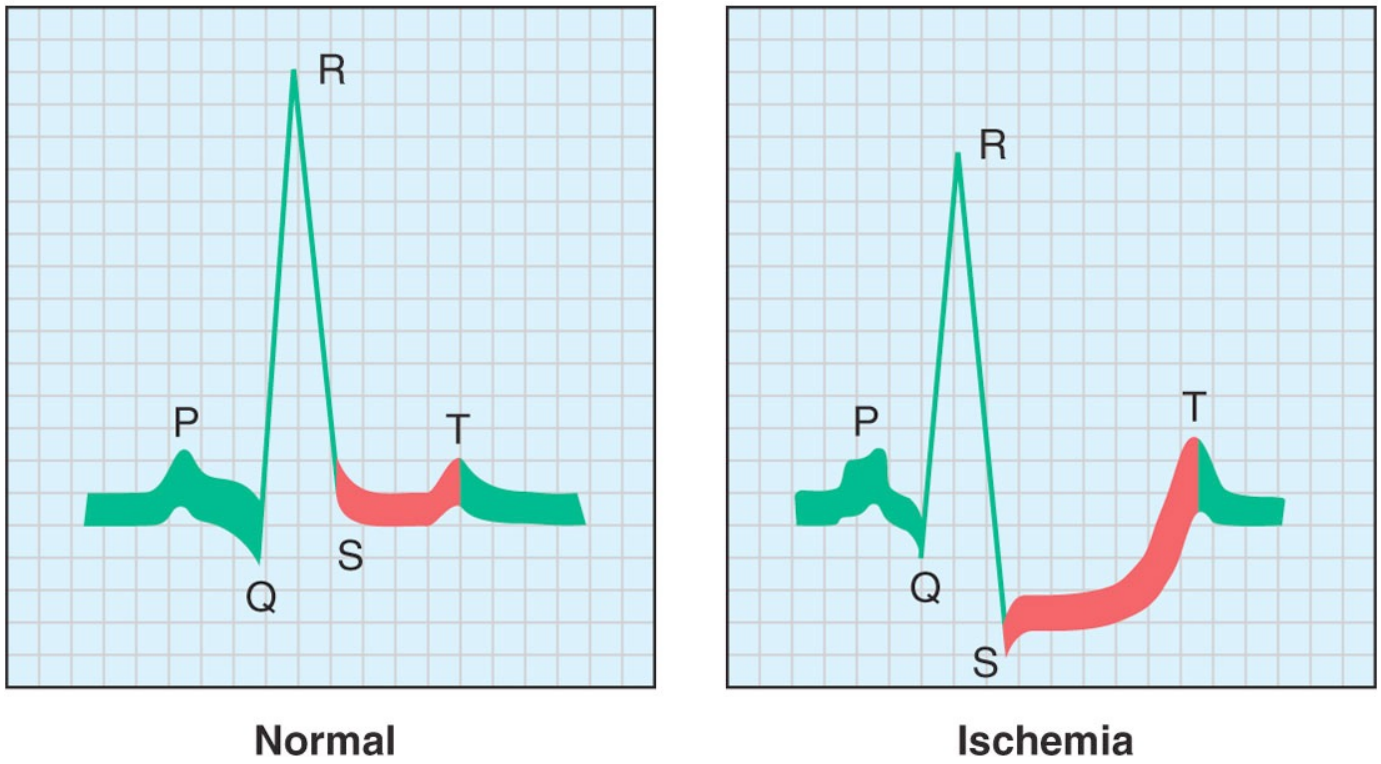


Figure 13.31b

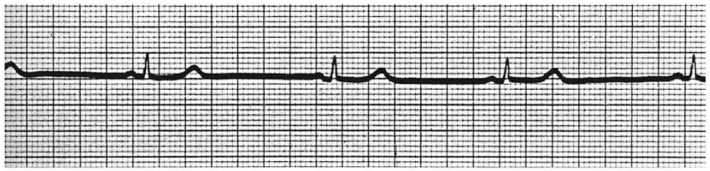
Depression of ST interval = damage to myocardium, intracellular accumulation of Ca++



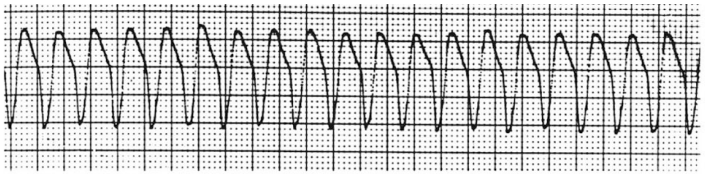
ischemia = loss of oxygen due to reduced blood flow -> cell damage & death (infarction)

Figure 13.33

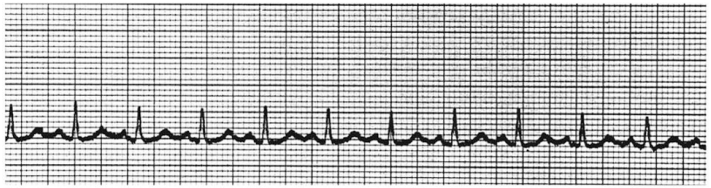
bradycardia = slow heart beat
tachycardia = rapid heart beat
fibrillation = "quivering" of myocardium; uncoordinated contraction
arrhythmia = loss of rhythm



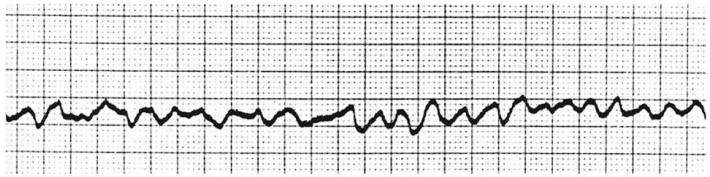
Sinus bradycardia



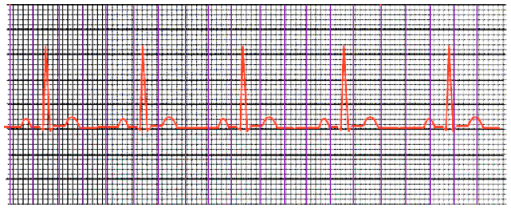
Ventricular tachycardia



Sinus tachycardia



Ventricular fibrillation

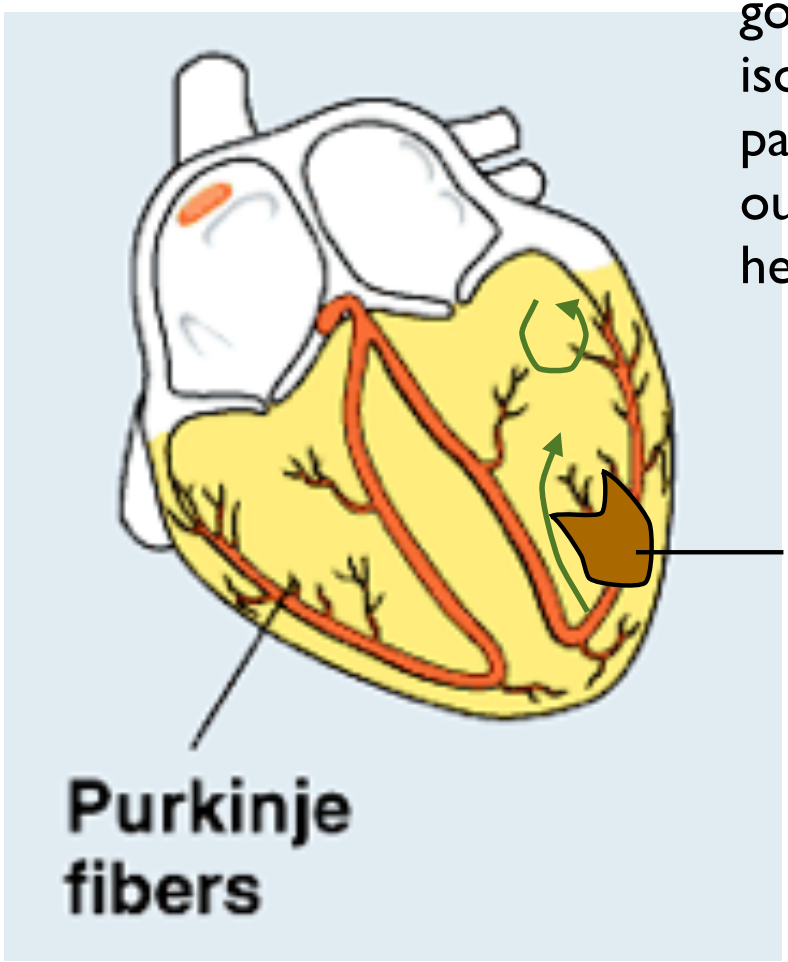


Normal

Figure 13.34

Circus Rhythms:

because of delay of AP going around damage, or isolation due to damage, parts of ventricle contract out of step with rest of heart



AV Node Block:

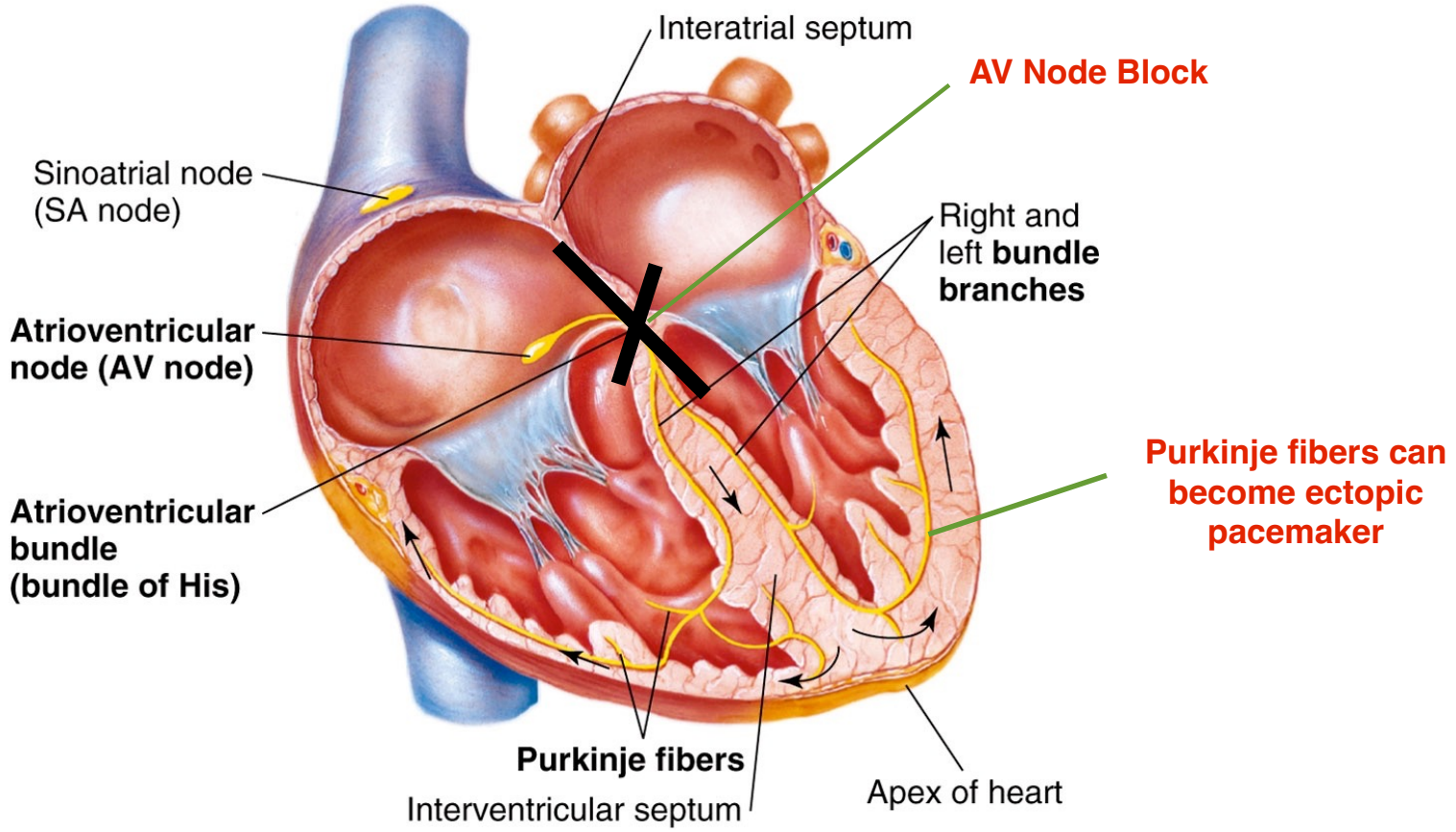
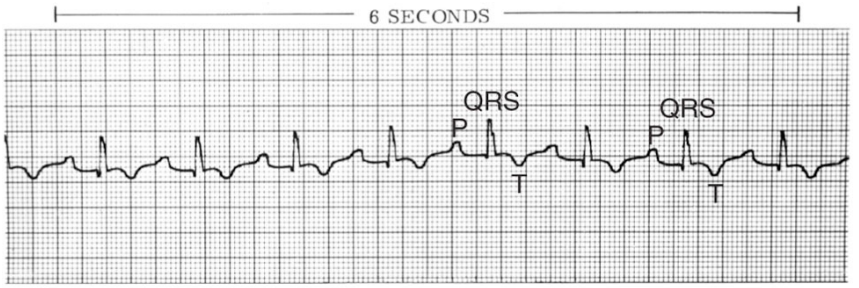


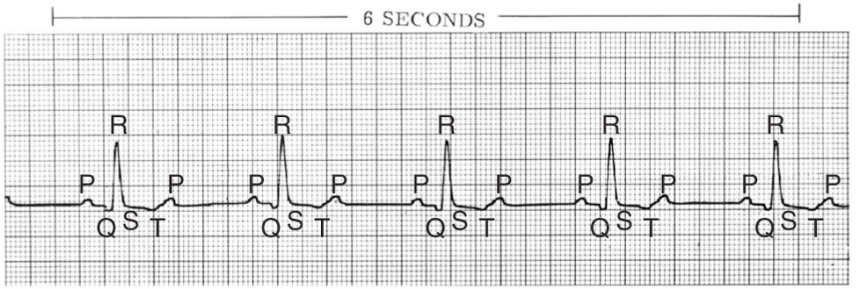
Figure 13.20

P-R interval > 0.2 sec
(but P still drives QRS)



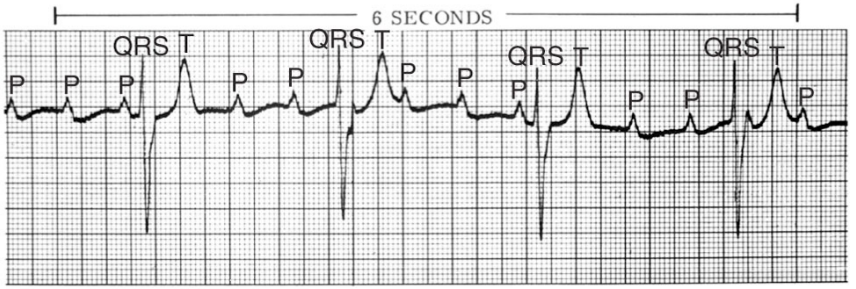
First-degree AV block

P waves without
QRS waves



Second-degree AV block

P waves without QRS;
spontaneous QRS waves
produced by
ectopic pacemaker



Third-degree AV block

Figure 13.35

Pharmacological Regulation of Heart Rate

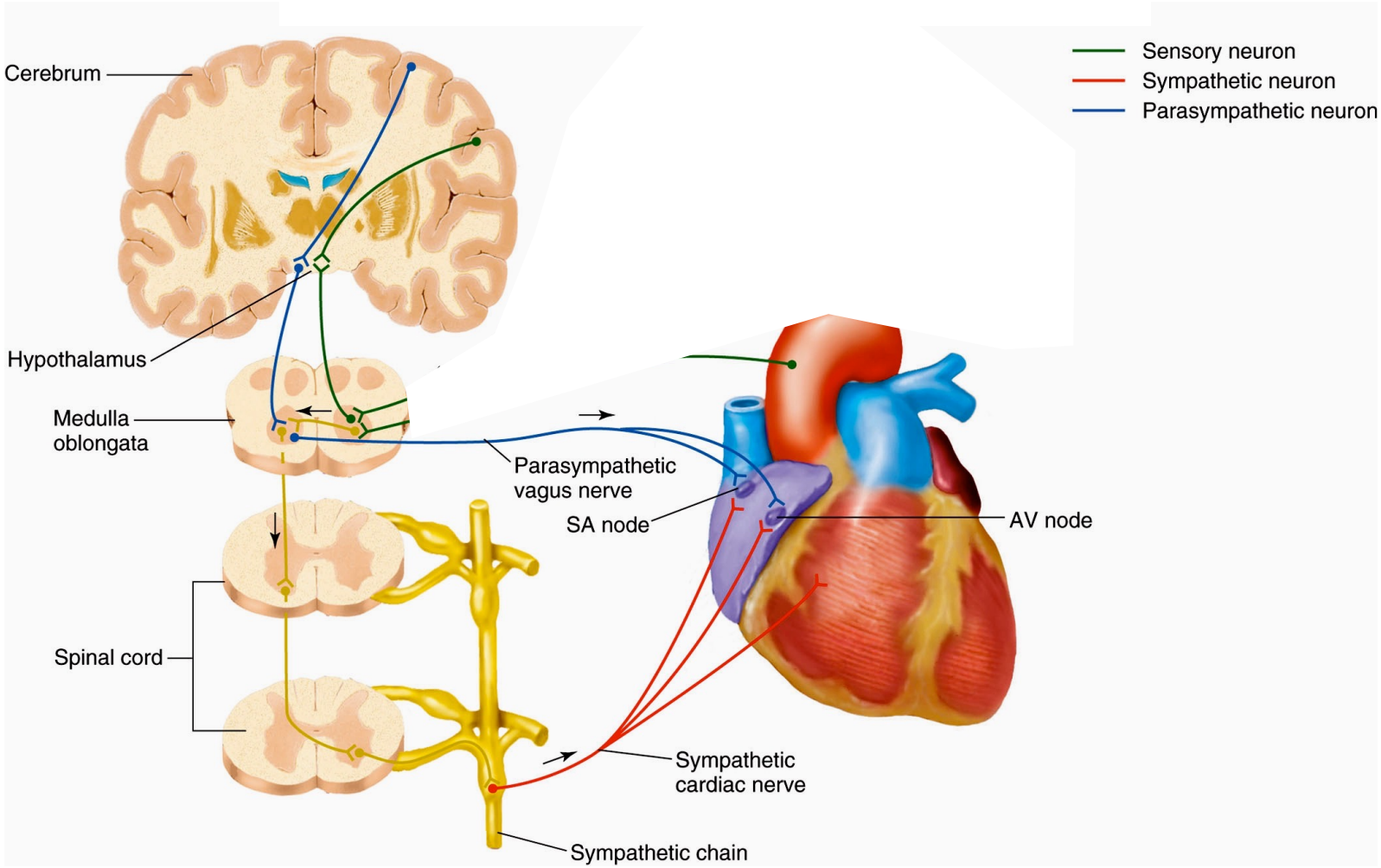
Autonomic Nervous System:

Sympathetic NS raises HR.
Sympathetic chain ganglia -> norepinephrine release onto pacemaker cells -> beta-adrenergic receptors -> increased cAMP -> open HCN channels, open Ca^{++} channels.

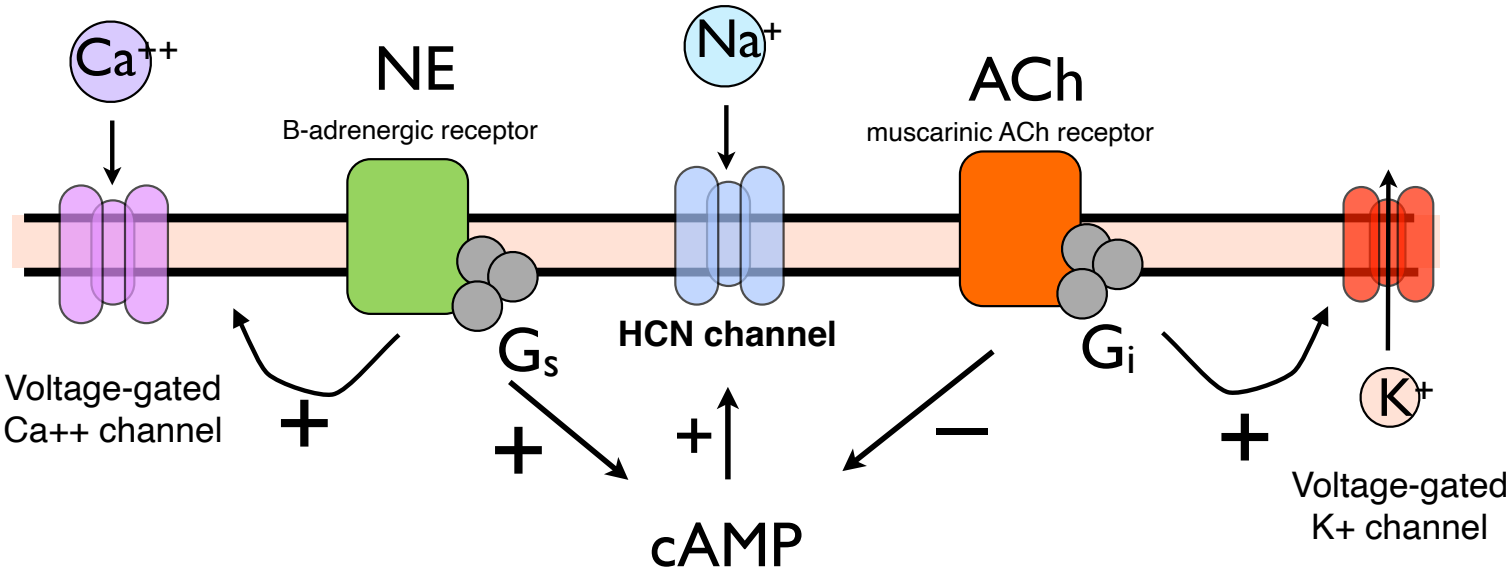
Parasympathetic NS slows HR.
Vagus nerve -> acetylcholine release onto pacemaker cells -> muscarinic receptors -> decreased cAMP -> close HCN channels, open K+ channels

Drugs to treat Elevated Heart Rate (tachycardia)
Lidocaine - blocks voltage-gated Na^{+} channels
Propranolol - “beta blocker”: blocks norepi from binding beta-adrenergic receptors
Verapamil - blocks the voltage-gated Ca^{++} channels

Autonomic Nervous System & Heart Rate



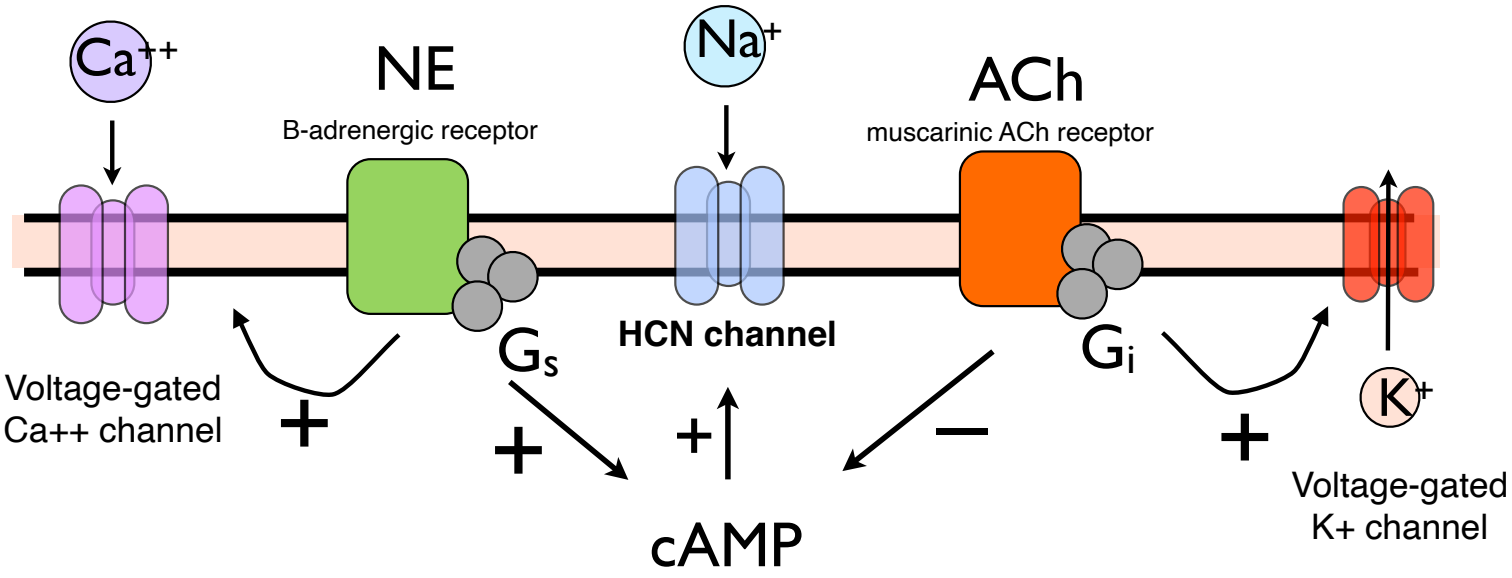
Autonomic Nervous System & Heart Rate



Hyperpolarization-activated **C**yclic-nucleotide **N**a+ channels

What would the effects of NE and ACh agonists & antagonists be on heart rate?

Autonomic Nervous System & Heart Rate



Hyperpolarization-activated **C**yclic-nucleotide **N**a+ channels

What would the effects of NE and ACh agonists & antagonists be on heart rate?

Effect of Norepinephrine on Pacemaker Cells

HCN channels open faster & Ca++ channels open faster -> faster beat

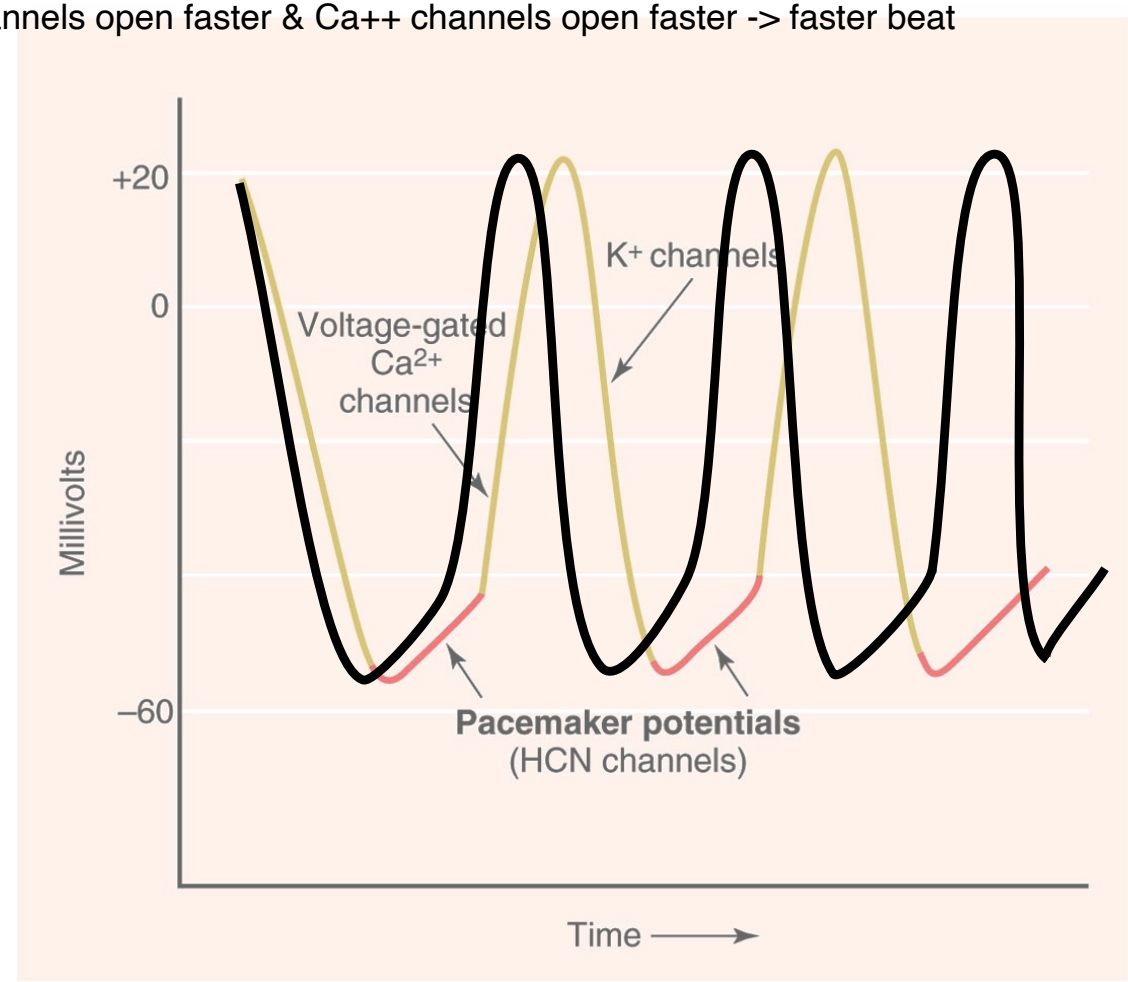


Figure 13.18

Effect of Acetylcholine on Pacemaker Cells

HCN channels open slower, more K+ channels open -> slower beat

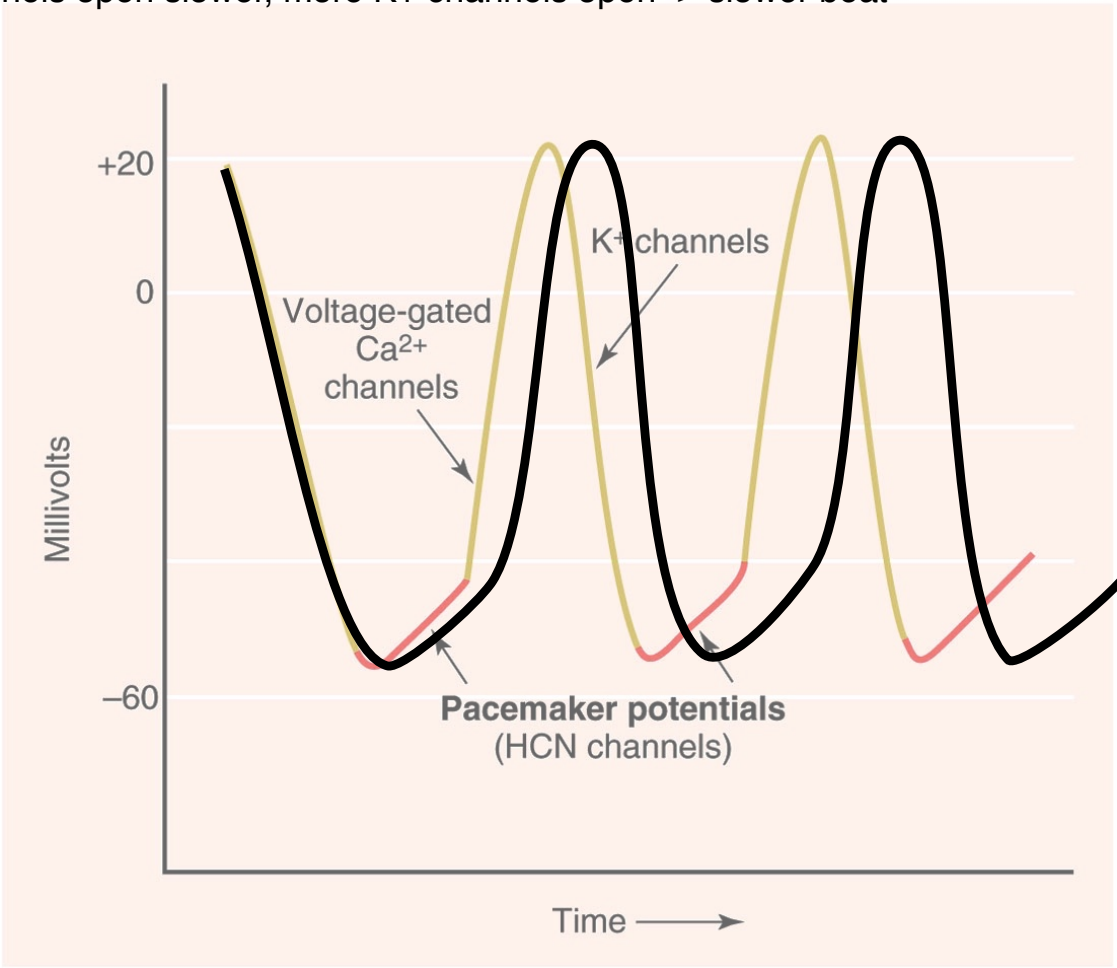
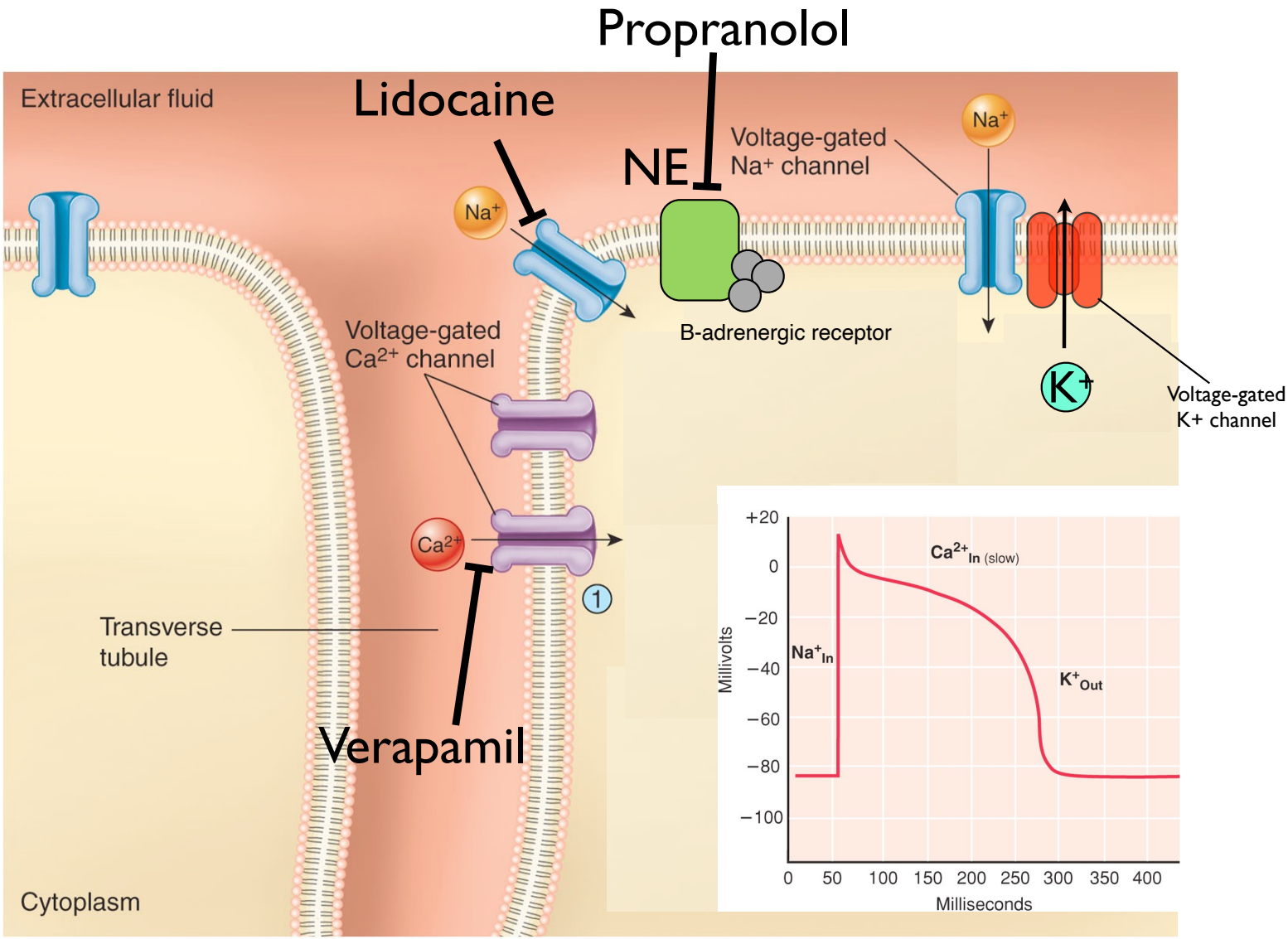


Figure 13.18


Propranolol
Extracellular fluid
Lidocaine
NE
Voltage-gated
Na+ channel
Na+
Na+
B-adrenergic receptor
Voltage-gated
Ca2+ channel
K+
Voltage-gated
K+ channel
Ca2+
1
Transverse
tubule
Verapamil
Cytoplasm
+20
0
−20
−40
−60
−80
−100
Millivolts
Ca2+In (slow)
Na+In
K+Out
0
50
100
150
200
250
300
350
400
Milliseconds

Blood Vessels

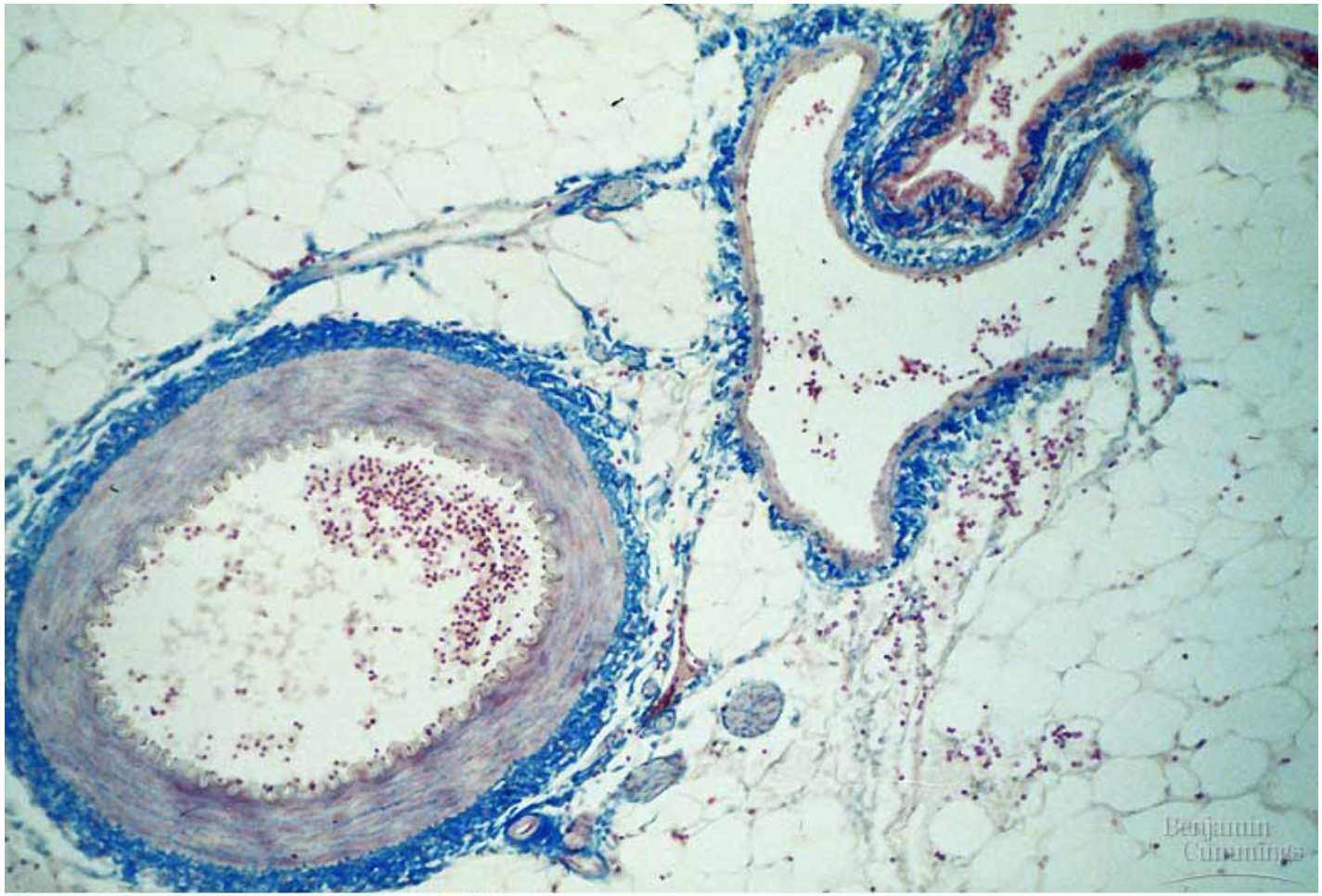
Arteries (arterial blood)
vessels carrying blood from heart towards the capillaries. Thick muscular walls to keep pressure up. High in oxygen (except for pulmonary arteries).

Veins (venous blood)
vessels carrying blood from capillaries back to heart. Very thin flabby walls with low pressure, but have one-way valves to prevent blood from backing up. Low in oxygen (except for pulmonary veins).

Capillaries
very small vessels (1 blood cell wide, with endothelium 1 cell thick) that perfuse all the tissues. Most capillaries are **fenestrated**, or have channels, or have discontinuous endothelium so that dissolved molecules can easily pass from blood to interstital fluid & tissues. (Except for **blood brain barrier** formed by tight junctions of the capillary endothelium in brain.)

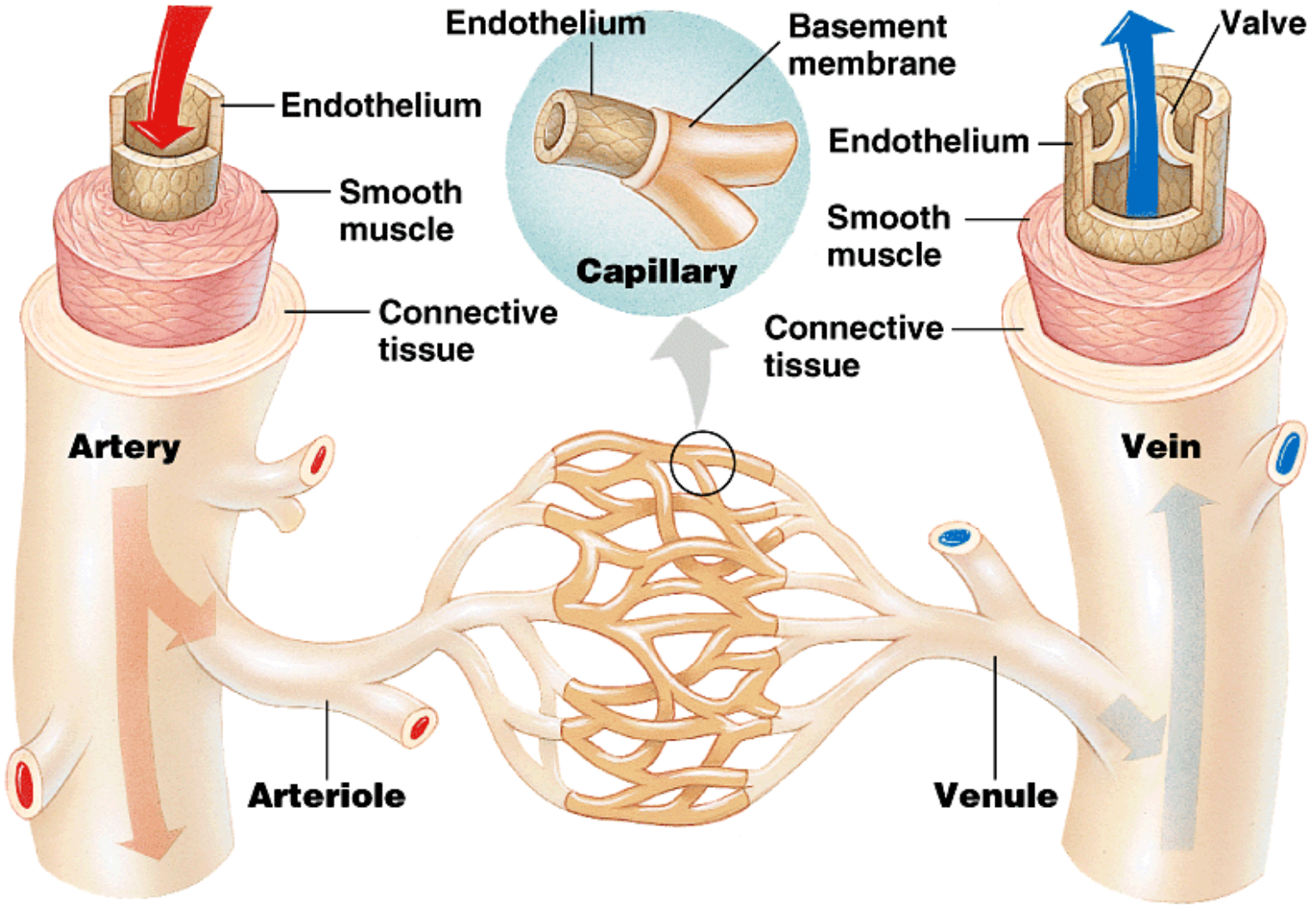
Precapillary Sphincters can regulate blood flow to capillaries or bypass thru shunt.

Vein with thin floppy wall



Artery with thick, muscular elastic wall

Figure 42.8 The structure of blood vessels



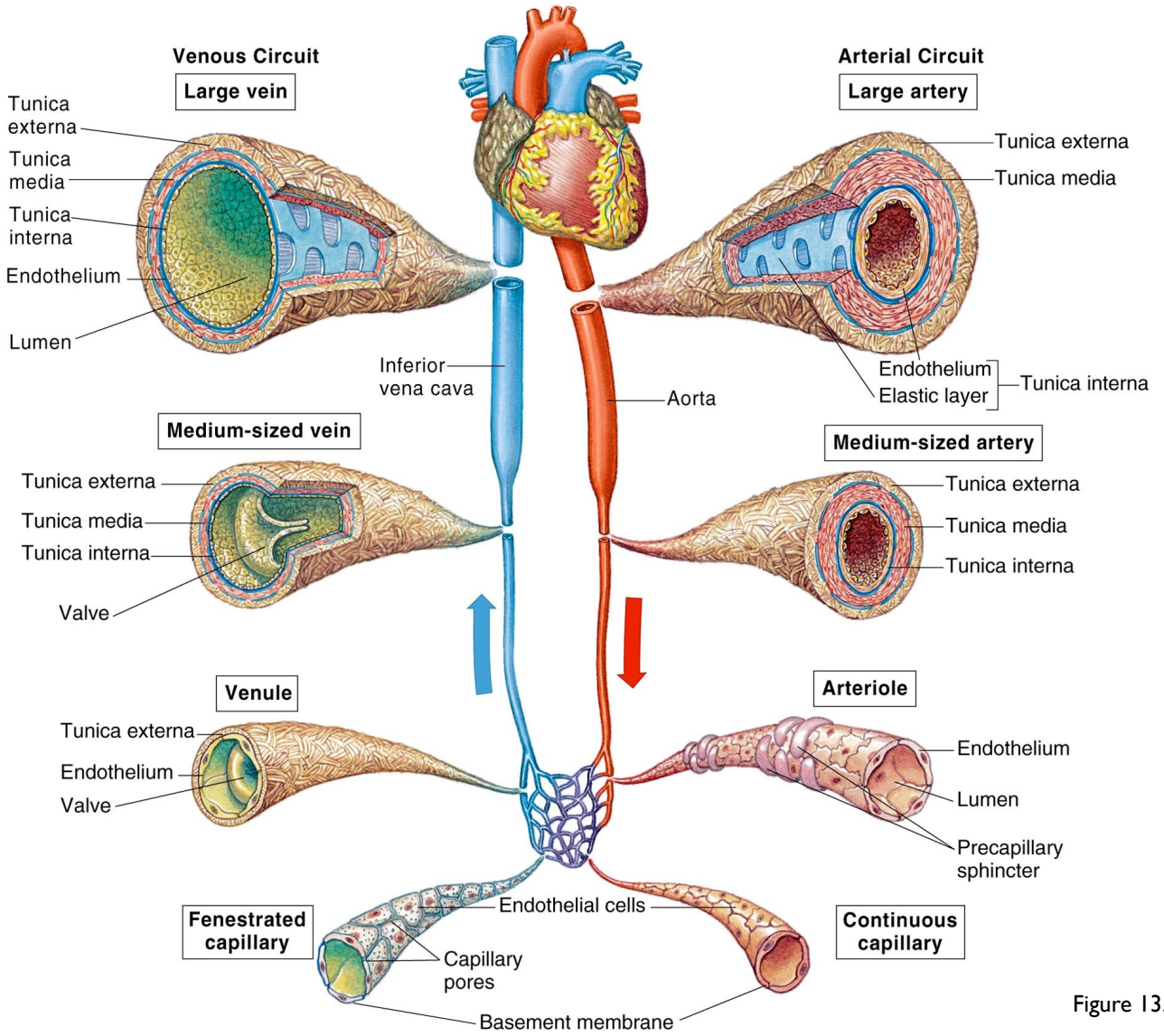

Venous Circuit
Large vein
Tunica externa
Tunica media
Tunica interna
Endothelium
Lumen
Inferior vena cava
Aorta
Arterial Circuit
Large artery
Tunica externa
Tunica media
Endothelium
Elastic layer
Tunica interna
Medium-sized vein
Tunica externa
Tunica media
Tunica interna
Valve
Medium-sized artery
Tunica externa
Tunica media
Tunica interna
Venule
Tunica externa
Endothelium
Valve
Arteriole
Endothelium
Lumen
Precapillary sphincter
Fenestrated capillary
Endothelial cells
Capillary pores
Basement membrane
Continuous capillary

Figure 13.26

Veins: one-way valves, blood moved by skeletal muscle contraction

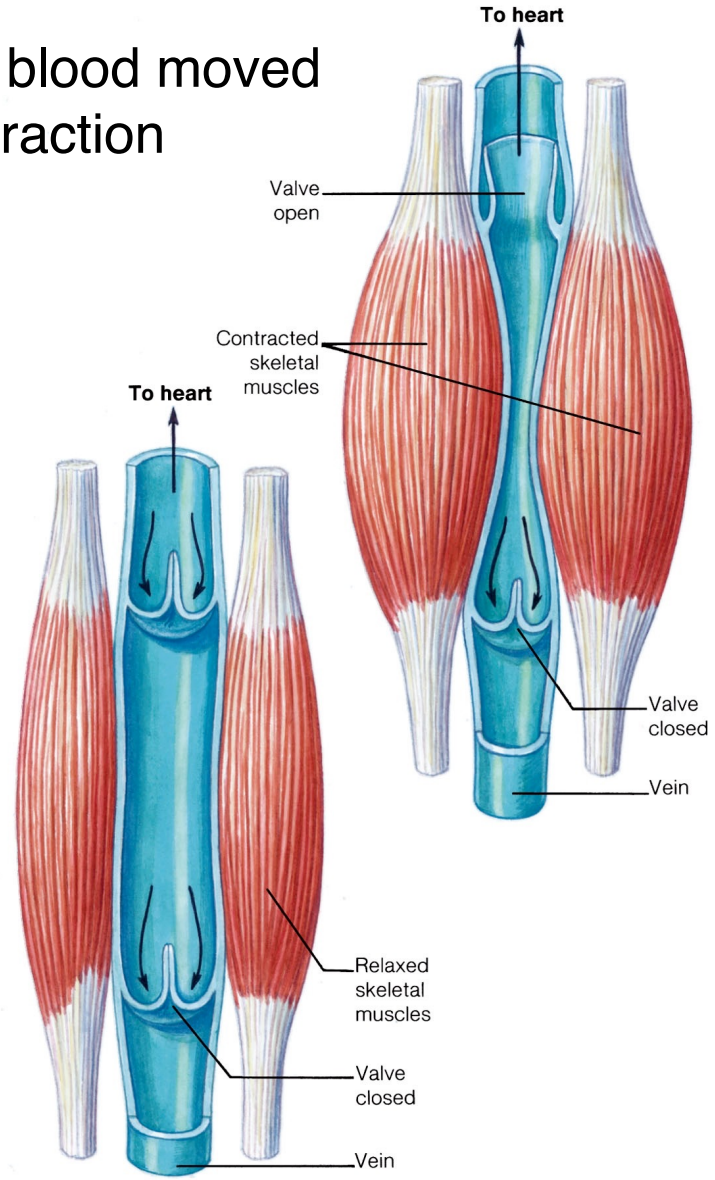
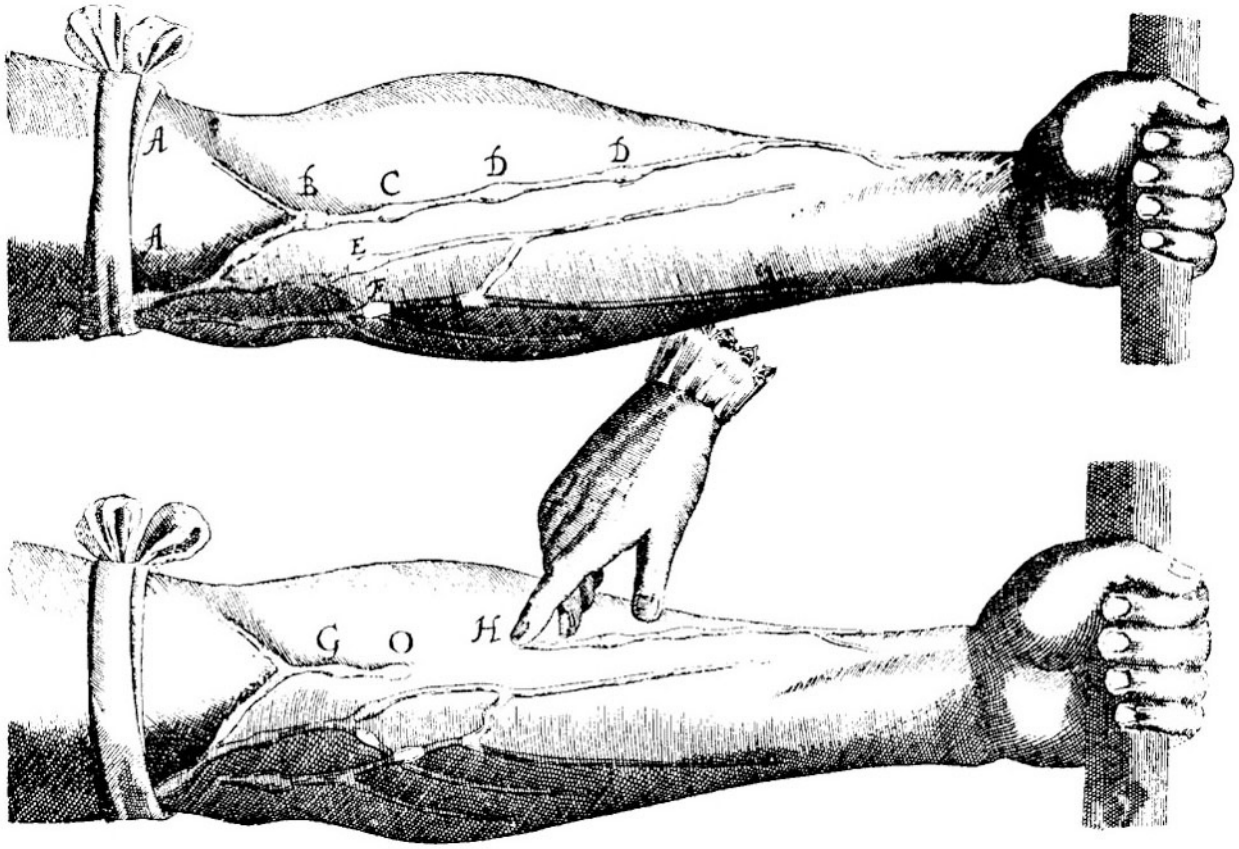


Figure 13.29

Figure 13.30



After William Harvey, On the Motion of the Heart and Blood in Animals, 1628

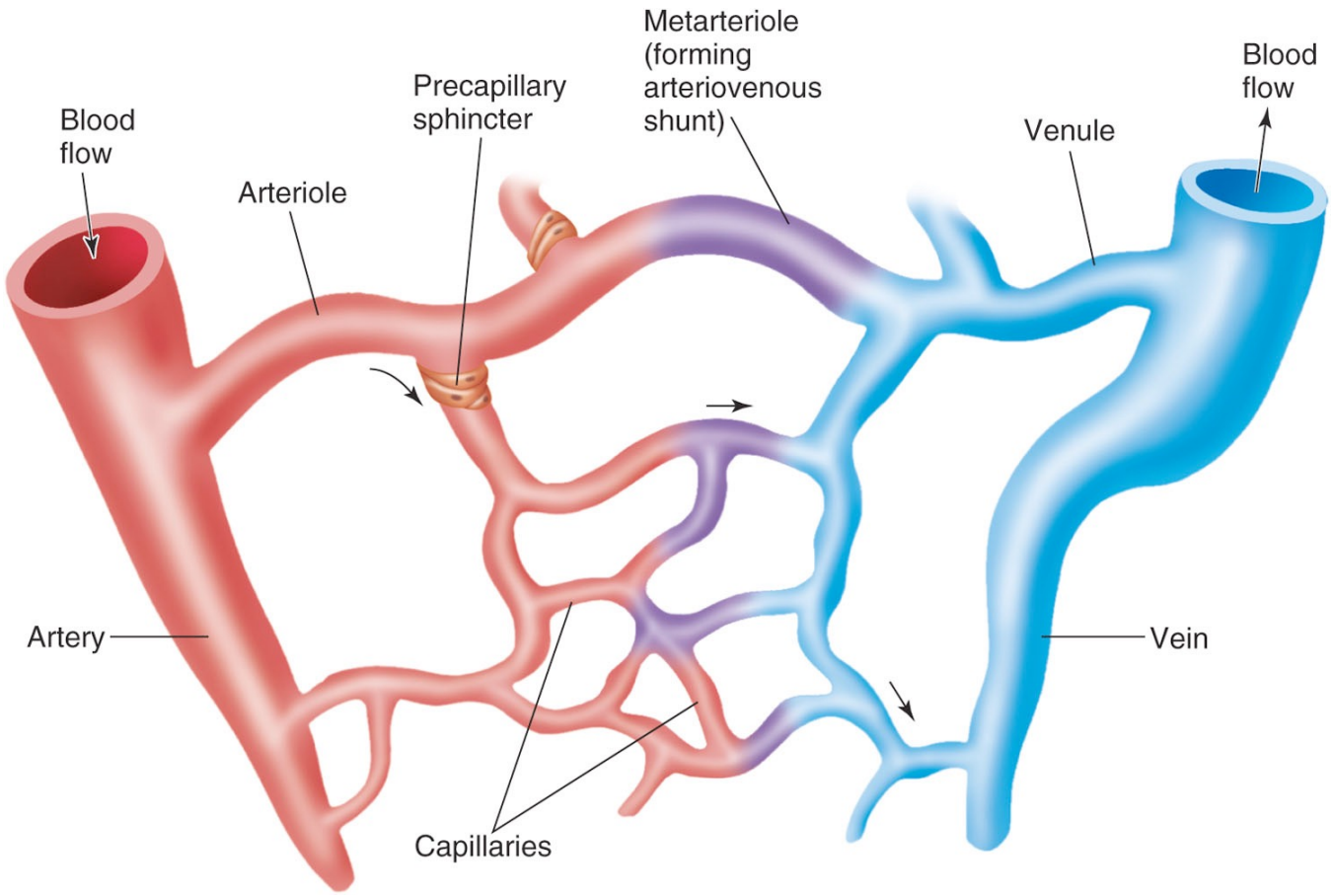

Blood flow
Arteriole
Precapillary sphincter
Metarteriole (forming arteriovenous shunt)
Venule
Blood flow
Artery
Vein
Capillaries

Figure 13.27

Figure 42.12 Blood flow in capillary beds

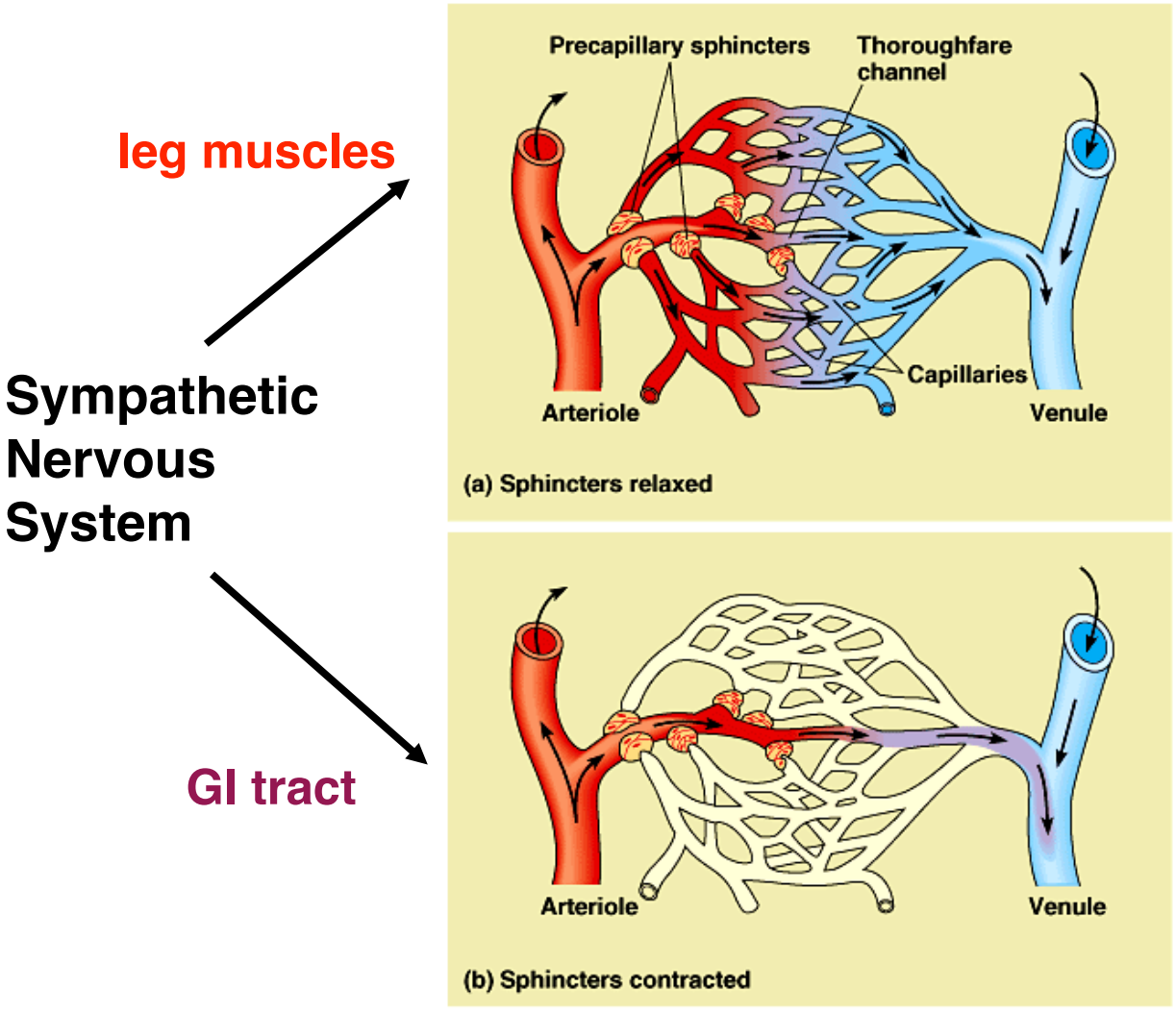
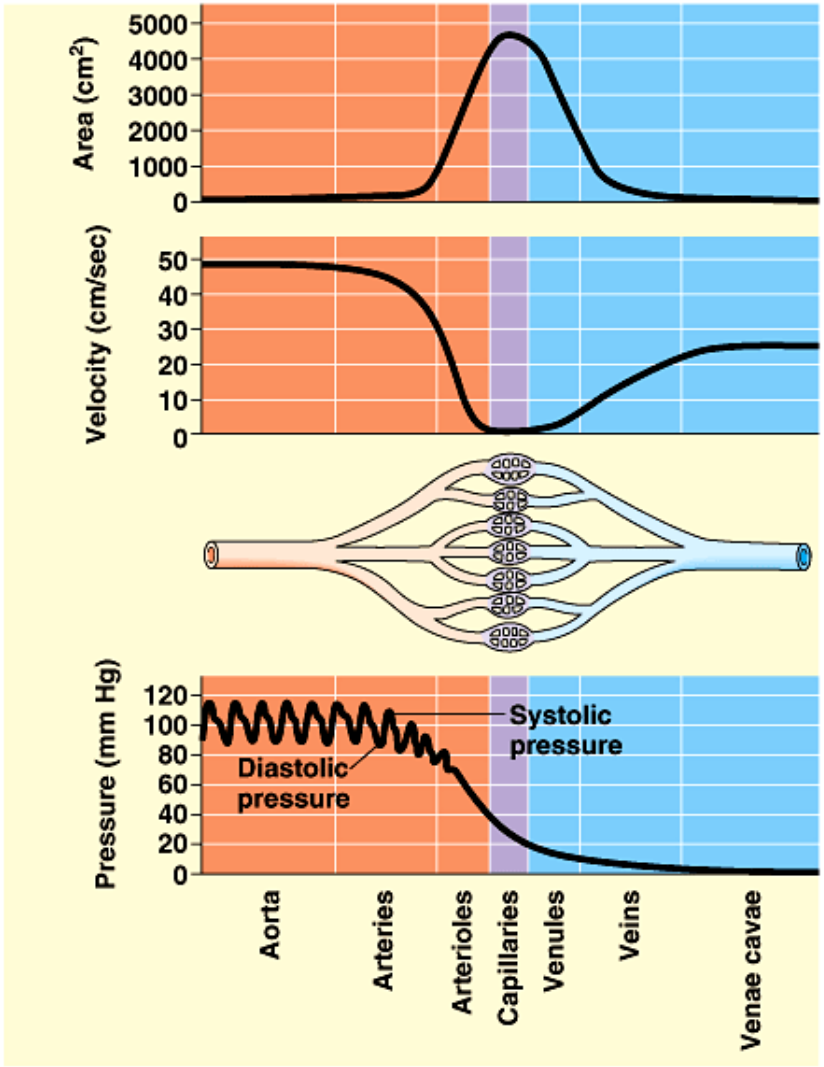


Table 13.8 | Characteristics of the Vascular Supply to the Mesenteries in a Dog

Kind of Vessels	Diameter (mm)	Number	Total Cross-Sectional Area (cm^2)	Length (cm)	Total Volume (cm^3)
Aorta	10	1	0.8	40	30
Large arteries	3	40	3.0	20	60
Main artery branches	1	600	5.0	10	50
Terminal branches	.06	1,800	5.0	1	25
Arterioles	0.02	40,000,000	125	0.2	25
Capillaries	0.008	1,200,000,000	600	0.1	60
Venules	0.03	80,000,000	570	0.2	110
Terminal veins	1.5	1,800	30	1	30
Main venous branches	2.4	600	27	10	270
Large veins	6.0	40	11	20	220
Vena cava	12.5	1	1.2	40	50
					930

Note: The pattern of vascular supply is similar in dogs and humans.
Source: Animal Physiology, 4th ed. by Gordon et al., © 1982. Adapted by permission of Prentice-Hall, Inc., Upper Saddle River, NJ.

Figure 42.10 The interrelationship of blood flow velocity, cross-sectional area of blood vessels, and blood pressure



Endothelial cell lining capillary

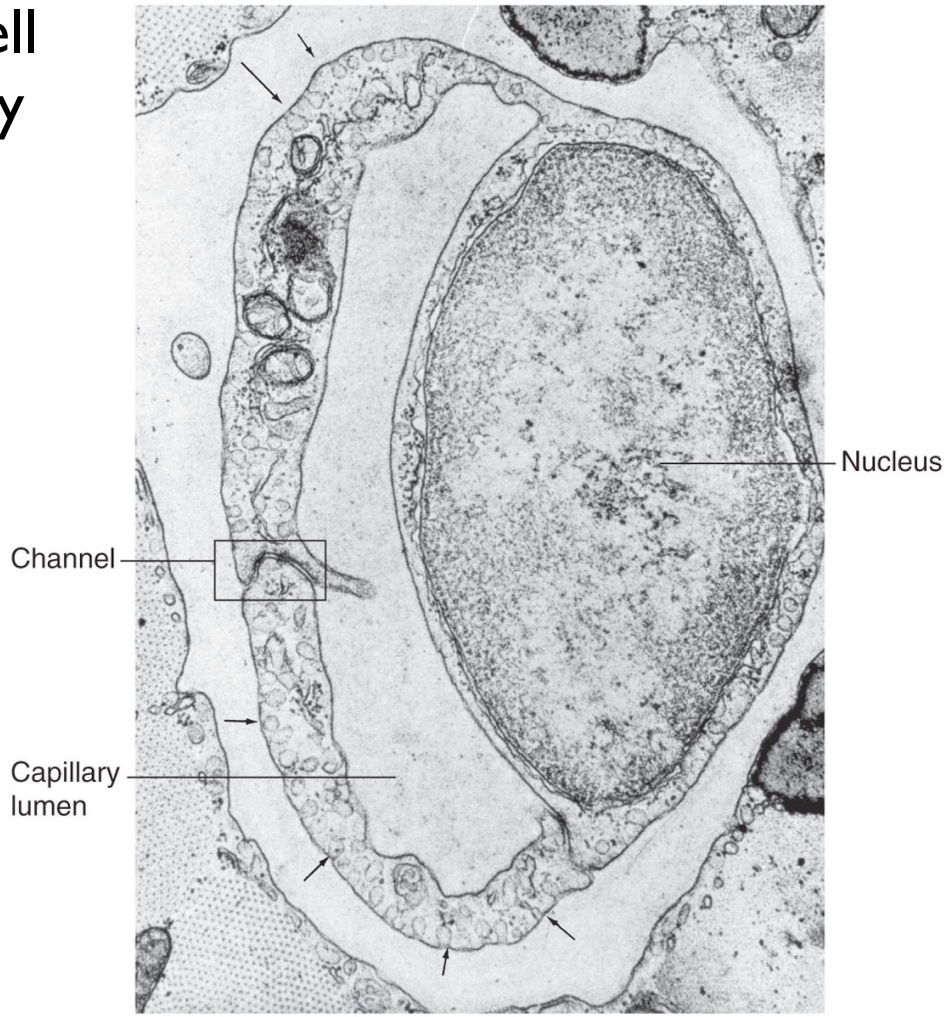
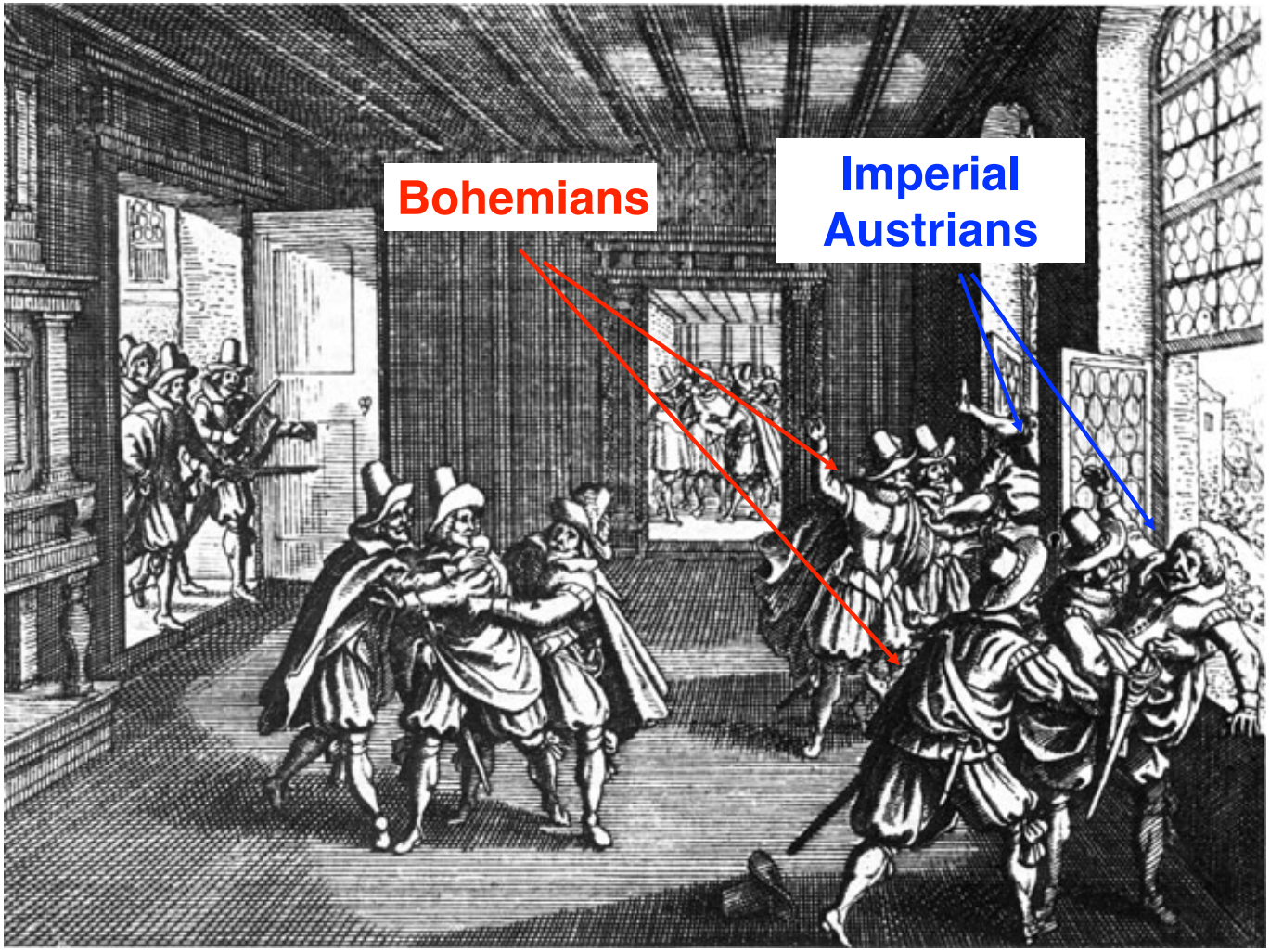
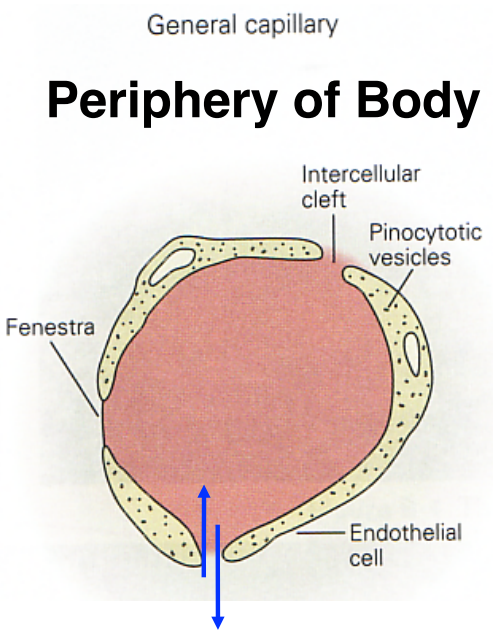


Figure 13.28

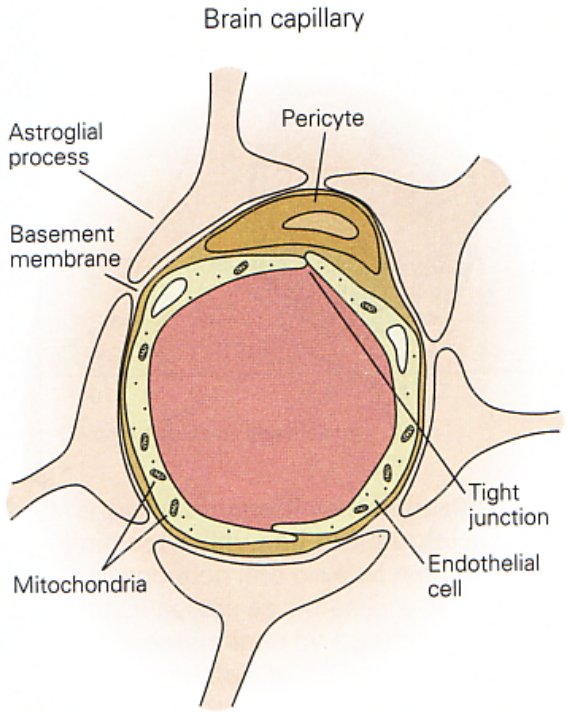
Defenestration of Prague in 1618: started 30-years war



Fenestrated Capillaries vs. Blood Brain Barrier



Periphery of Body



Brain

Only transported or hydrophobic molecules can cross

Composition of Blood

Red Blood Cells

Biconcave discoids. Contain hemoglobin, which binds O_2 and helps transport CO_2. ***Red blood cells not have nuclei, so no DNA! (also no mitochondria)***

White Blood Cells

Immune system cells. Source of DNA for PCR fingerprinting studies using blood.

Platelets

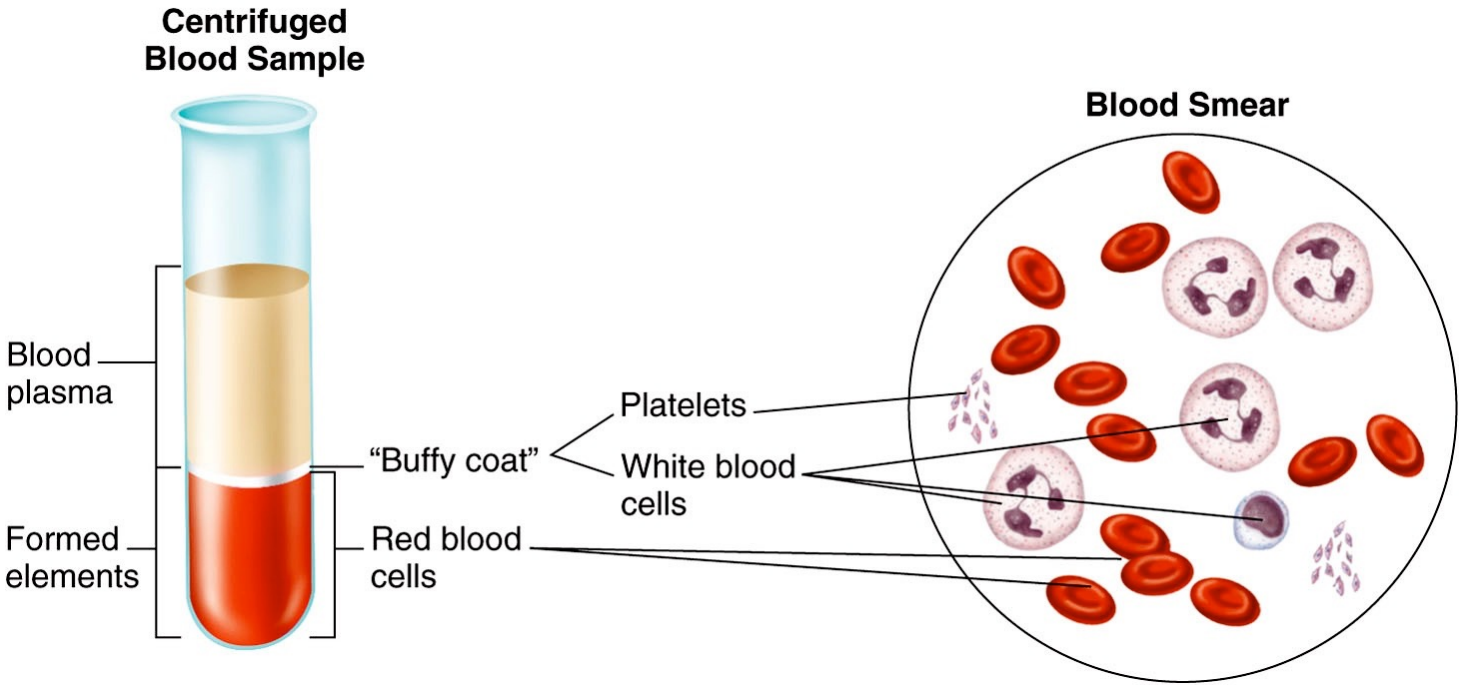
Very small fragments of cells which help in blood clotting.

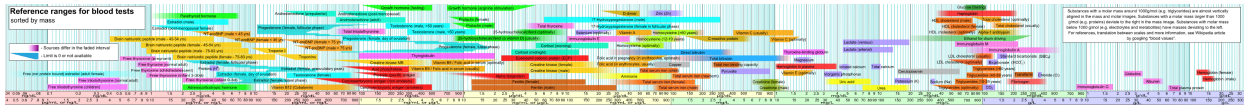
All derived from bone marrow stem cells.

Table 13.2 | Formed Elements of the Blood

Component	Description	Number Present	Function
Erythrocyte (red blood cell)	Biconcave disc without nucleus; contains hemoglobin; survives 100 to 120 days	4,000,000 to 6,000,000 / mm^3	Transports oxygen and carbon dioxide
Leukocytes (white blood cells)		5,000 to 10,000 / mm^3	Aid in defense against infections by microorganisms
Granulocytes	About twice the size of red blood cells; cytoplasmic granules present; survive 12 hours to 3 days		
1. Neutrophil	Nucleus with 2 to 5 lobes; cytoplasmic granules stain slightly pink	54% to 62% of white cells present	Phagocytic
2. Eosinophil	Nucleus bilobed; cytoplasmic granules stain red in eosin stain	1% to 3% of white cells present	Helps to detoxify foreign substances; secretes enzymes that dissolve clots; fights parasitic infections
3. Basophil	Nucleus lobed; cytoplasmic granules stain blue in hematoxylin stain	Less than 1% of white cells present	Releases anticoagulant heparin
Agranulocytes	Cytoplasmic granules not visible; survive 100 to 300 days (some much longer)		
1. Monocyte	2 to 3 times larger than red blood cell; nuclear shape varies from round to lobed	3% to 9% of white cells present	Phagocytic
2. Lymphocyte	Only slightly larger than red blood cell; nucleus nearly fits cell	25% to 33% of white cells present	Provides specific immune response (including antibodies)
Platelet (thrombocyte)	Cytoplasmic fragment; survives 5 to 9 days	130,000 to 400,000 / mm^3	Enables clotting; releases serotonin, which causes vasoconstriction

Figure 13.1


Centrifuged Blood Sample
Blood plasma
Formed elements
"Buffy coat"
Red blood cells
Platelets
White blood cells
Blood Smear


Reference ranges for blood tests
sorted by mass

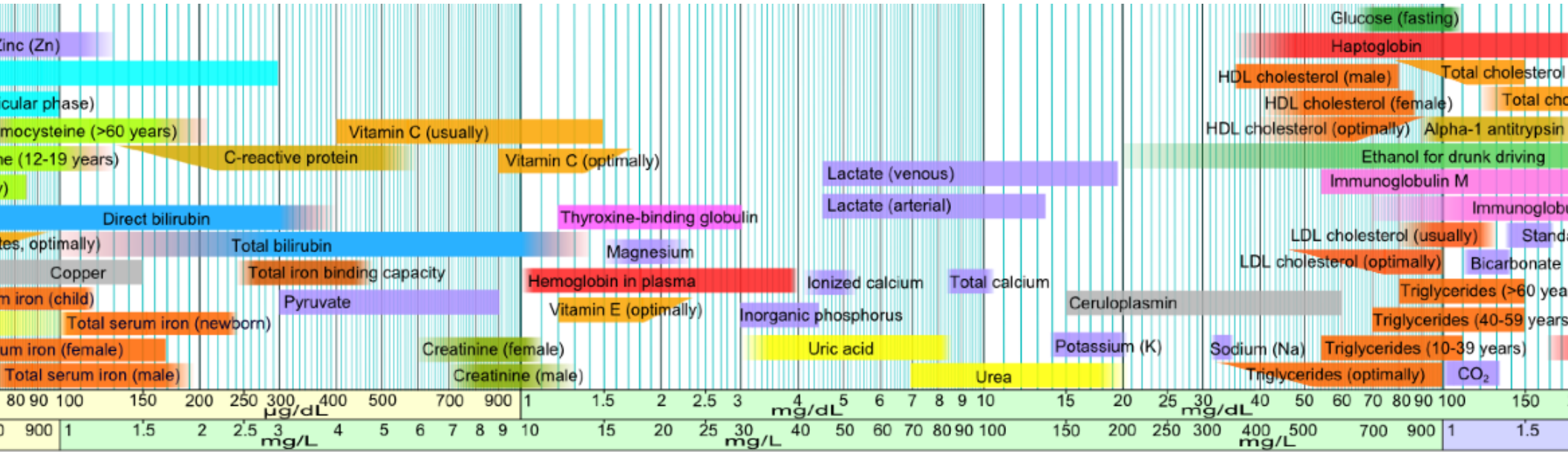

Glucose (fasting)
Haptoglobin
HDL cholesterol (male)
HDL cholesterol (female)
HDL cholesterol (optimally)
Alpha-1 antitrypsin
Ethanol for drunk driving
Immunoglobulin M
Lactate (venous)
Lactate (arterial)
Thyroxine-binding globulin
Vitamin C (usually)
C-reactive protein
Vitamin C (optimally)
Direct bilirubin
Total bilirubin
Magnesium
Copper
Total iron binding capacity
Hemoglobin in plasma
Ionized calcium
Total calcium
Pyruvate
Vitamin E (optimally)
Inorganic phosphorus
Ceruloplasmin
Total serum iron (newborn)
Creatinine (female)
Uric acid
Potassium (K)
Sodium (Na)
Total serum iron (male)
Creatinine (male)
Urea
Triglycerides (optimally)
LDL cholesterol (usually)
LDL cholesterol (optimally)
Bicarbonate
Triglycerides (>60 yea
Triglycerides (40-59 years
Triglycerides (10-39 years)
CO_2
μg/dL
mg/dL
mg/dL
mg/L
mg/L
mg/L

Table 13.1 | Representative Normal Plasma Values

Measurement	Normal Range
Blood volume	80–85 ml/kg body weight
Blood osmolality	285–295 mOsm
Blood pH	7.38–7.44
Enzymes	
Creatine phosphokinase (CPK)	Female: 10–79 U/L Male: 17–148 U/L
Lactic dehydrogenase (LDH)	45–90 U/L
Phosphatase (acid)	Female: 0.01–0.56 Sigma U/ml Male: 0.13–0.63 Sigma U/ml
Hematology Values	
Hematocrit	Female: 36%–46% Male: 41%–53%
Hemoglobin	Female: 12–16 g/100 ml Male: 13.5–17.5 g/100 ml
Red blood cell count	4.50–5.90 million/mm^3
White blood cell count	4,500–11,000/mm^3
Hormones	
Testosterone	Male: 270–1,070 ng/100 ml Female: 6–86 ng/100 ml
Adrenocorticotrophic hormone (ACTH)	6–76 pg/ml
Growth hormone	Children: over 10 ng/ml Adult male: below 5 ng/ml
Insulin	2–20 μU/ml (fasting)

http://en.wikipedia.org/wiki/Reference_ranges_for_blood_tests

Table 13.1

Constituents of Blood

Nutrients:
- O_2
- Glucose
- amino acids
- cholesterol
- vitamins
- triglycerides

Waste products:
- CO_2
- bilirubin
- urea

Ions:
- Na^+
- K^+
- Cl^-
- Ca^{++}
- Mg^{++}
- PO_3^-

Buffers:
- HCO_3^-

Red Blood Cells

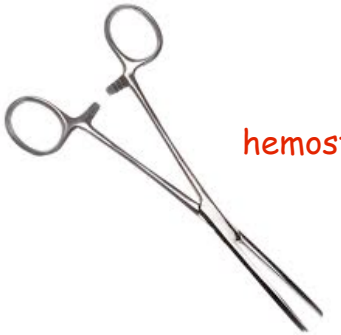
Immune Cells and Factors

Hormones & Binding factors

Clotting Factors and Platelets

Disease Diagnostics:
- Liver markers
- cardiac markers
- tumor markers

Blood Clotting (hemostasis)



Vasoconstriction, formation of platelet plug, fibrin web.

Intact blood vessel: Endothelial cells inhibit platelet aggregation by
1) physically separating platelets from collagen
2) secreting prostacyclin & nitric oxide (NO), & cause **vasodilation**
3) expressing CD39 enzyme which breaks down ADP in the blood

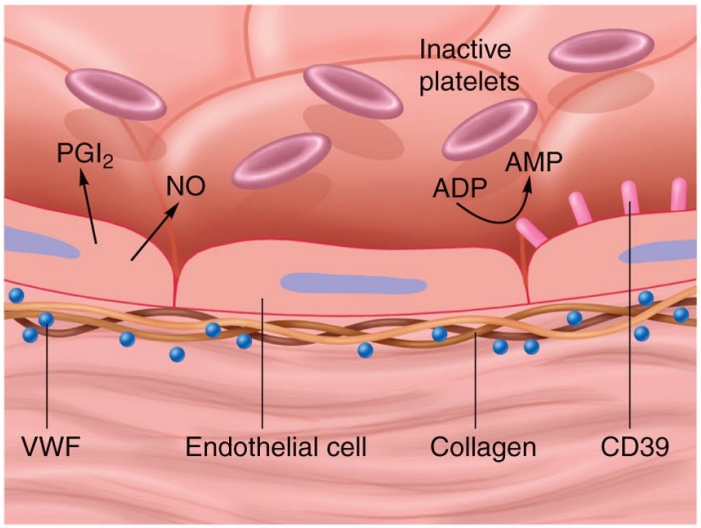
Damaged blood vessel:
1) Platelets bind to collagen and **von Willbrand's factor** (protein produced by endothelial cells that binds platelets and collagen together)

2) Platelets release secretory granules (platelet release reaction):
ADP & thromboxane A -> recruit more platelets to plug
serotonin causes **vasoconstriction** (aspirin inhibits prostaglandin production)

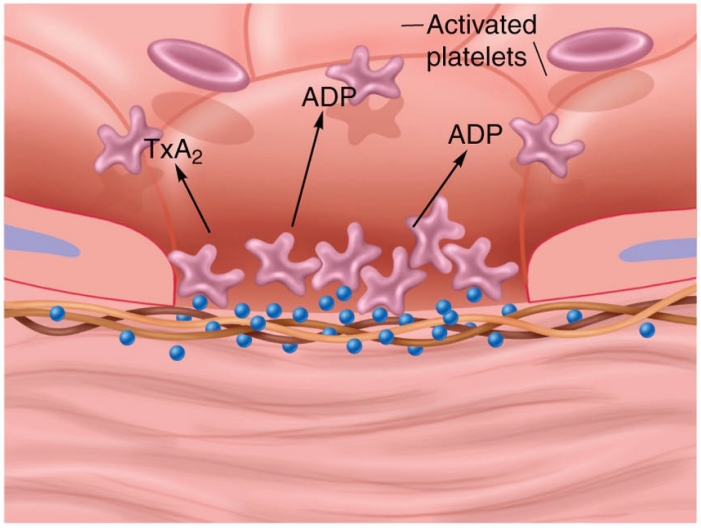
3) Platelets activate **plasma clotting factors**, converting soluble **fibrinogen** -> insoluble **fibrin** -> platelet plug.

hemo- related to blood
hemostasis- preventing blood loss (i.e. stop bleeding)
hemorrhage- bleeding

vasodilation- opening blood vessels wider
vasoconstriction - making blood vessels narrower



(a)



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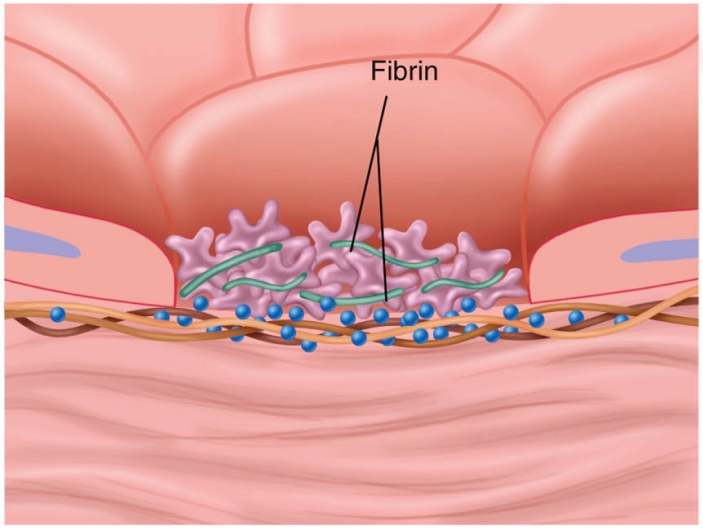
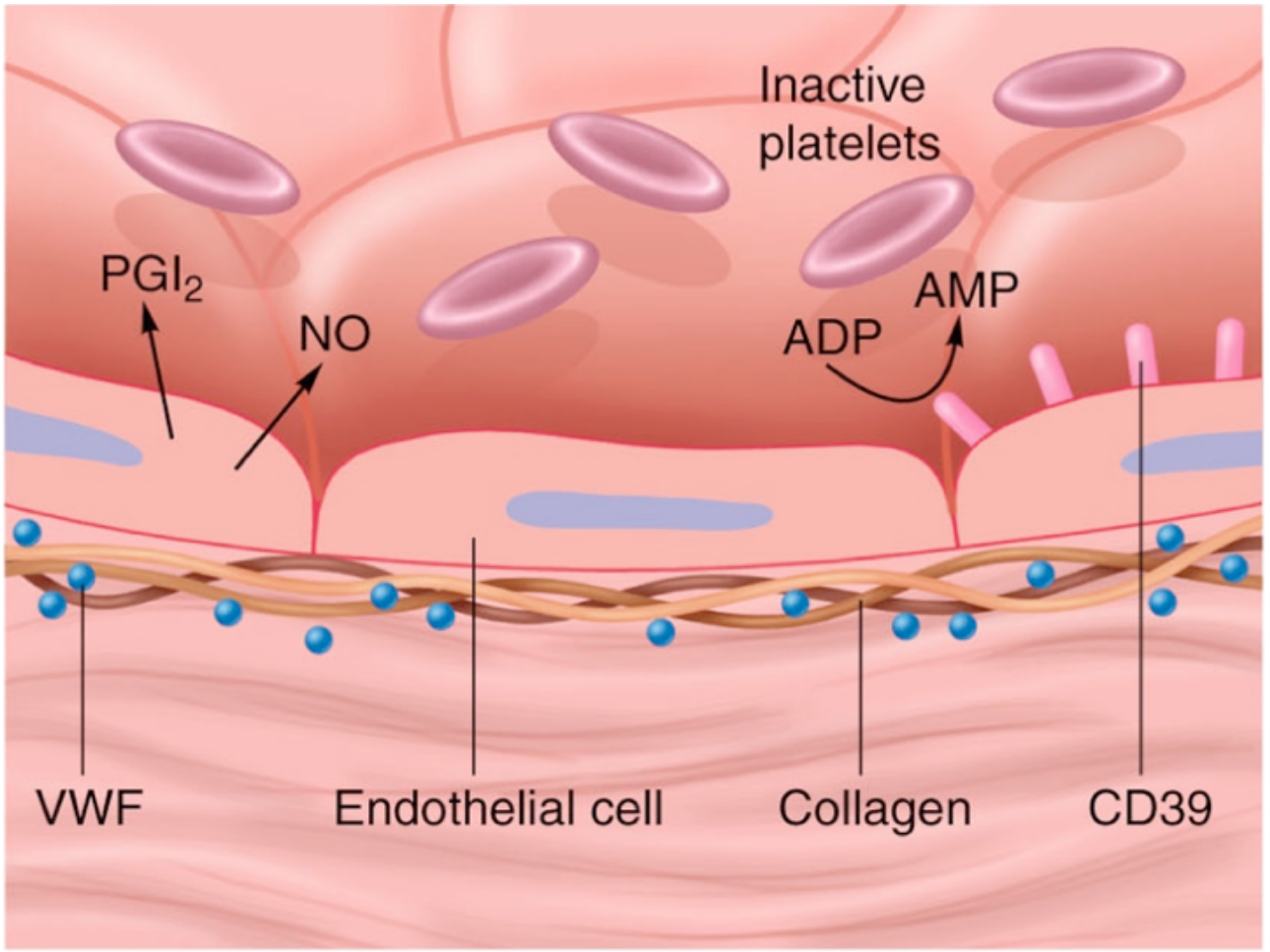


(c)

Figure 13.7

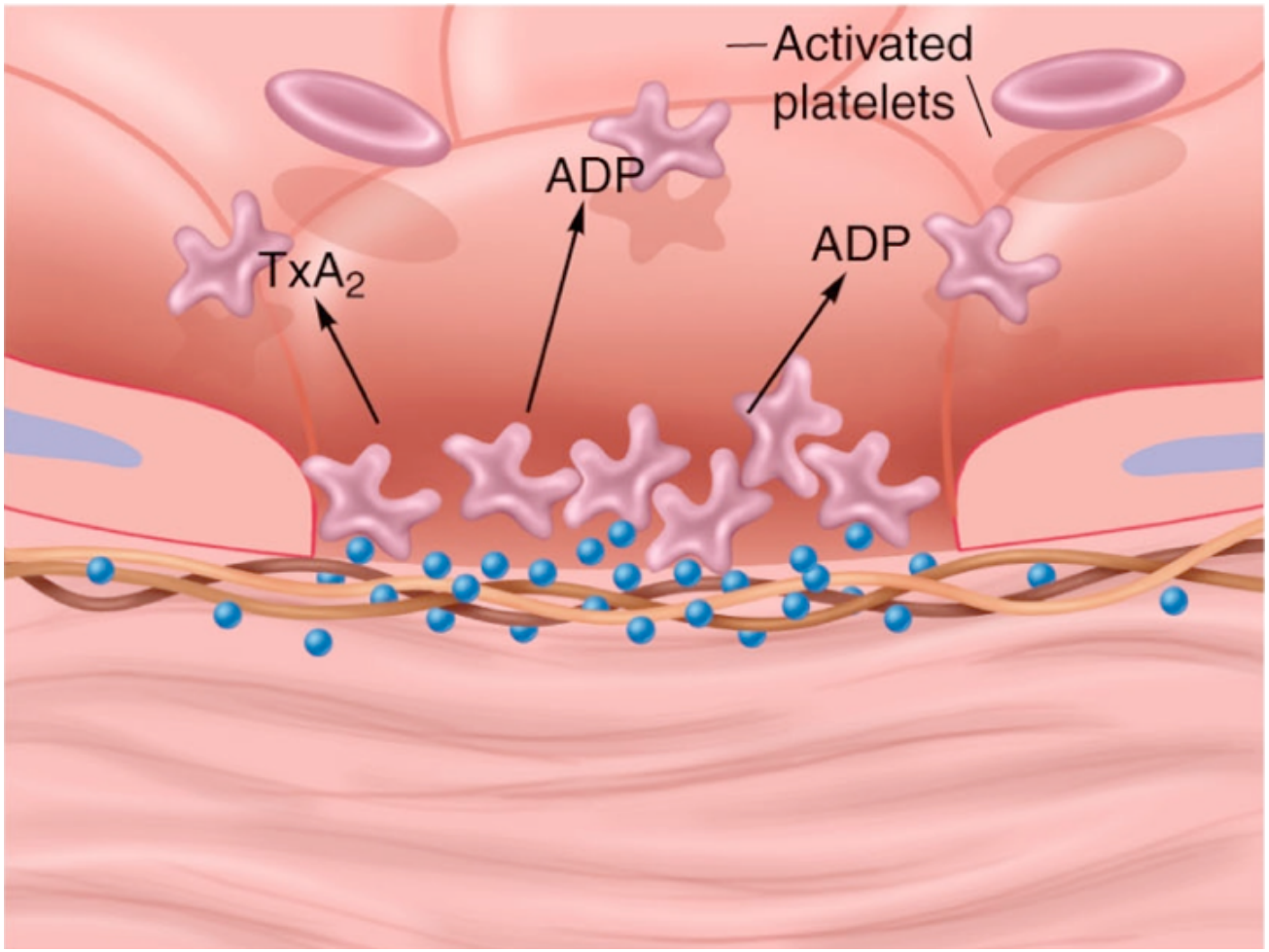
Intact Blood Vessel:

Prostaglandin & NO keep vessel dilated; ADP levels low, so platelets inactive



Damaged Blood Vessel:

Prostaglandin TxA2, high levels of ADP activate platelets.
Activated platelets bind to collagen and von Willebrand's factor



Clot Formation:

Platelet plug forms; activated plasma clotting factors causes fibrin formation to reinforce platelet plug

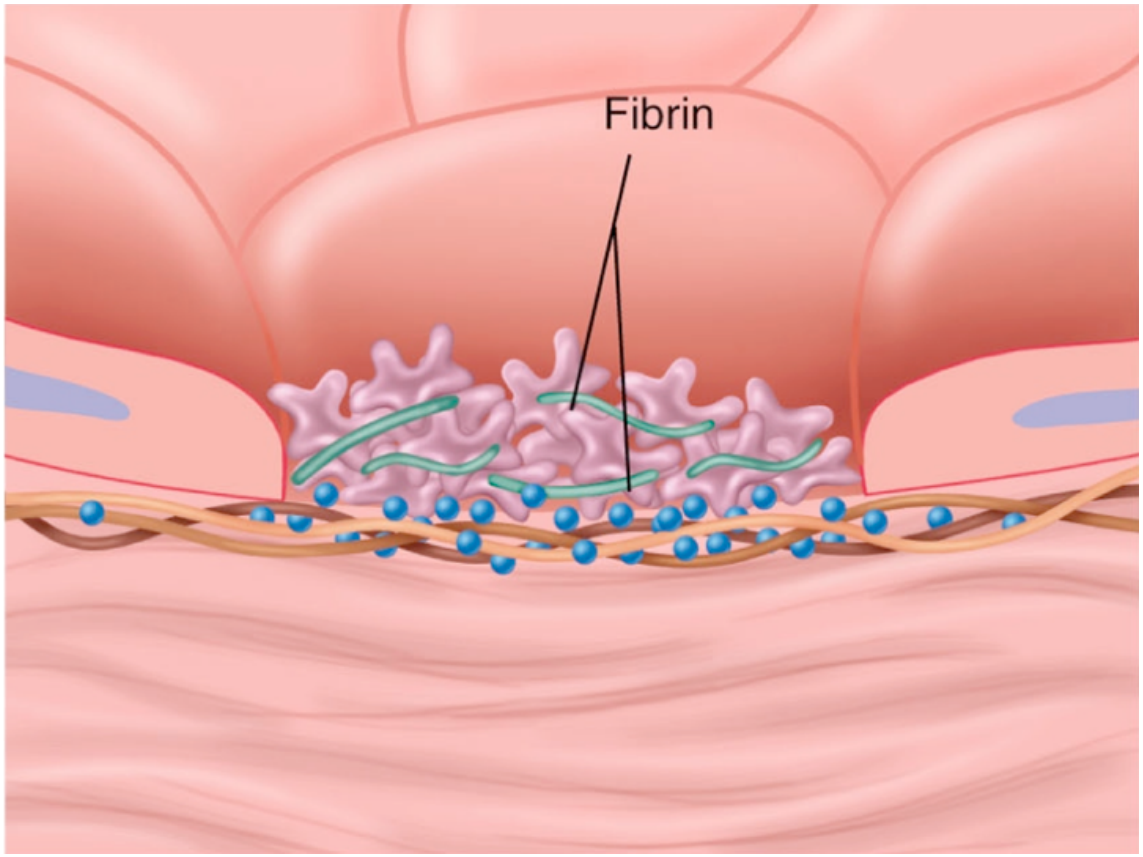
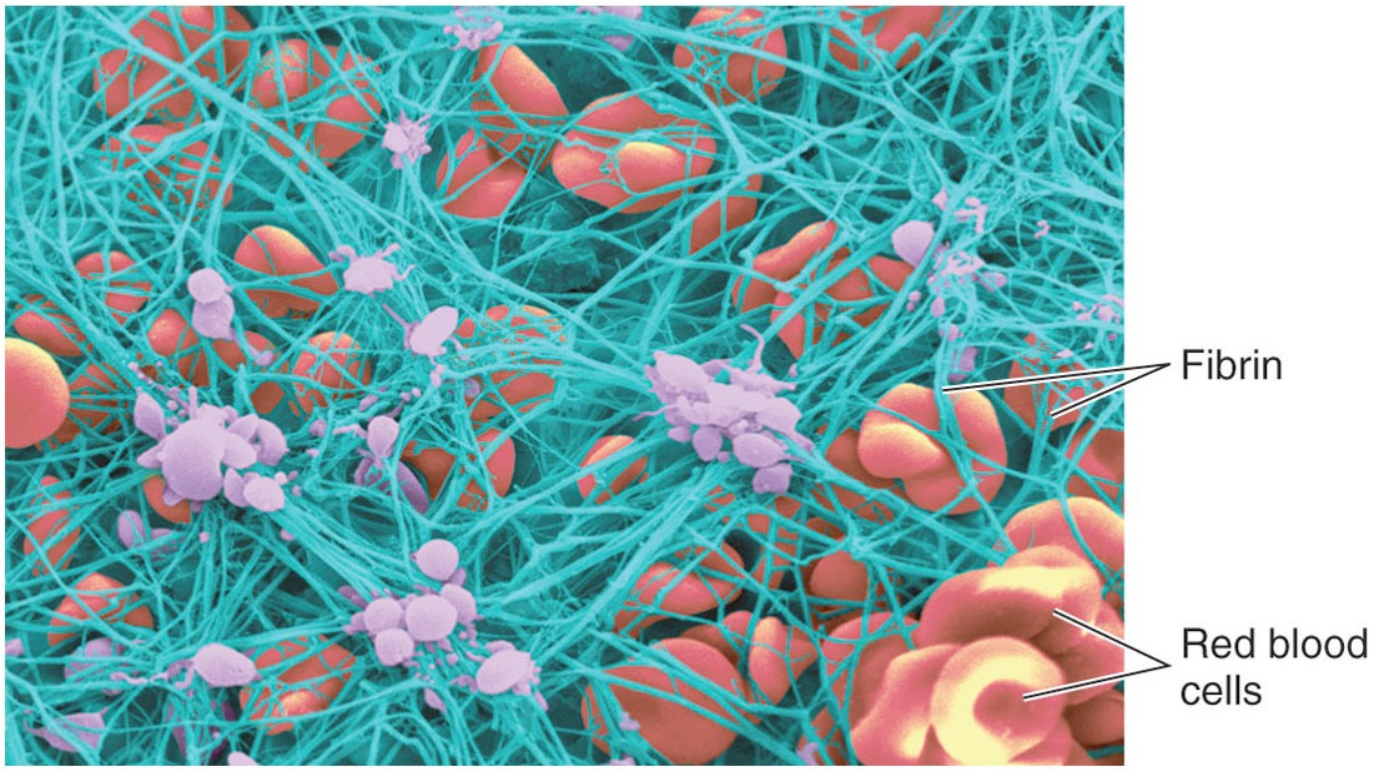


Figure 13.8



From Nature Volume 413, Issue 6855, 4 October 2001, cover. Photo by Dr. John W. Weisel, University of Pennsylvania

Clotting Factors & Fibrin Formation

Intrinsic Pathway: Blood will clot on its own, e.g. in a test tube

Extrinsic Pathway: Damaged tissue releases **tissue factor** that accelerates clotting

Key events of clotting:

Prothrombin converted into **thrombin**, an active enzyme (**thrombosis = clotting)**

Thrombin converts **fibrinogen** to **fibrin**, an insoluble fibrous molecule.

Vitamin K (*Koagulationsvitamin*) converts glutamate residues of clotting factors into gamma-carboxyglutamate, which increases binding of Ca++ to clotting factors. Provided by gut bacteria. Vitamin K deficiency or blockade by drugs leads to decreased clotting ability.

Clot Dissolution:
Factor XII activates Kallikrein (enzyme).
Kallikrein converts plasminogen into plasmin (enzyme).
Plasmin digests fibrin to dissolve clot.
Tissue plasminogen activator (TPA) & streptokinase are synthetic enzymes administered after stroke or cardiac **thrombosis** (vessel blocked by blood clot)

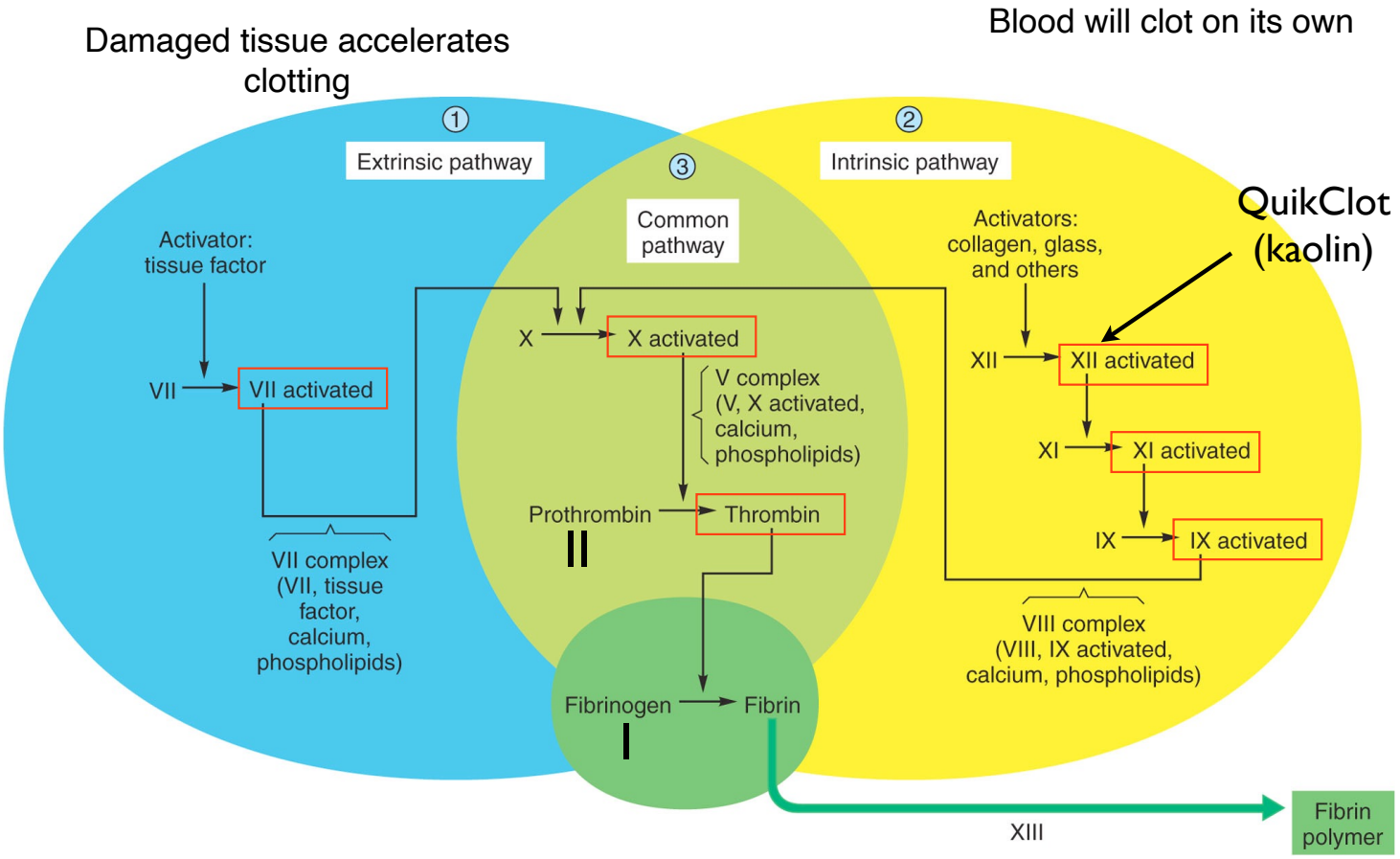
Table 13.4

Table 13.4 | The Plasma Clotting Factors

Factor	Name	Function	Pathway
I	Fibrinogen	Converted to fibrin	Common
II	Prothrombin	Converted to thrombin (enzyme)	Common
III	Tissue thromboplastin	Cofactor	Extrinsic
IV	Calcium ions (Ca^{2+})	Cofactor	all
V	Proaccelerin	Cofactor	Common
VII*	Proconvertin	Enzyme	Extrinsic
VIII	Antihemophilic factor	Cofactor	Intrinsic
IX	Plasma thromboplastin component; Christmas factor	Enzyme	Intrinsic
X	Stuart-Prower factor	Enzyme	Common
XI	Plasma thromboplastin antecedent	Enzyme	Intrinsic
XII	Hageman factor	Enzyme	Intrinsic
XIII	Fibrin stabilizing factor	Enzyme	Common

*Factor VI is no longer referenced; it is now believed to be the same substance as activated factor V.

Figure 13.9



active enzyme

Most enzymes require Ca^{++} (factor IV)

QuikClot Combat Gauze®

Item #: 200

QuikClot Combat Gauze, with kaolin technology, is the CoTCCC hemostatic dressing of choice for the U.S. Department of Defense (DOD).[20]

CONTACT A QUIKCLOT MILITARY SPECIALIST

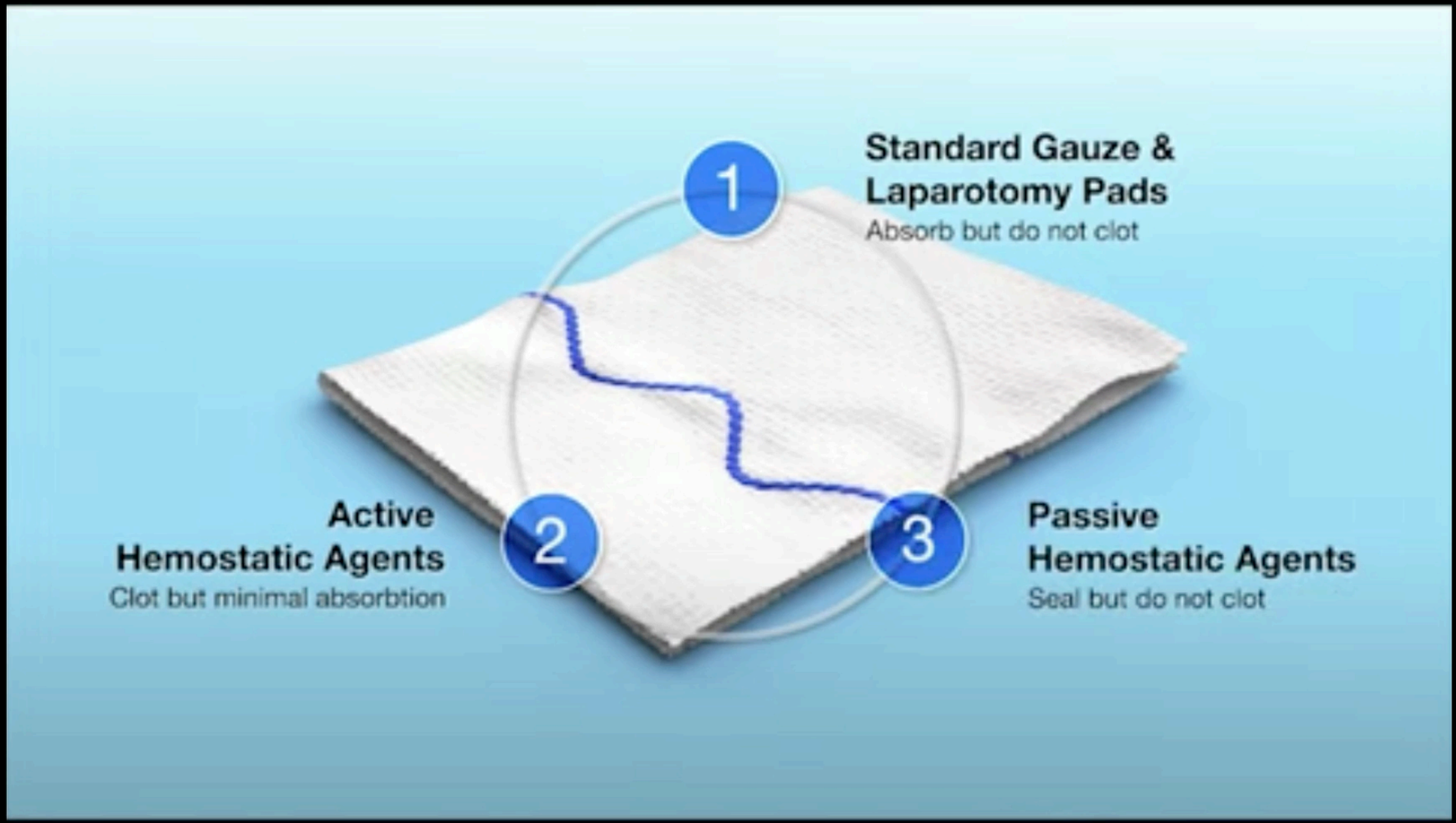
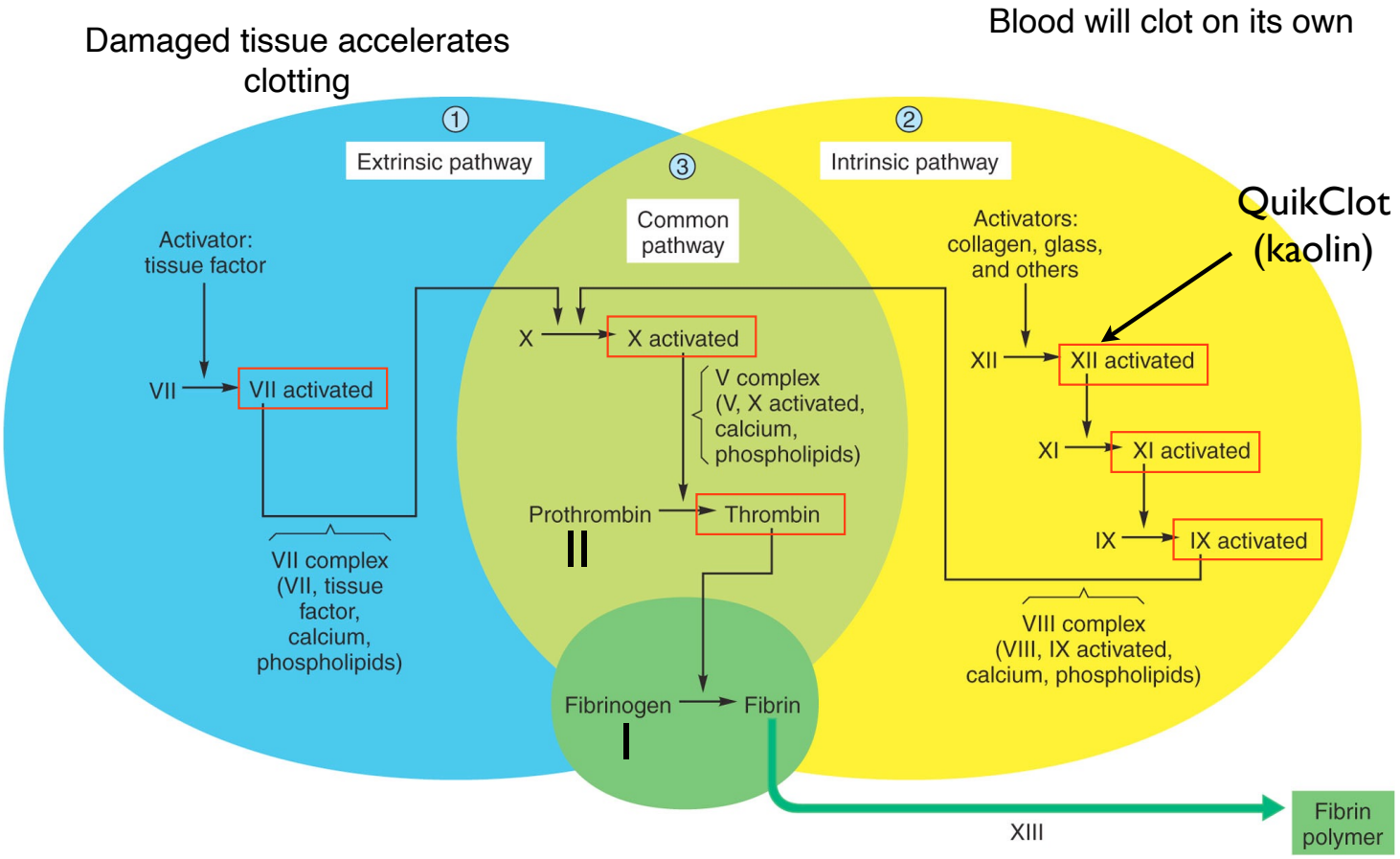

1
Standard Gauze &
Laparotomy Pads
Absorb but do not clot
2
Active
Hemostatic Agents
Clot but minimal absorbtion
3
Passive
Hemostatic Agents
Seal but do not clot

Figure 13.9



active enzyme

Most enzymes require Ca^{++} (factor IV)

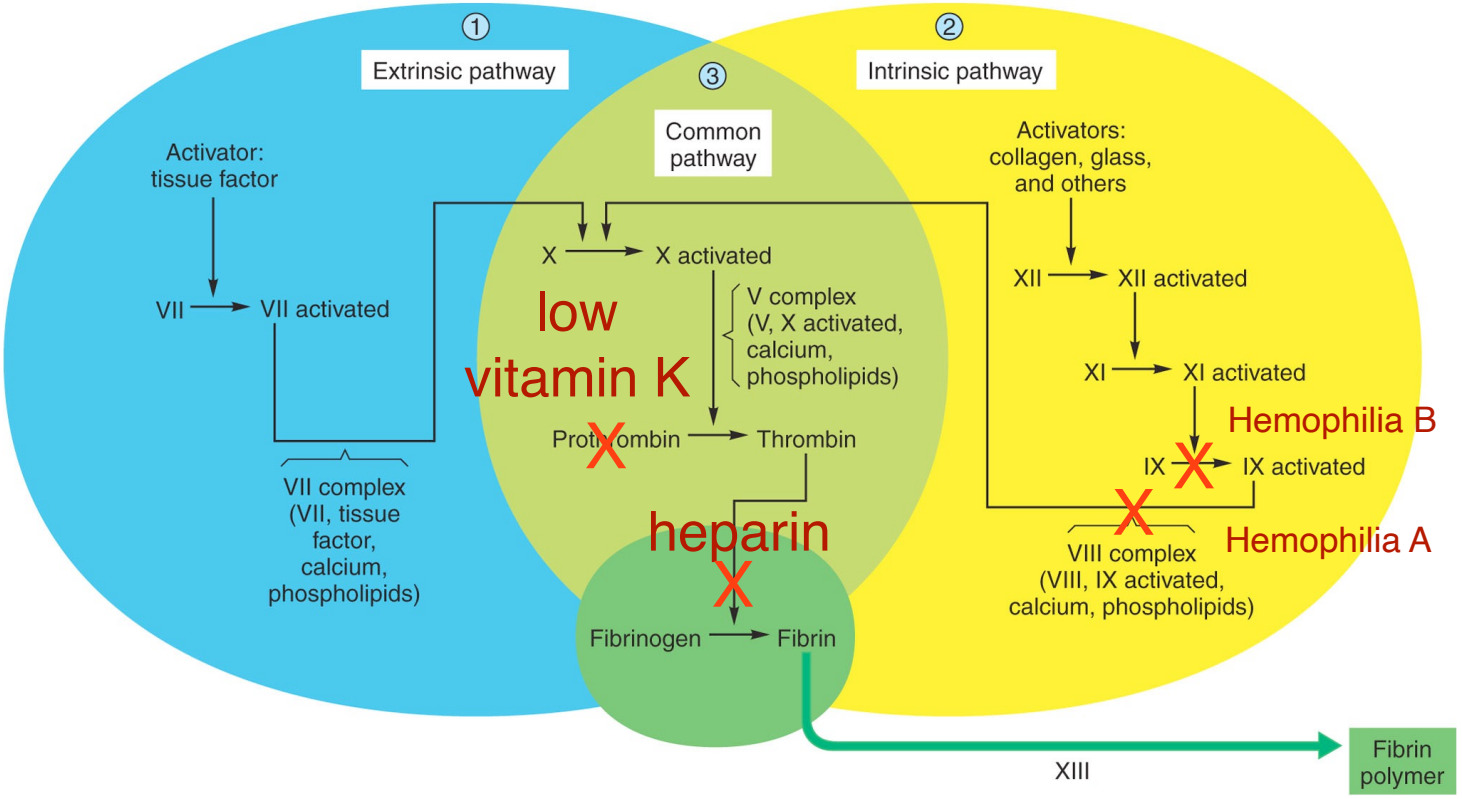
Table 13.5

Table 13.5 | Some Acquired and Inherited Clotting Disorders and a Listing of Anticoagulant Drugs

Category	Cause of Disorder	Comments
Acquired clotting disorders	Vitamin K deficiency	Inadequate formation of prothrombin and other clotting factors in the liver
Inherited clotting disorders	Hemophilia A (defective factor $VIII_{AHF}$)	Recessive trait carried on X chromosome; results in delayed formation of fibrin
	Von Willebrand's disease (defective factor $VIII_{VWF}$)	Dominant trait carried on autosomal chromosome; impaired ability of platelets to adhere to collagen in subendothelial connective tissue
	Hemophilia B (defective factor IX); also called Christmas disease	Recessive trait carried on X chromosome; results in delayed formation of fibrin
Anticoagulants		
Aspirin	Inhibits prostaglandin production, resulting in a defective platelet release reaction	
Coumarin	Inhibits activation of vitamin K	
Heparin	Inhibits activity of thrombin	
Citrate	Combines with Ca^{2+}, and thus inhibits the activity of many clotting factors	

hemophilia - "love to bleed"

Figure 13.9



Most enzymes require Ca^{++} (factor IV)

citrate, EDTA

Hemophilia A & B are X-linked recessive disease

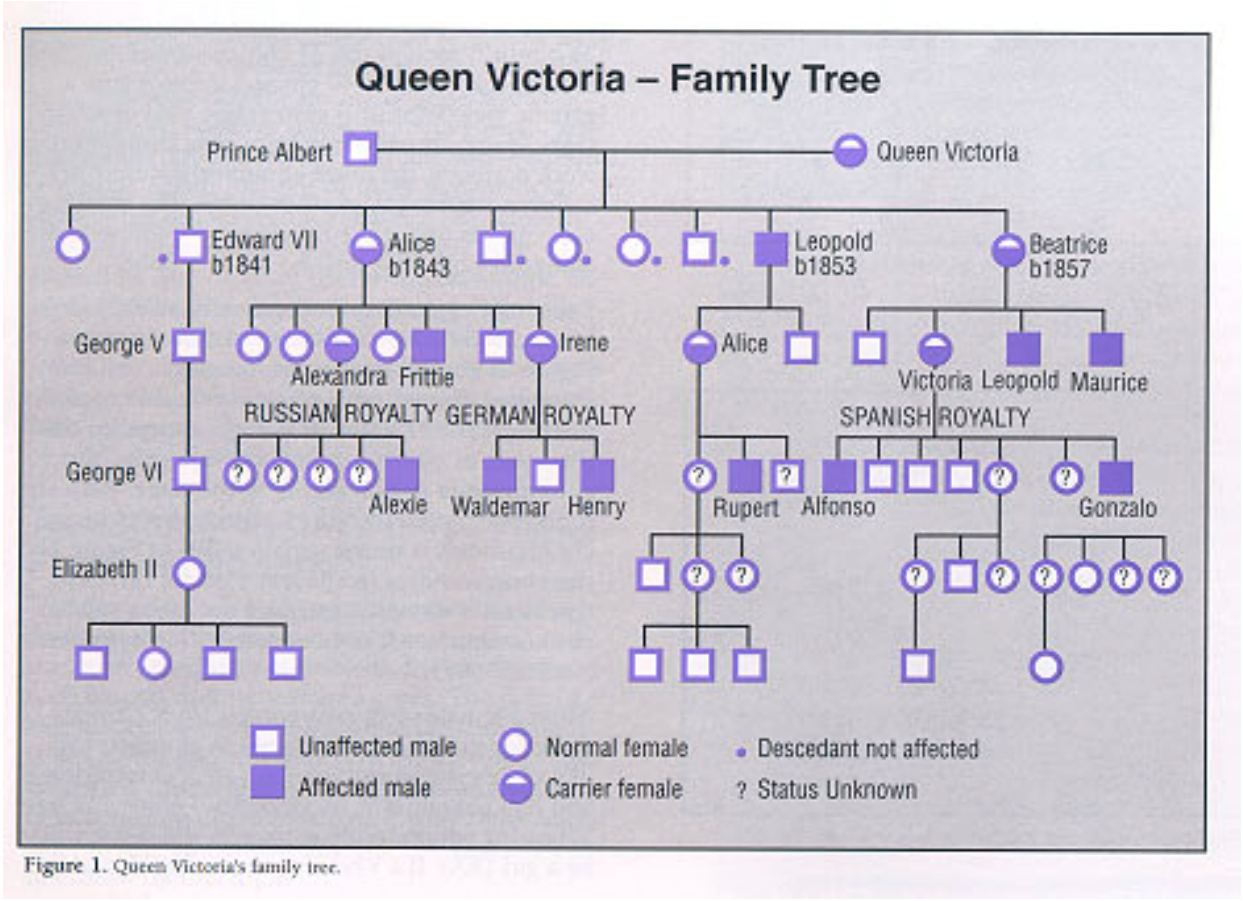
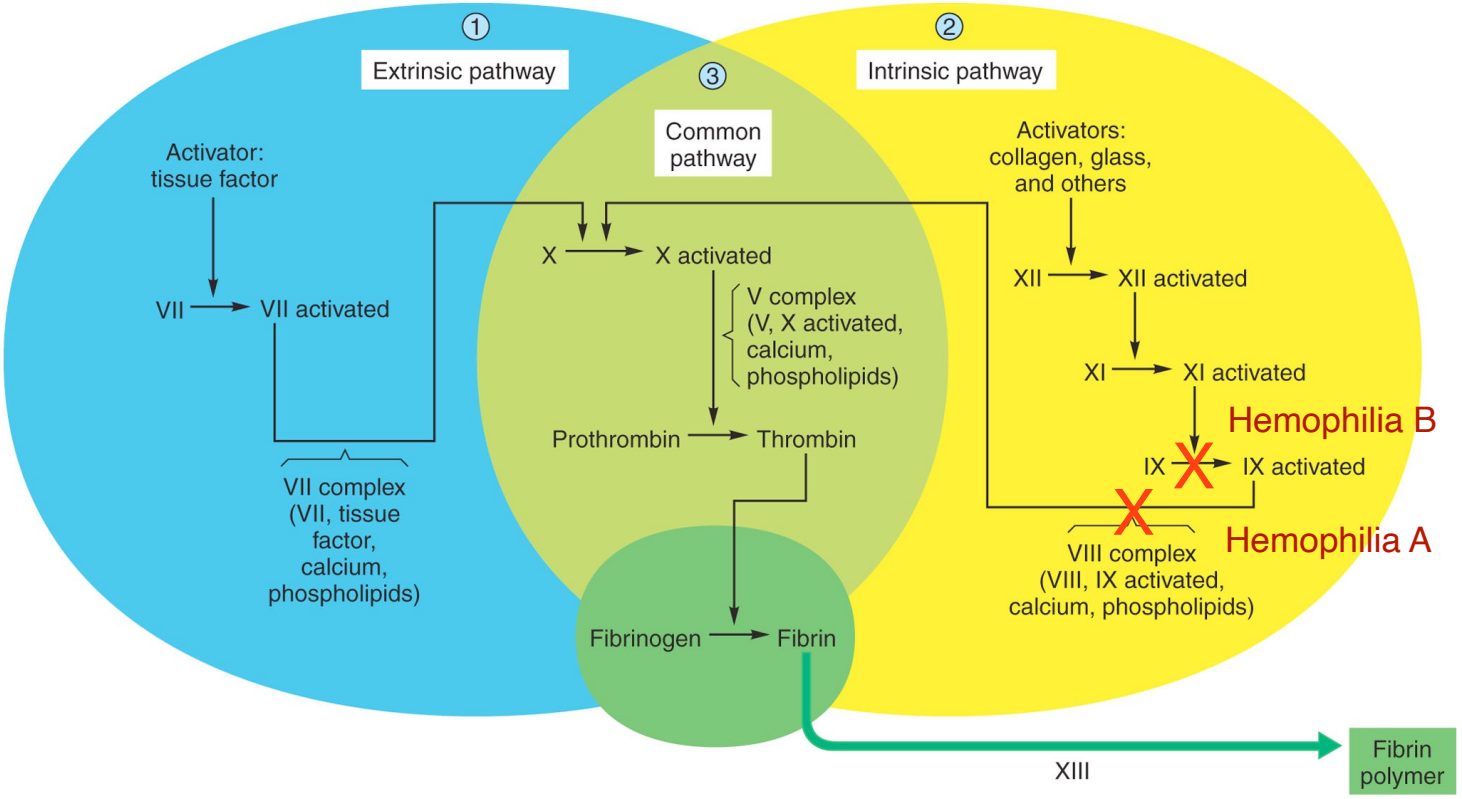


Figure 1. Queen Victoria's family tree.

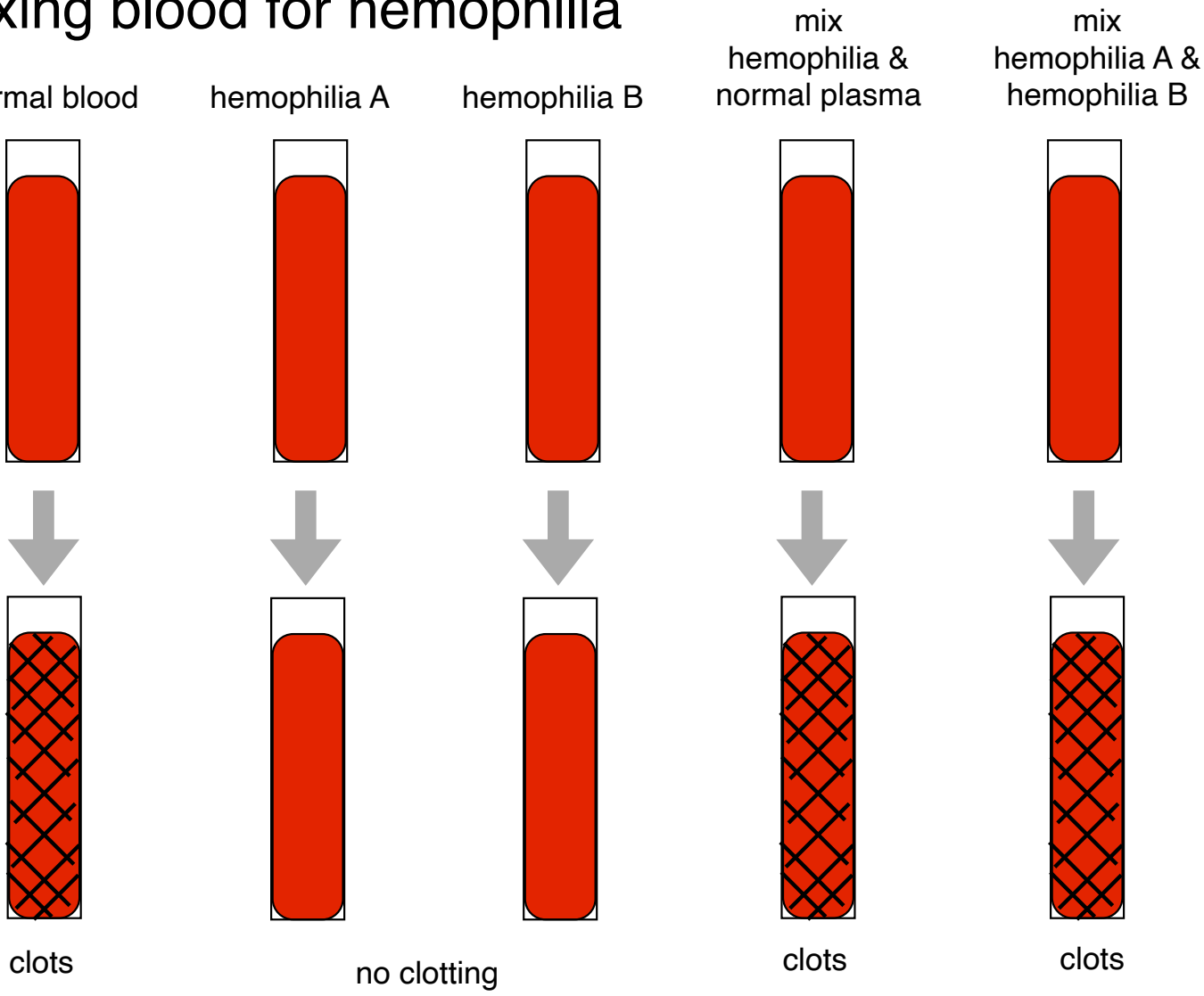
Figure 13.9

Top Hat



Most enzymes require Ca^{++} (factor IV)

Mixing blood for hemophilia



The main treatment for hemophilia is called replacement therapy. Concentrates of clotting factor VIII (for hemophilia A) or clotting factor IX (for hemophilia B) are slowly dripped or injected into a vein. These infusions help replace the clotting factor that's missing or low.