SISTEM KARDIOVASKULAR

DENNY AGUSTININGSIH

Tekanan Darah

- PARAMETER YANG MUDAH DIAMATI
- TERMASUK SALAH SATU TANDA VITAL

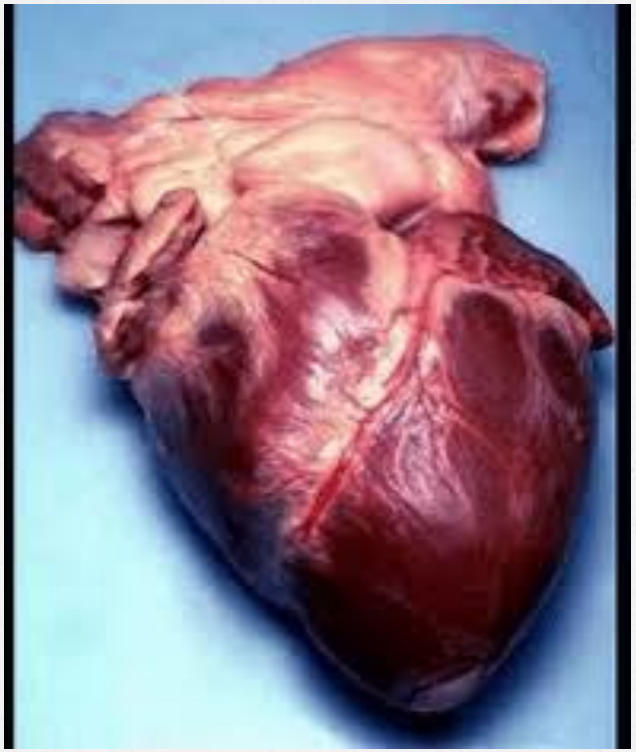
APA YANG DIMAKSUD DENGAN TEKANAN DARAH?

Desakan darah terhadap dinding pembuluh darah akibat pompa jantung

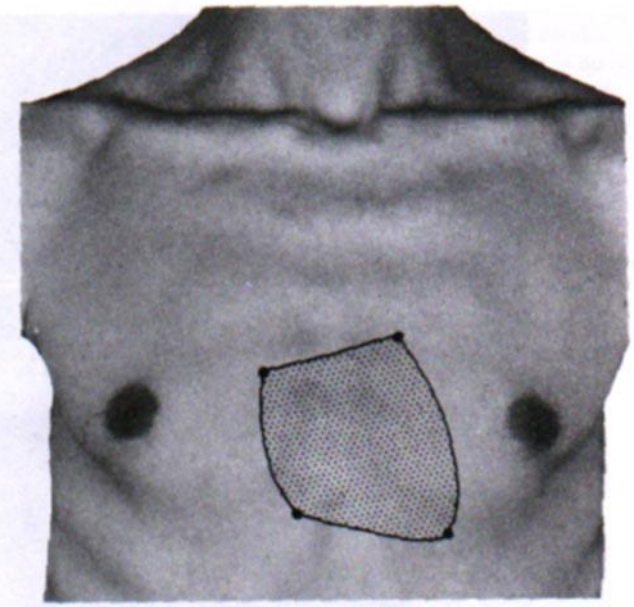
FAKTOR-FAKTOR YG MEMPENGARUHI TEKANAN DARAH

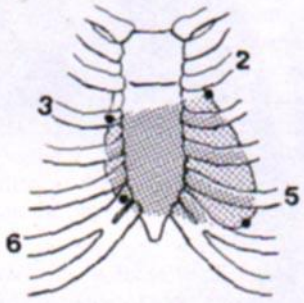
1. POMPA JANTUNG
2. KONDISI PEMBULUH DARAH ARTERI
   - diameter
   - kelenturan dinding
3. DARAH (cairan intravaskular)
   - Volume
   - viskositas

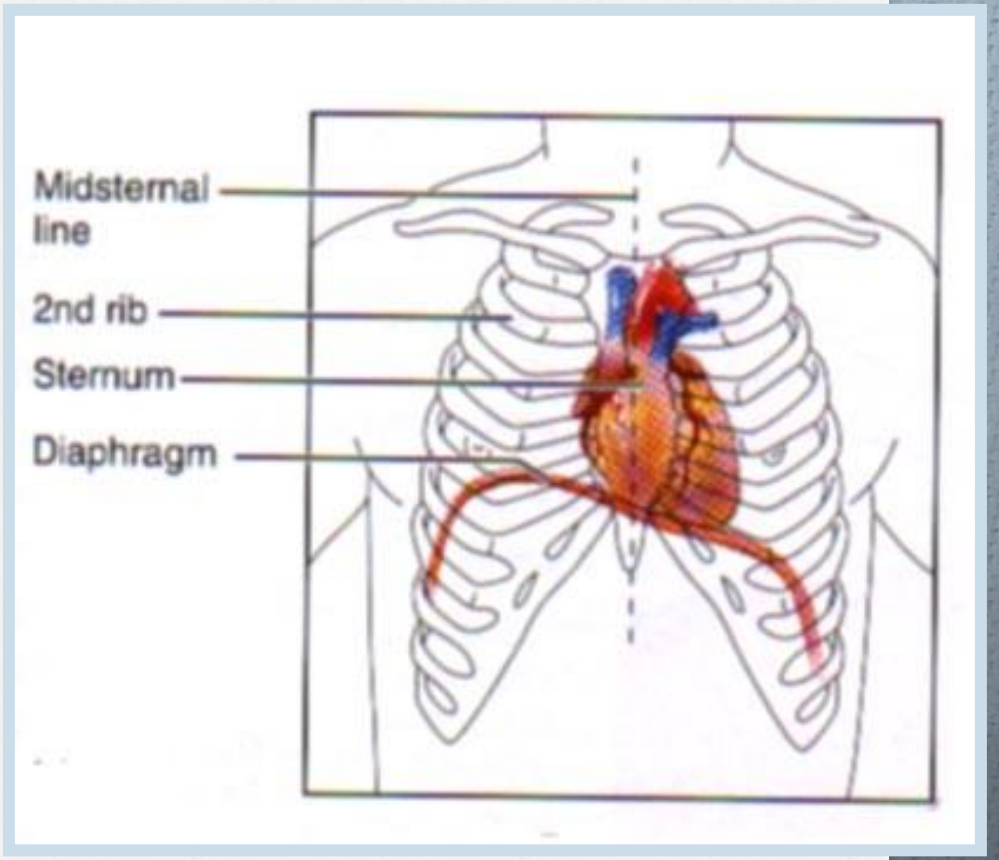
JANTUNG



Location of Heart in Thorax

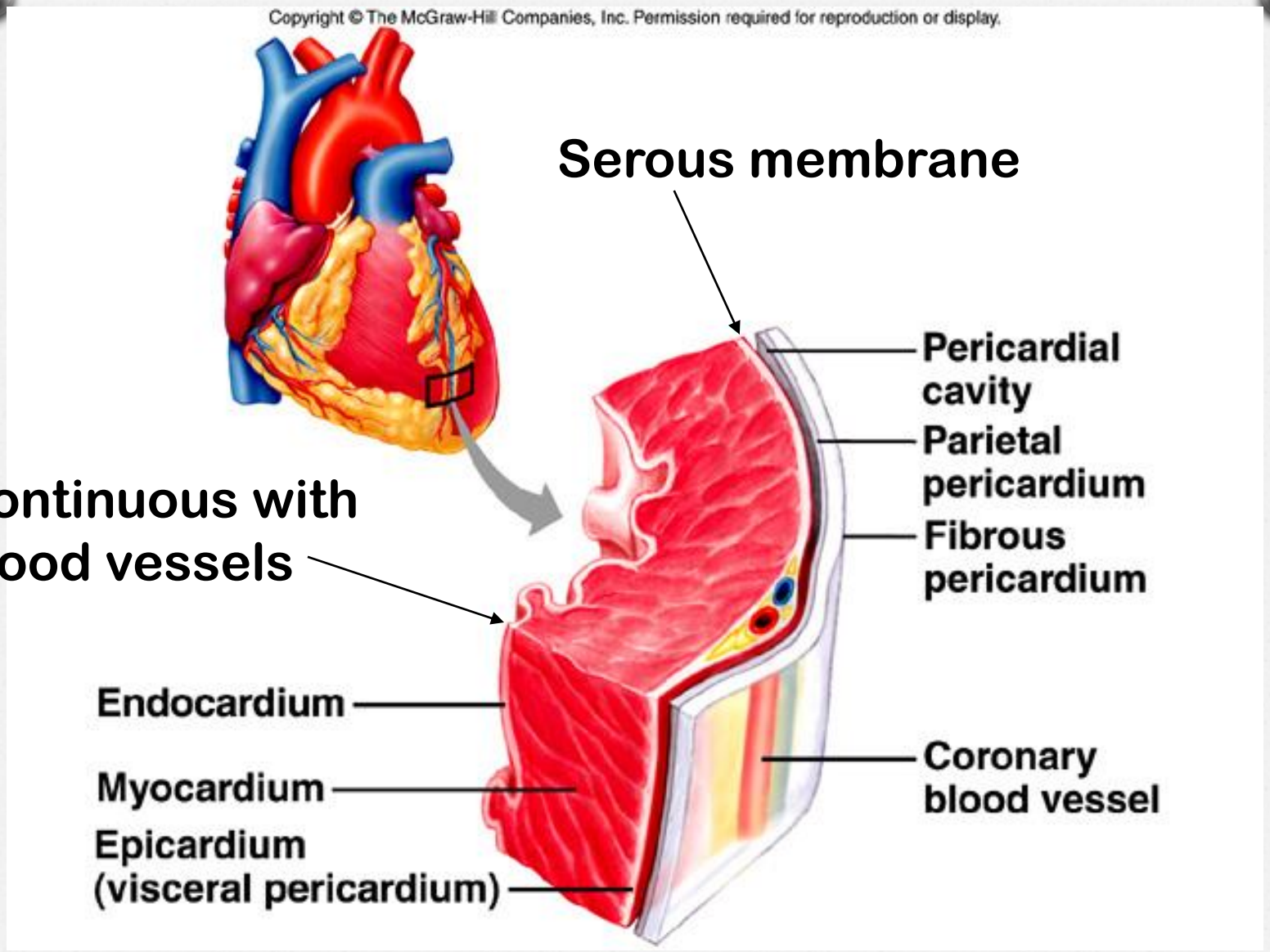




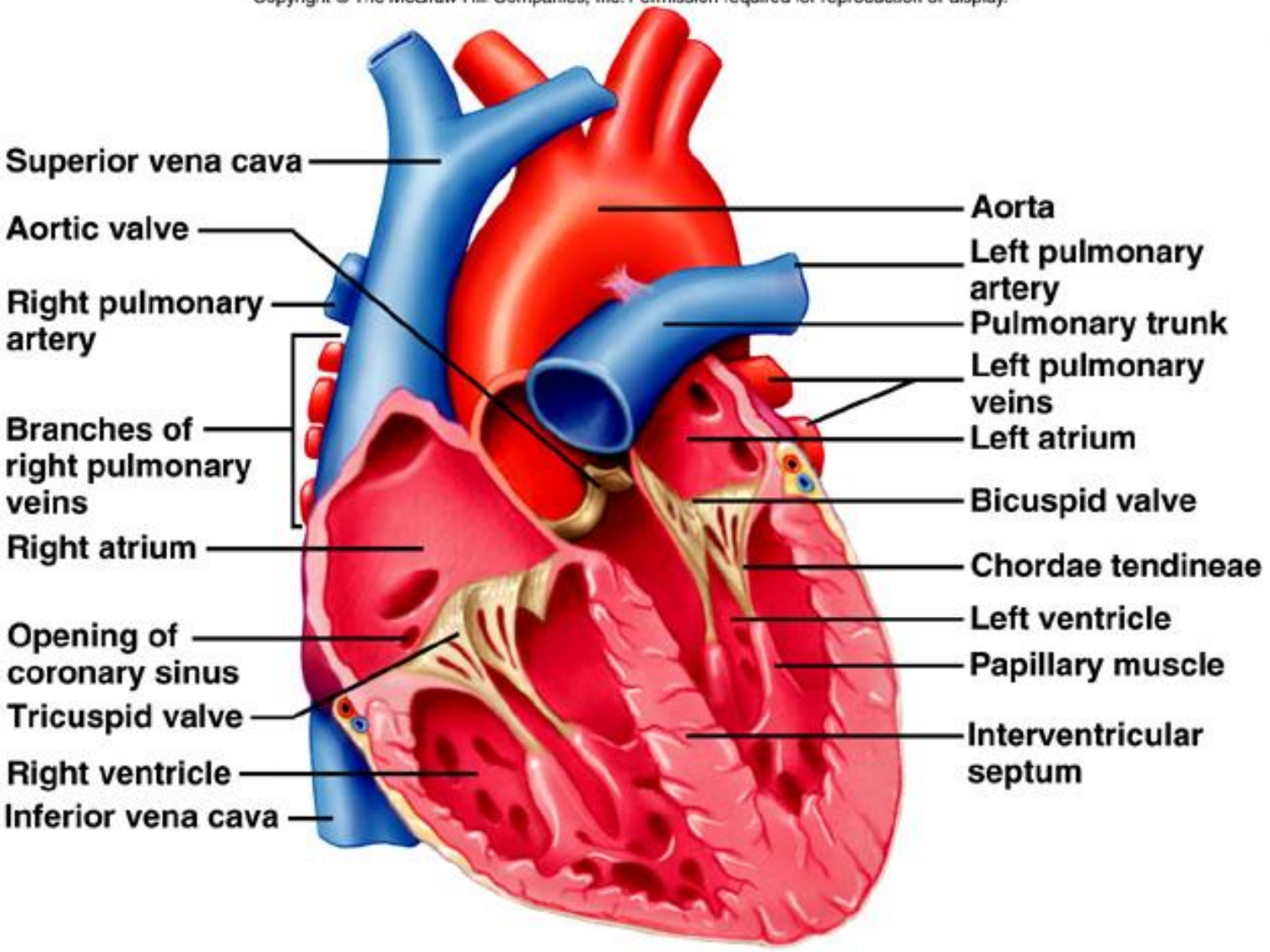


pg 523

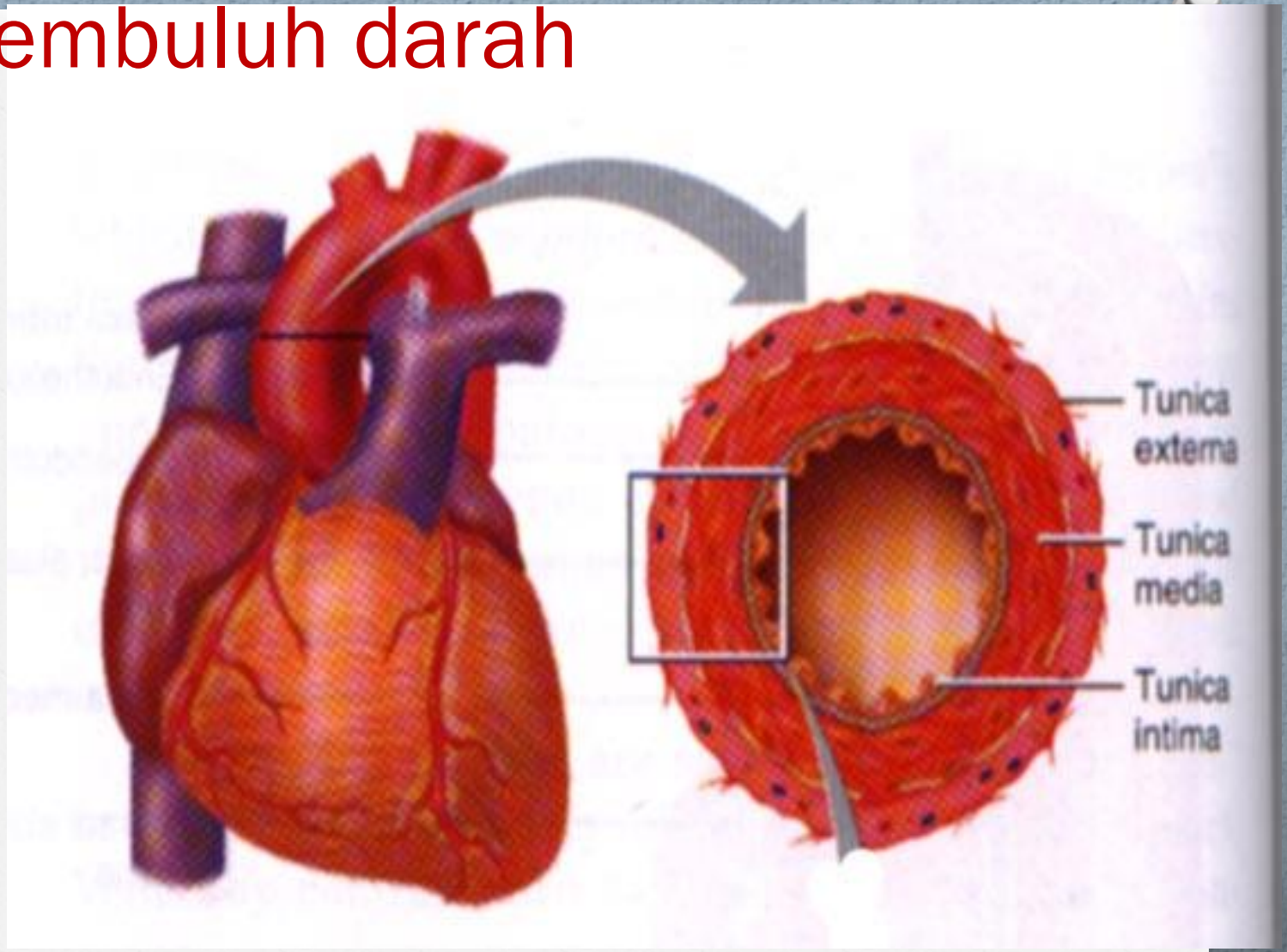
Lapisan-lapisan jantung



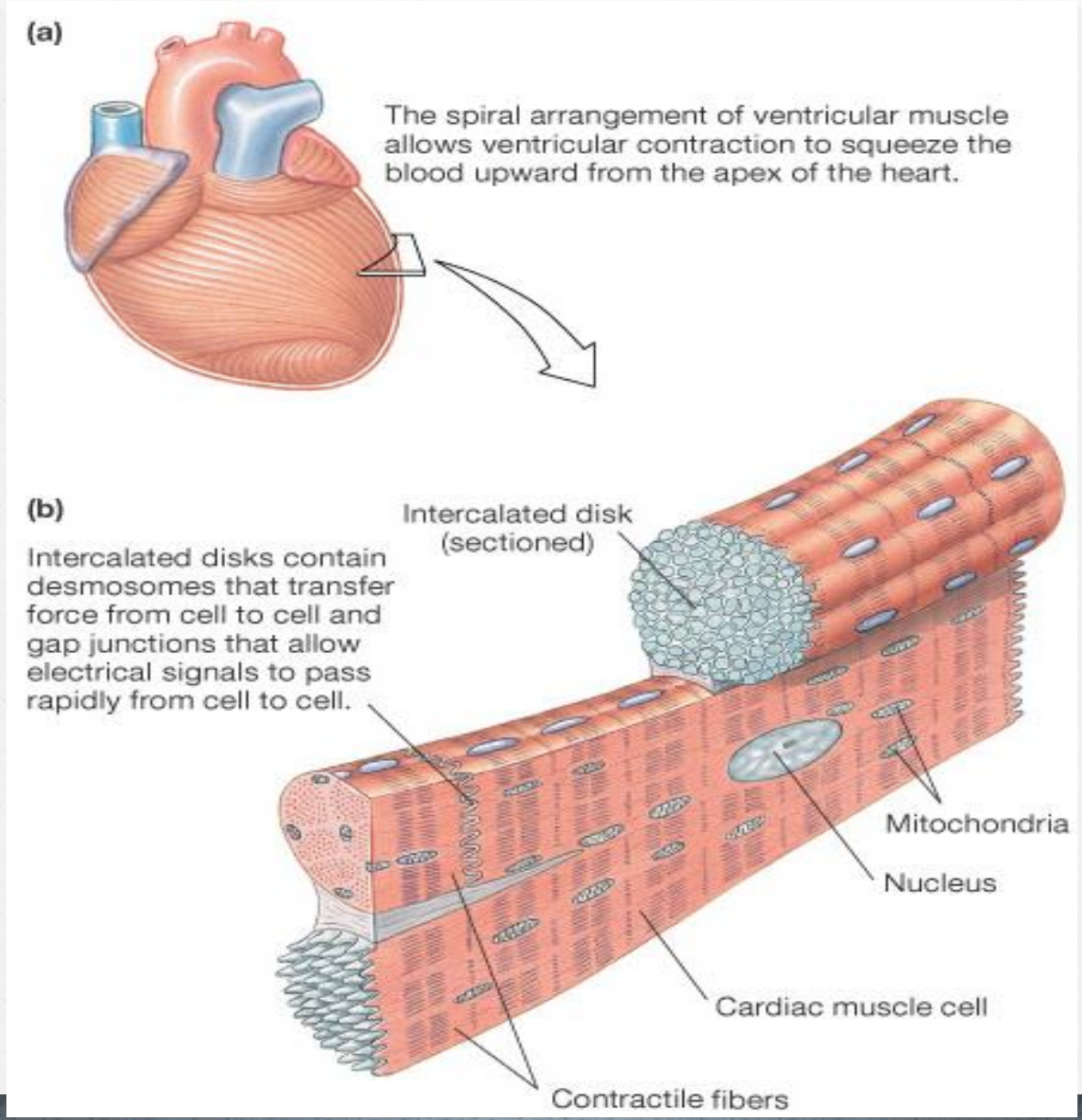
Chambers of the heart; valves



Pembuluh darah



Otot jantung



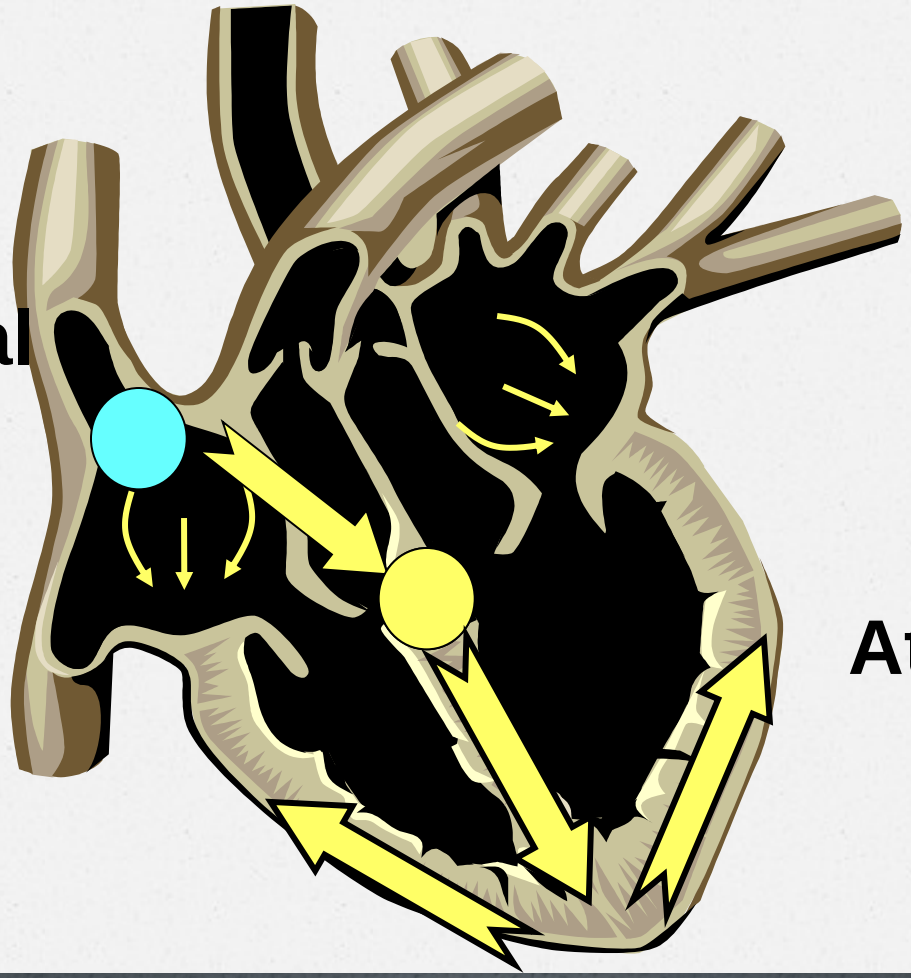
BAGAIMANA JANTUNG DAPAT MEMOMPA DARAH ?

1. **Faktor kelistrikan**
2. **Faktor Mekanik**

DUA JENIS SEL OTOT JANTUNG

- SEL KONTRAKTIL: 95%- 99%
  - Untuk kekuatan memompa darah
  - Tidak mudah lelah
- SEL AUTORITMIK/AUTOMATIK: 1%-5%
  - Bertanggung jawab untuk memulai dan/atau menjalarkan impuls listrik
  - pacemaker potential
  - Menentukan frekuensi dan irama denyut jantung

SISTEM KONDUKSI OTOT JANTUNG



Sinoatrial Node

Atrioventricular Node

Purkinje fiber

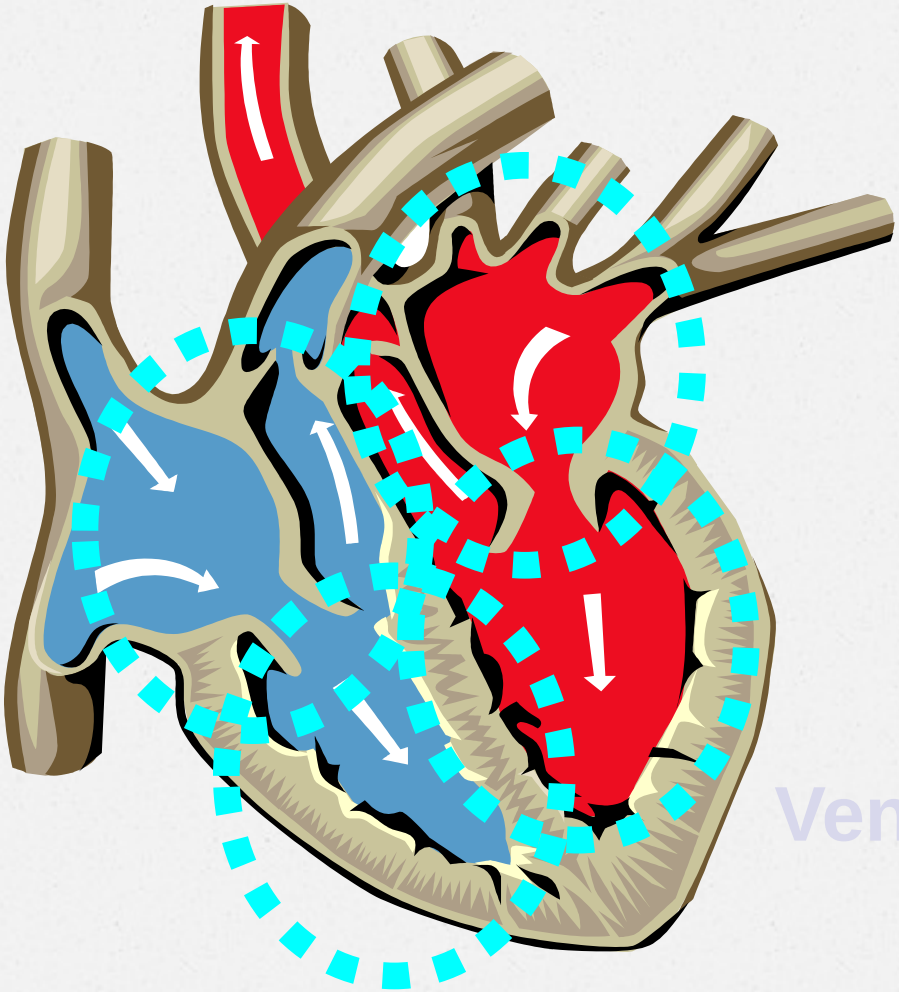
Kelistrikan jantung menentukan

1. Frekuensi denyut jantung
2. Irama denyut jantung
3. Terjadinya kontraksi otot jantung

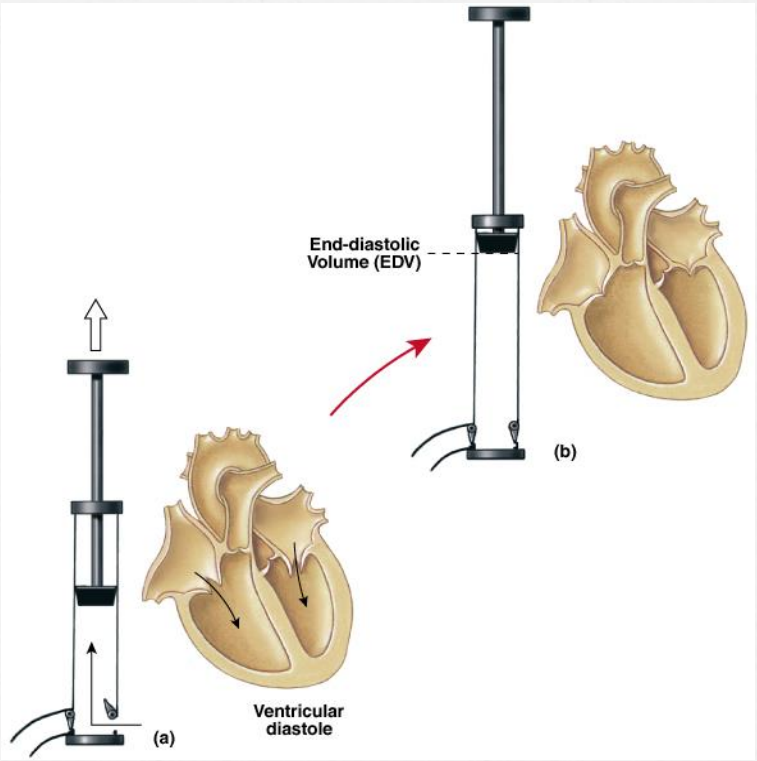
FAKTOR-FAKTOR YG MEMPENGARUHI FREKUENSI DENYUT JANTUNG

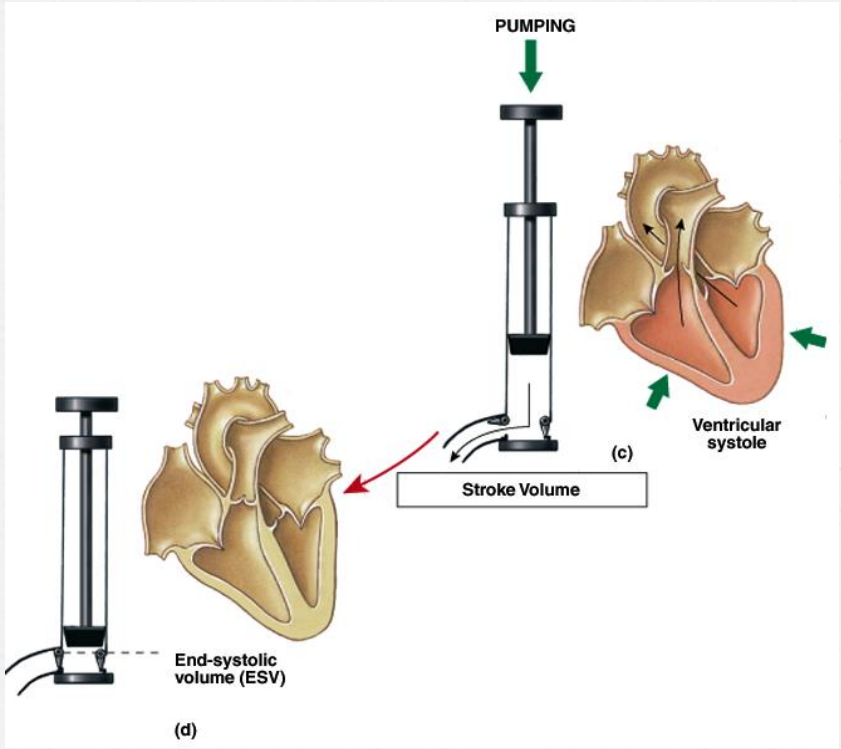
1. saraf simpatis dan parasimpatis
2. Hormon adrenalin, asetilkolin, tiroid, estrogen, testosteron
3. Ion Na, Ca, K
4. Suhu badan

TWO SEPARATE PUMPS

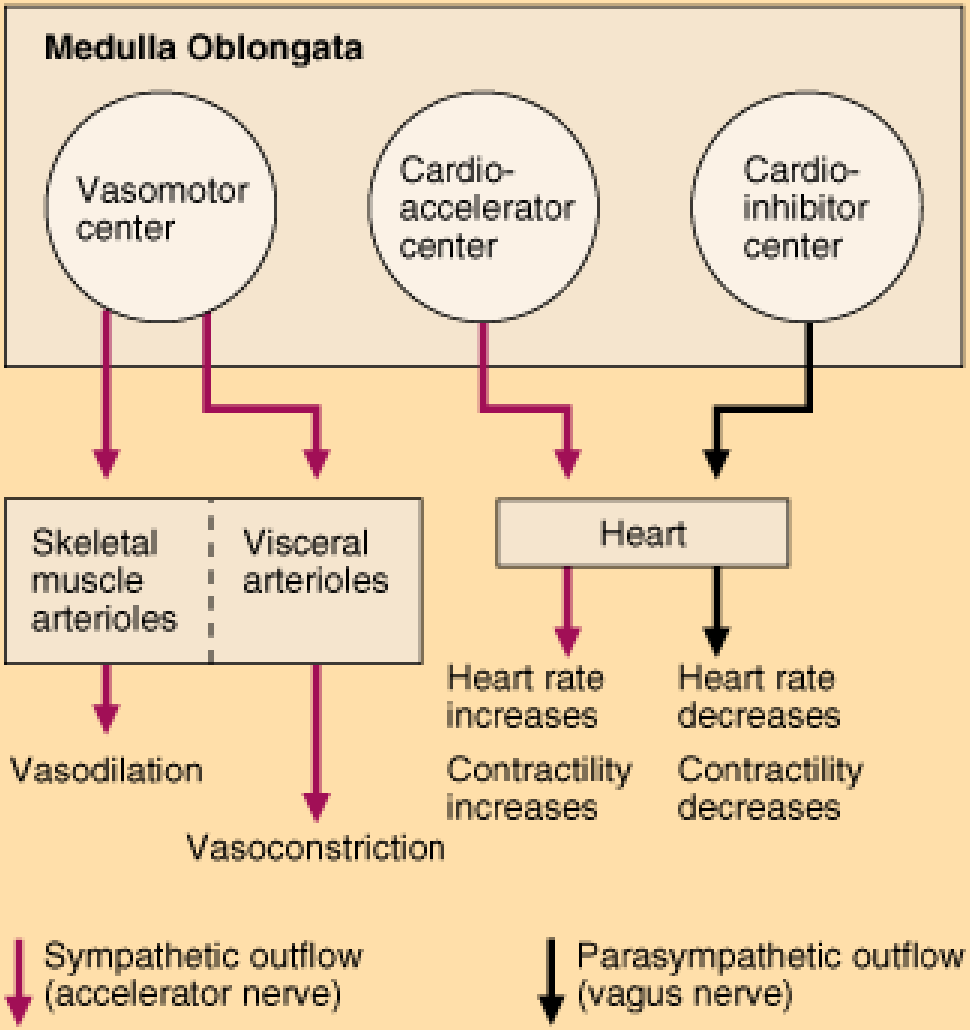


POMPA JANTUNG



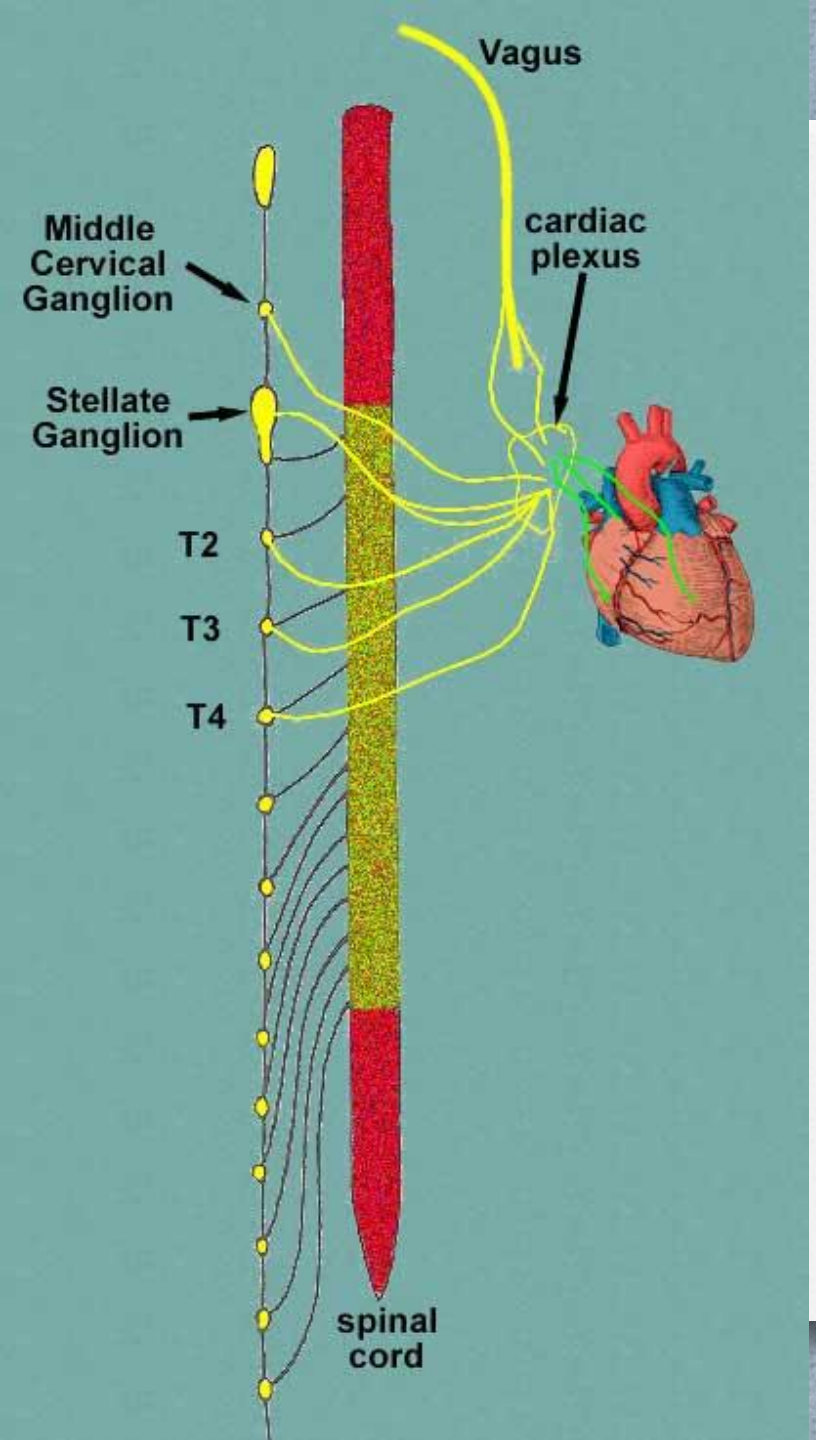


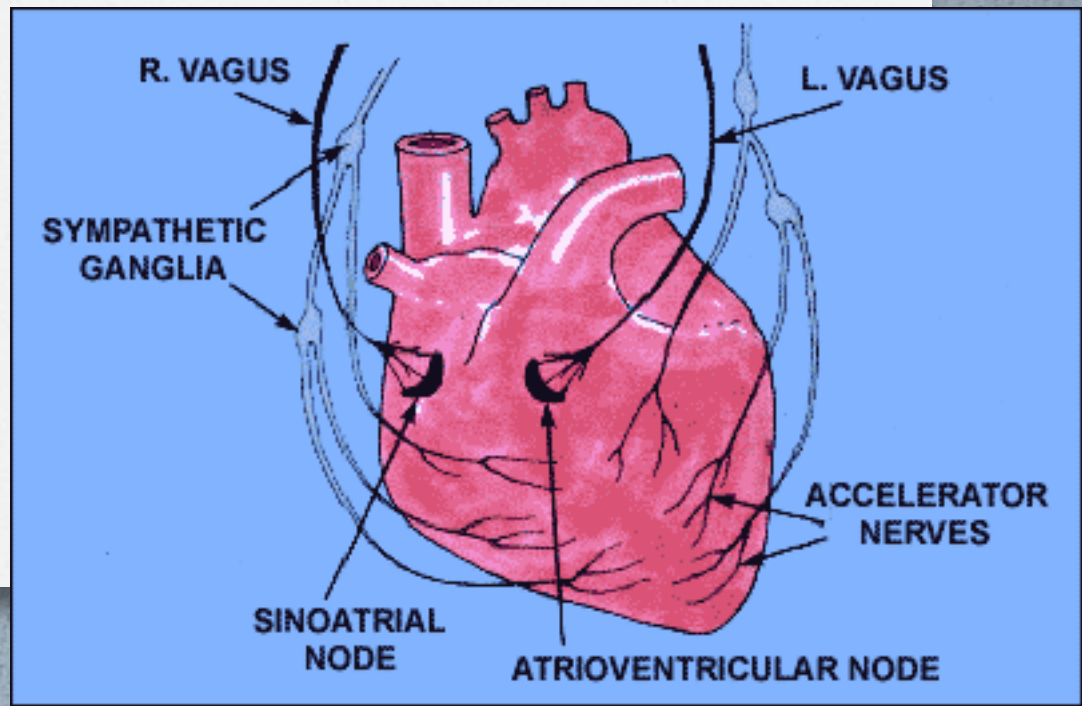
▶ Neural Control of Cardiovascular Function



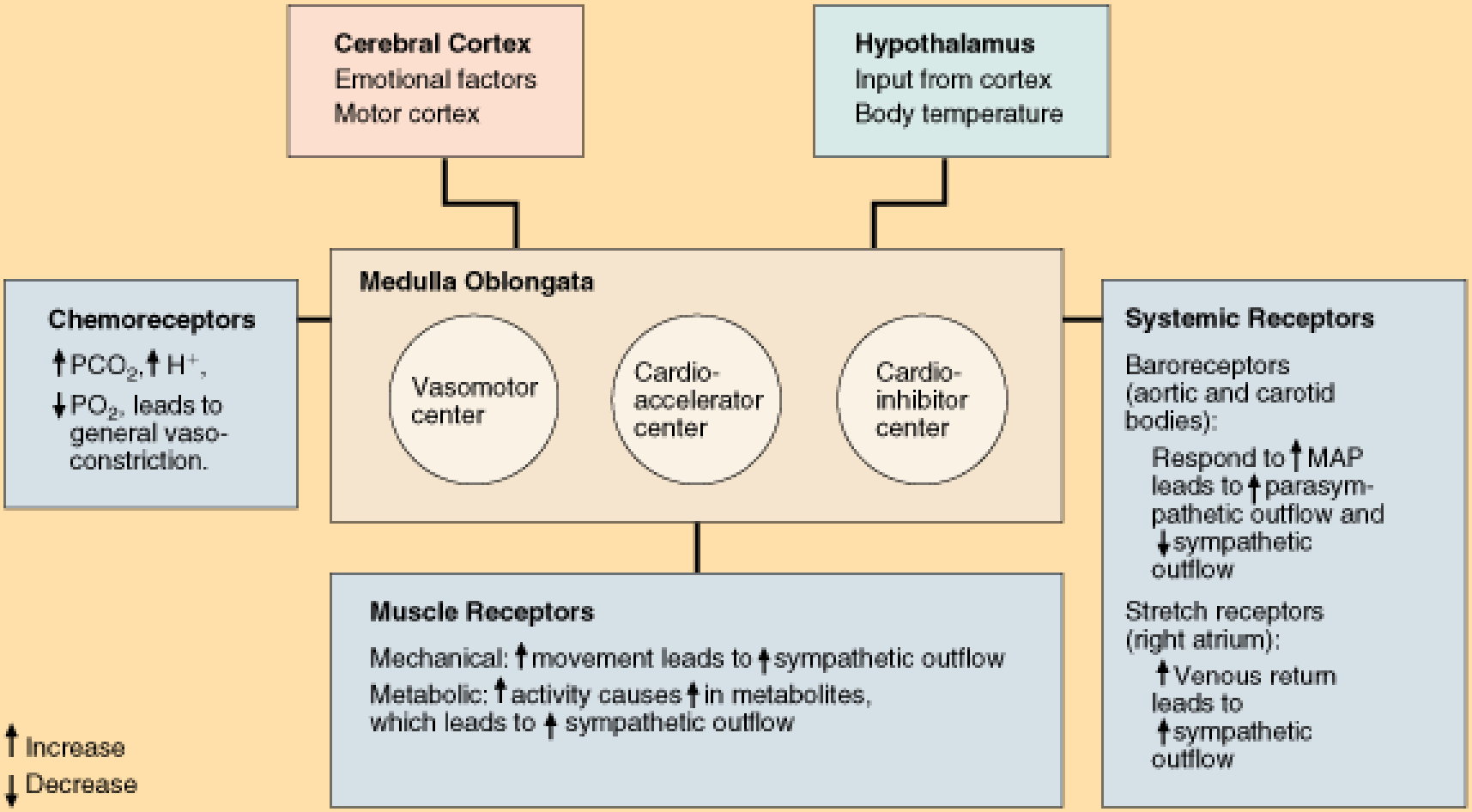
Heart Innervation

- Heart receives visceral motor innervation
  - Sympathetic (speeds up)
  - Parasympathetic (slows down)



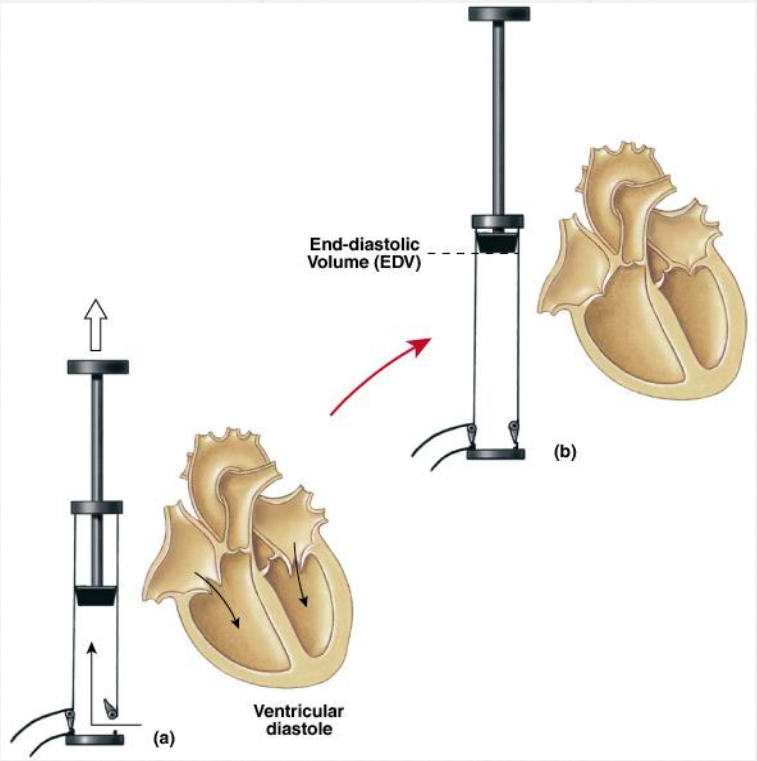


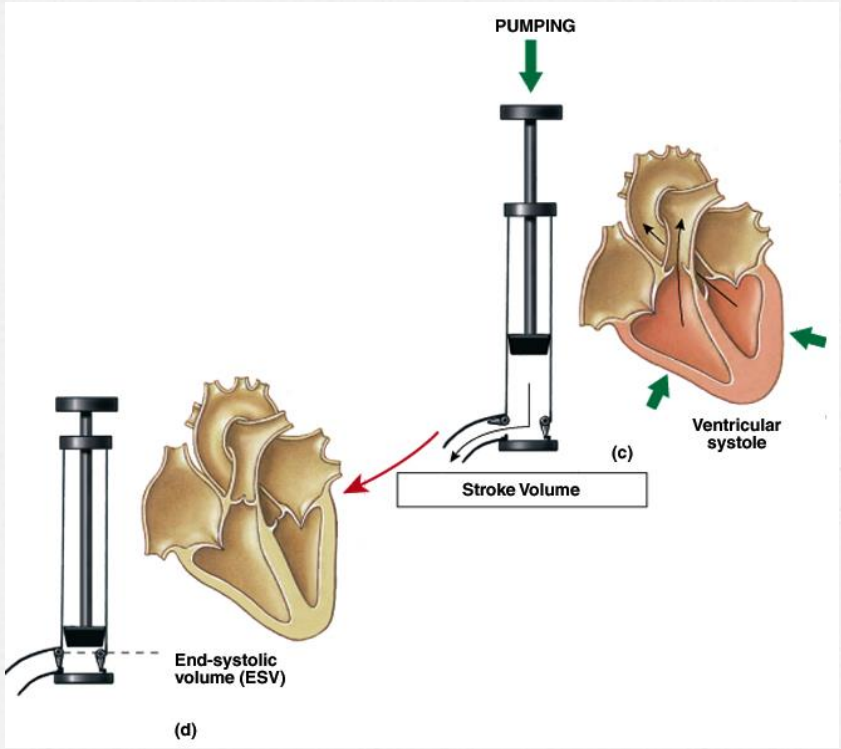
▶ Factors Affecting Neural Control of Cardiovascular Function



PEMBULUH DARAH

POMPA JANTUNG





TEKANAN DARAH

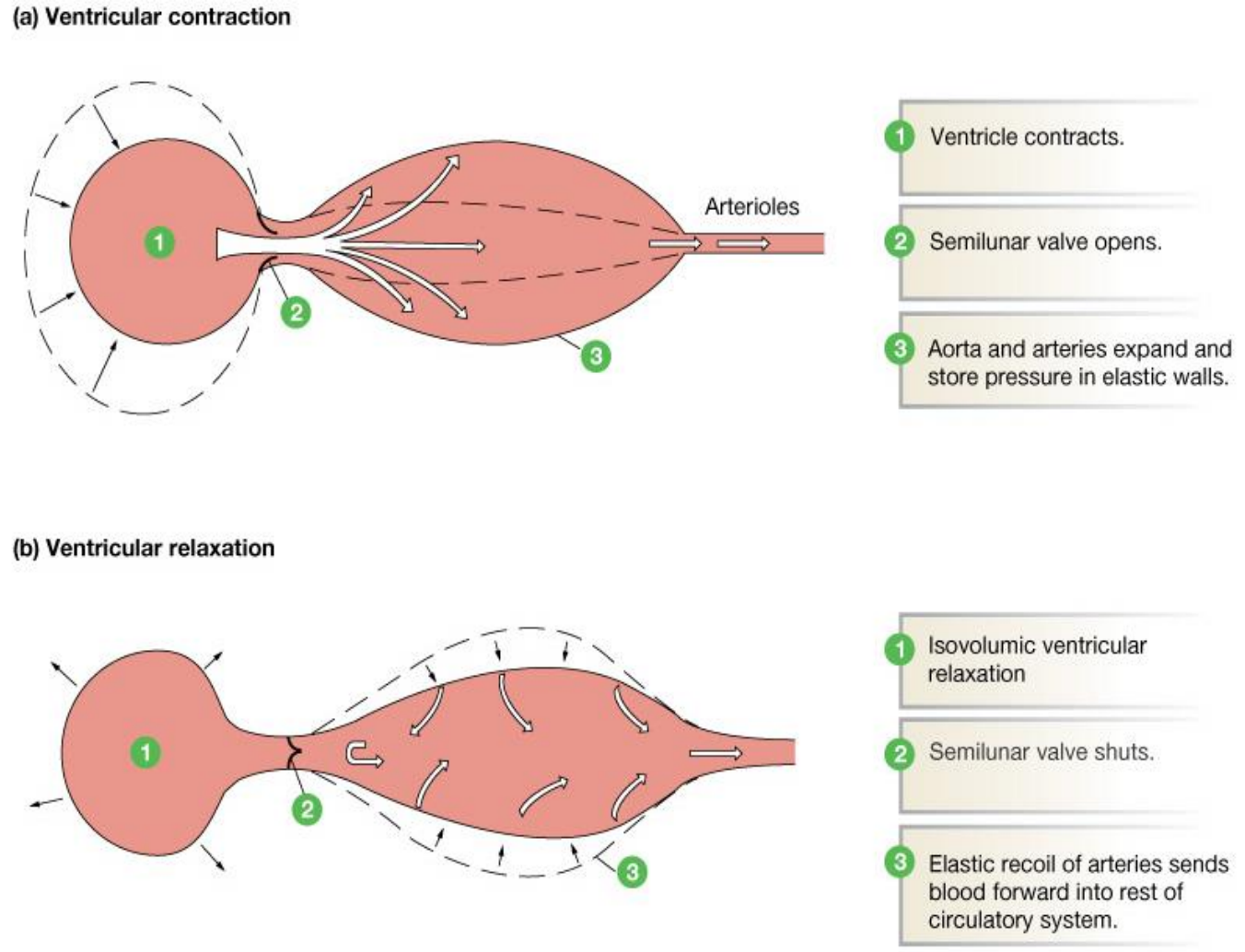


Figure 15-4: Elastic recoil in the arteries

- Arteri dapat dibayangkan seperti balon panjang tanpa lubang terbuka di ujungnya

- Selama masih ada aliran udara, maka balon tetap mengembang

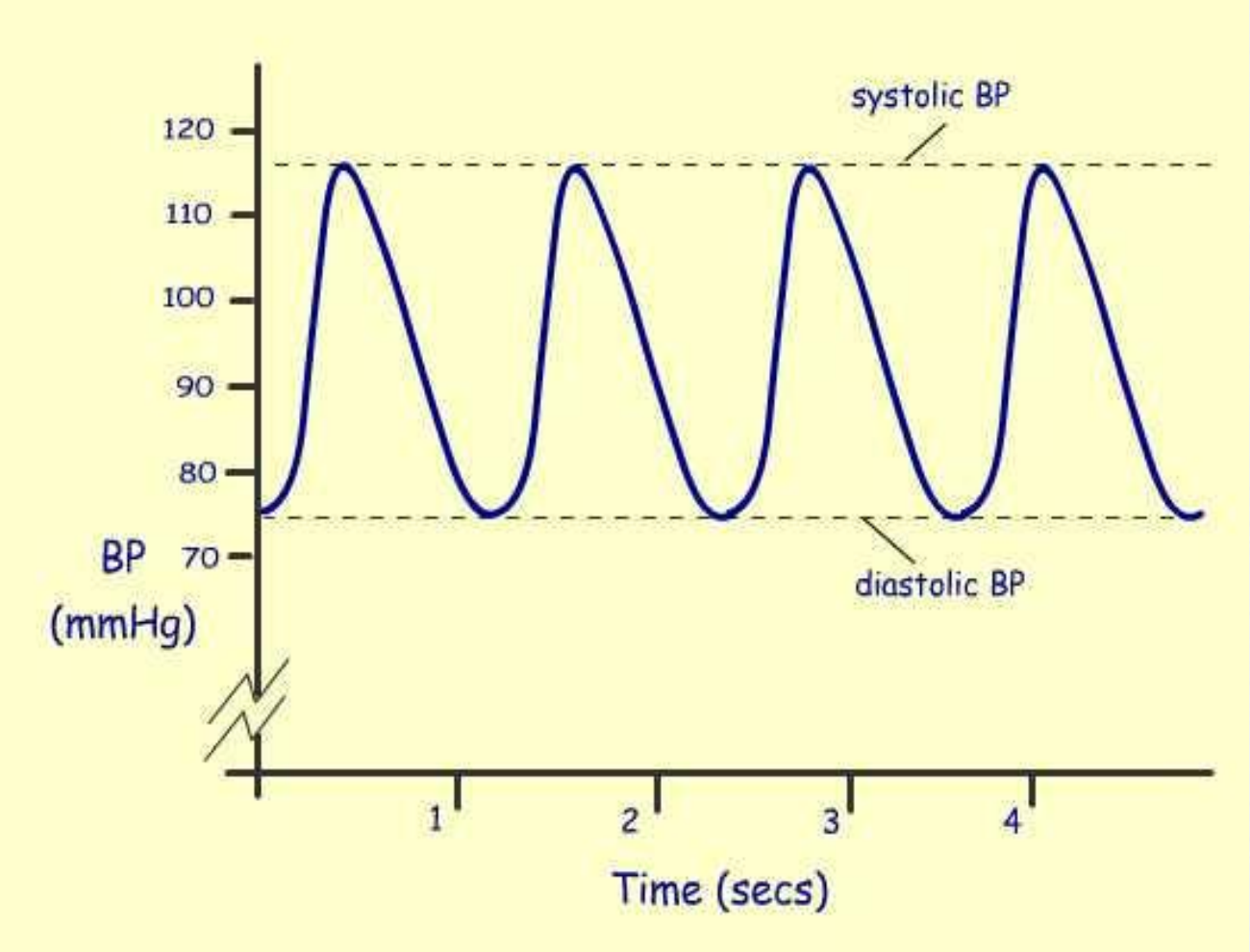
Systole and Diastole

- Kondisi arteri berfluktuasi diantara systole dan diastole
- Saat systole, tekanan di arteri meningkat akibat darah mengalir dari jantung
  - dinding arteri meregang
  - Teraba tegangan di arteri perifer sebagai denyut nadi

Systole and Diastole

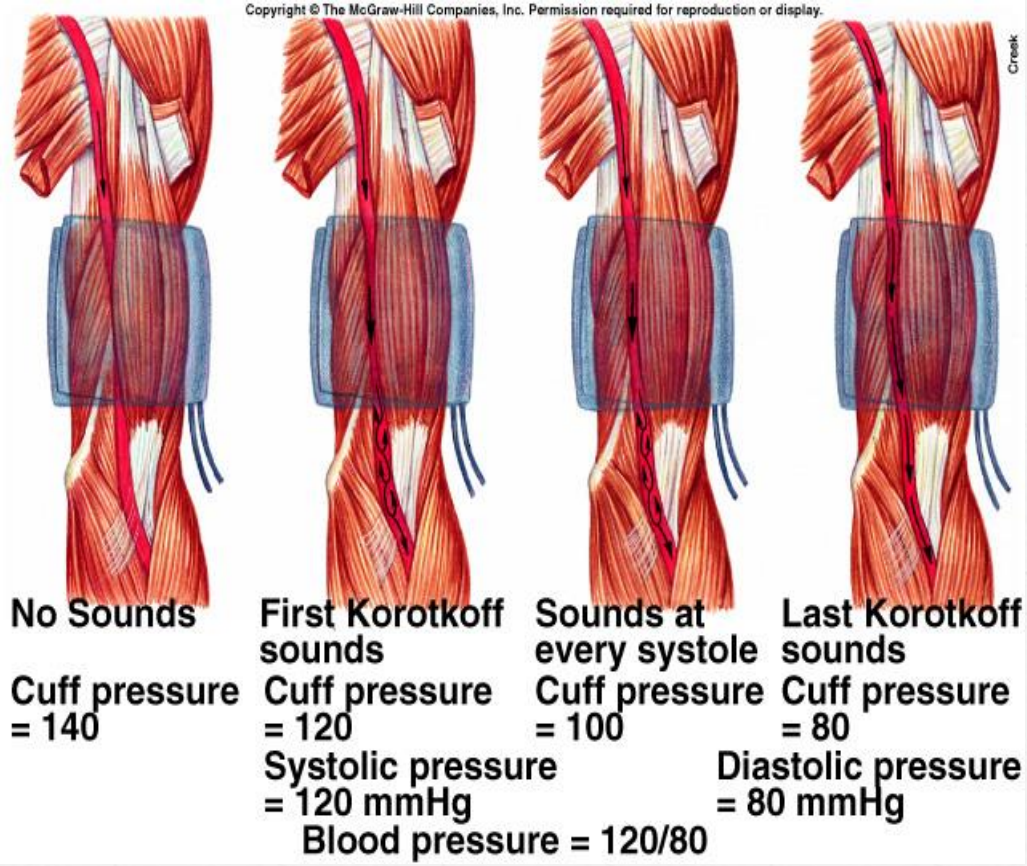
- Saat diastole, elastic recoil arteri mendorong darah masuk kapiler
  - Tekanan di arteri menurun karena darah berpindah
  - Tidak pernah sampai 0 mmHg

Here is a graph of changes in arterial BP



Measurement of Blood Pressure

- Blood pressure cuff is inflated above systolic pressure, occluding the artery.
- As cuff pressure is lowered, the blood will flow only when systolic pressure is above cuff pressure, producing the sounds of Korotkoff.
- Korotkoff sounds will be heard until cuff pressure equals diastolic pressure, causing the sounds to disappear.



Arterial blood pressure

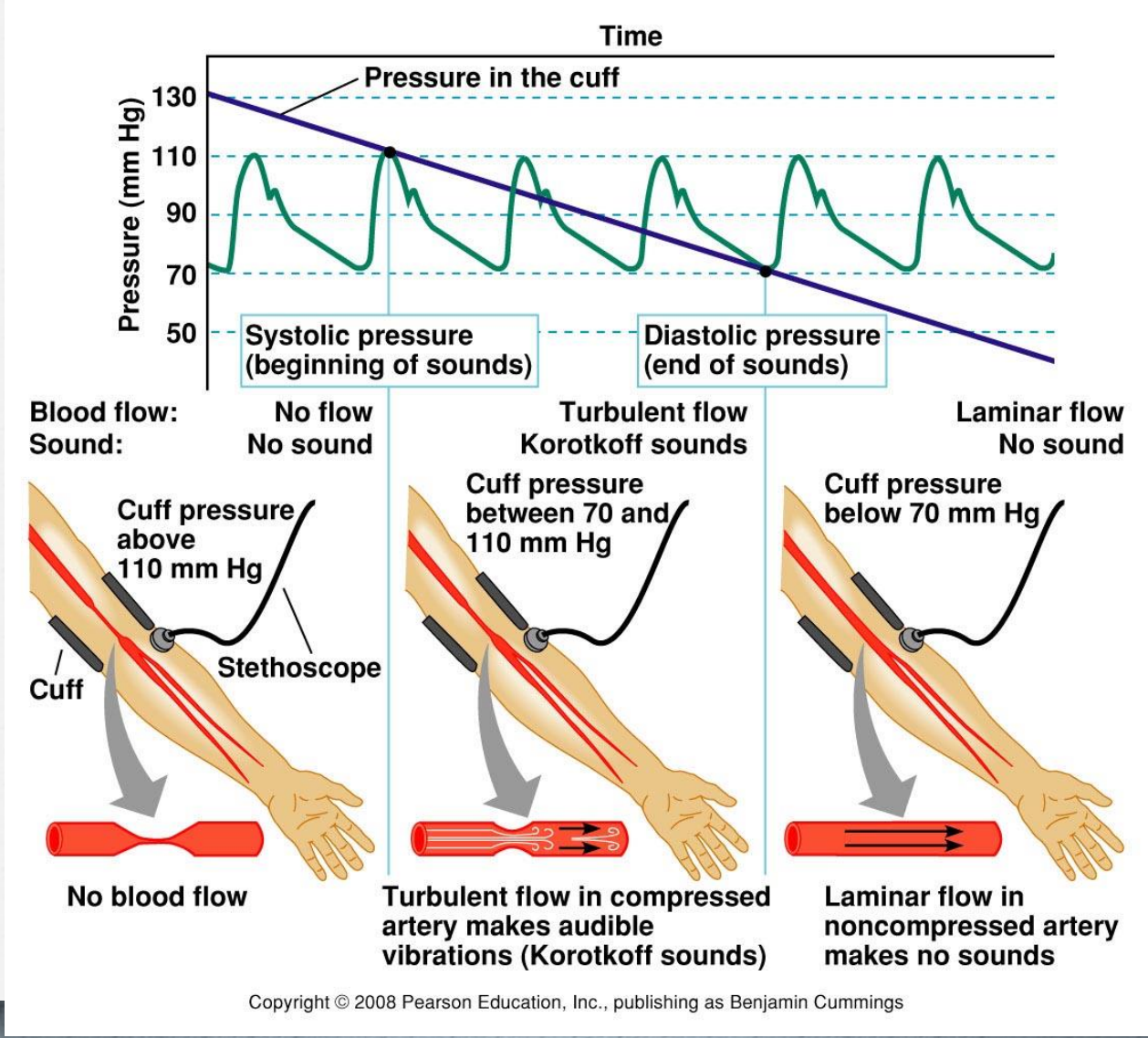
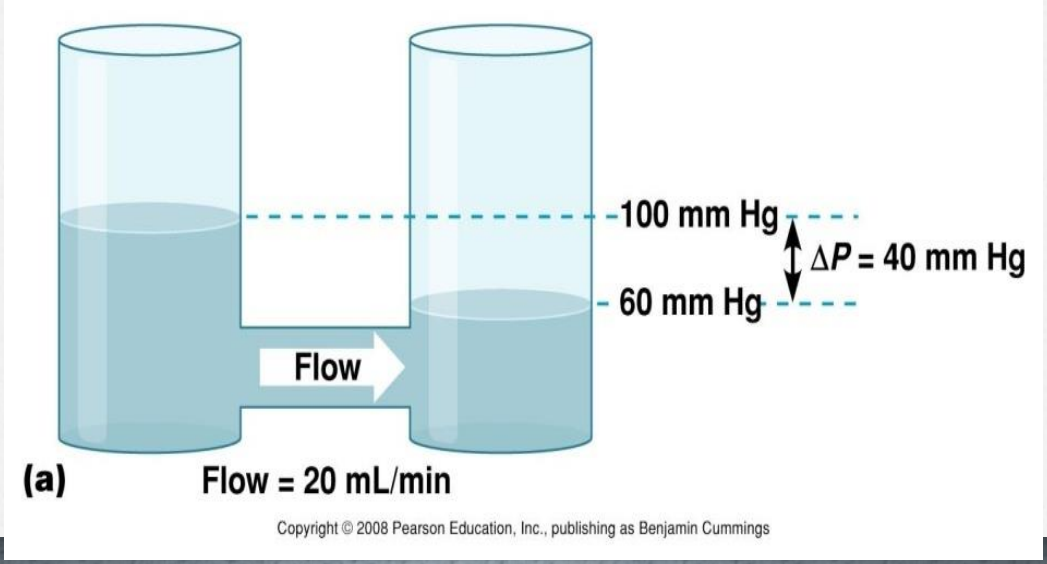


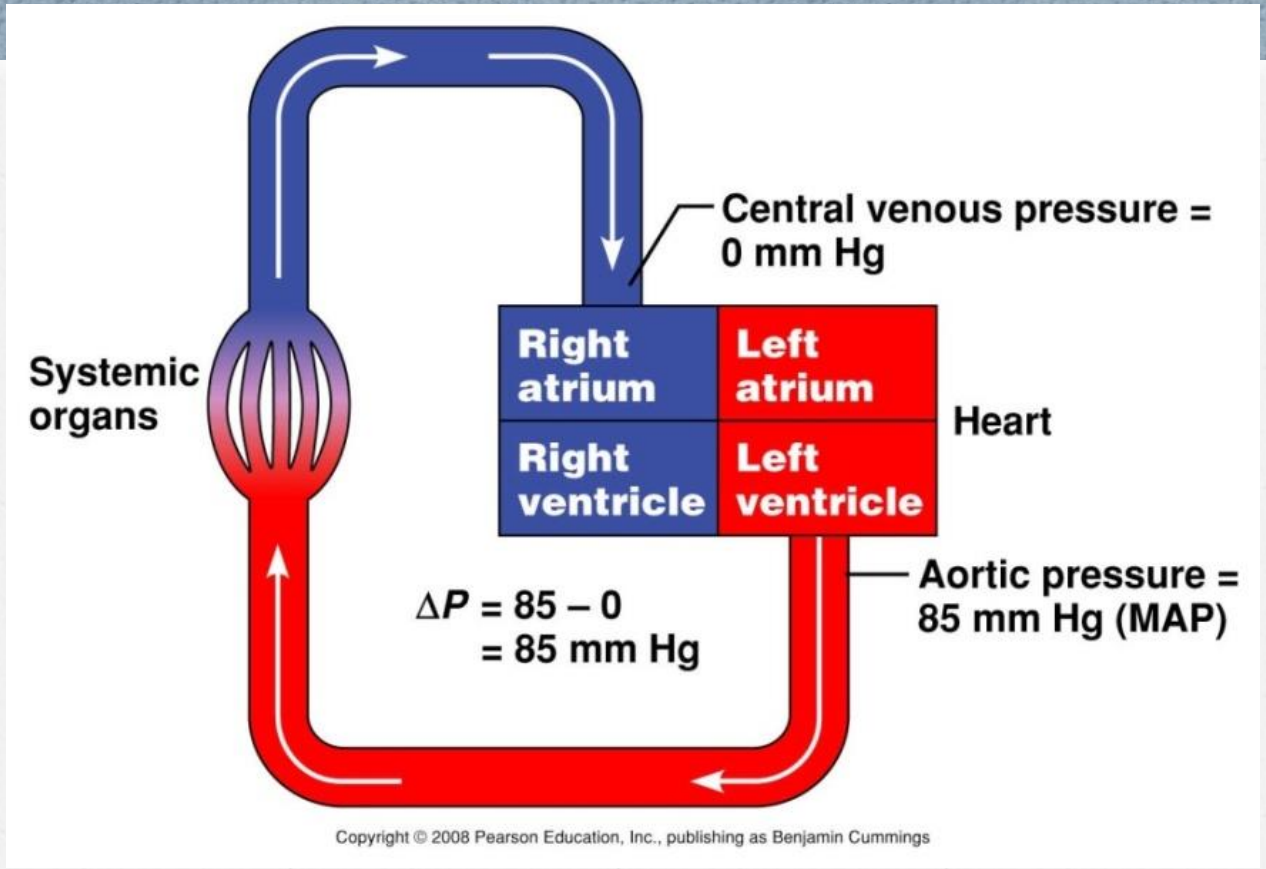
Figure 14.8

Physical laws governing blood flow and blood pressure

Flow of blood through out body =

pressure gradient within vessels X resistance to flow





Pressure gradient:

aortic pressure – central venous pressure

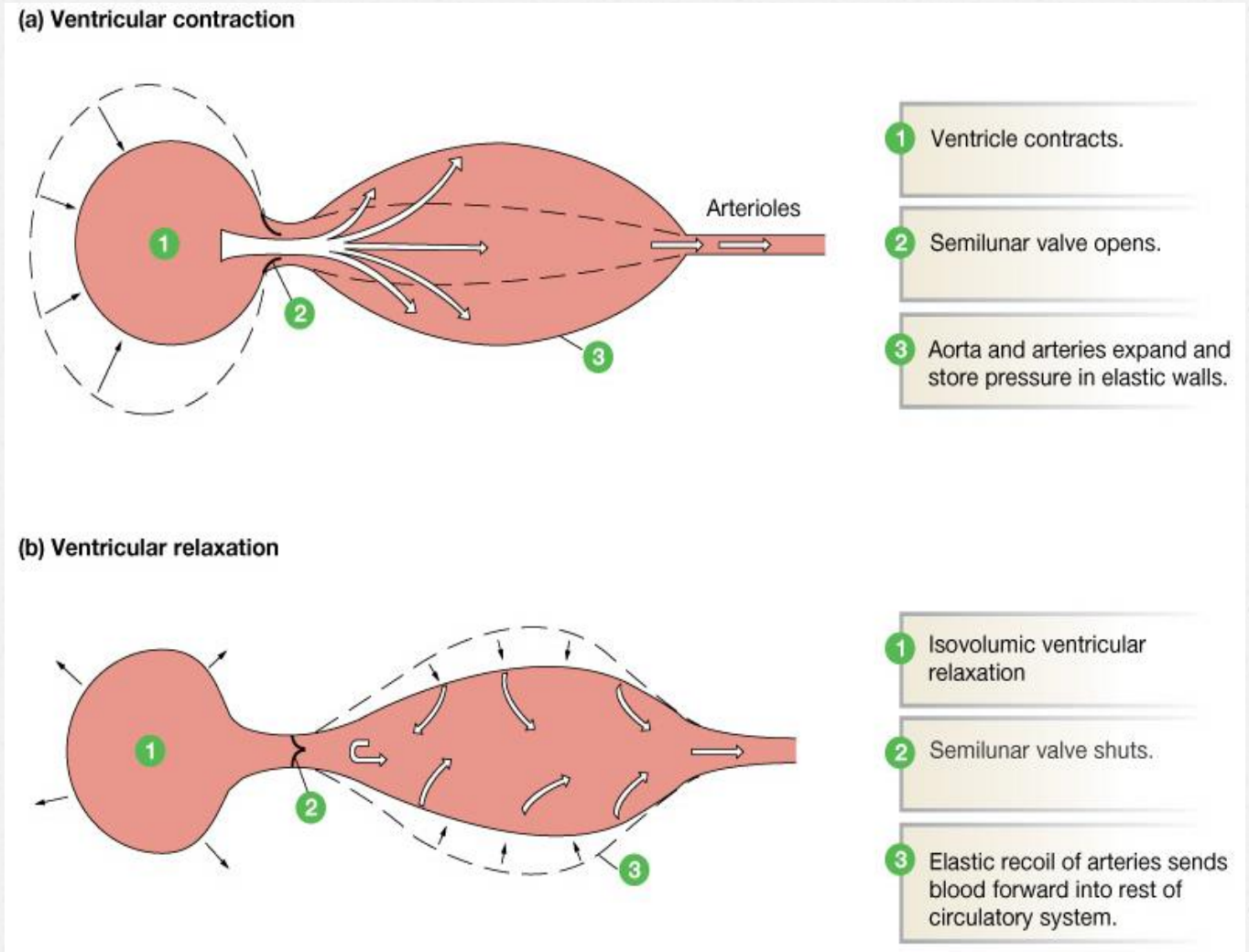
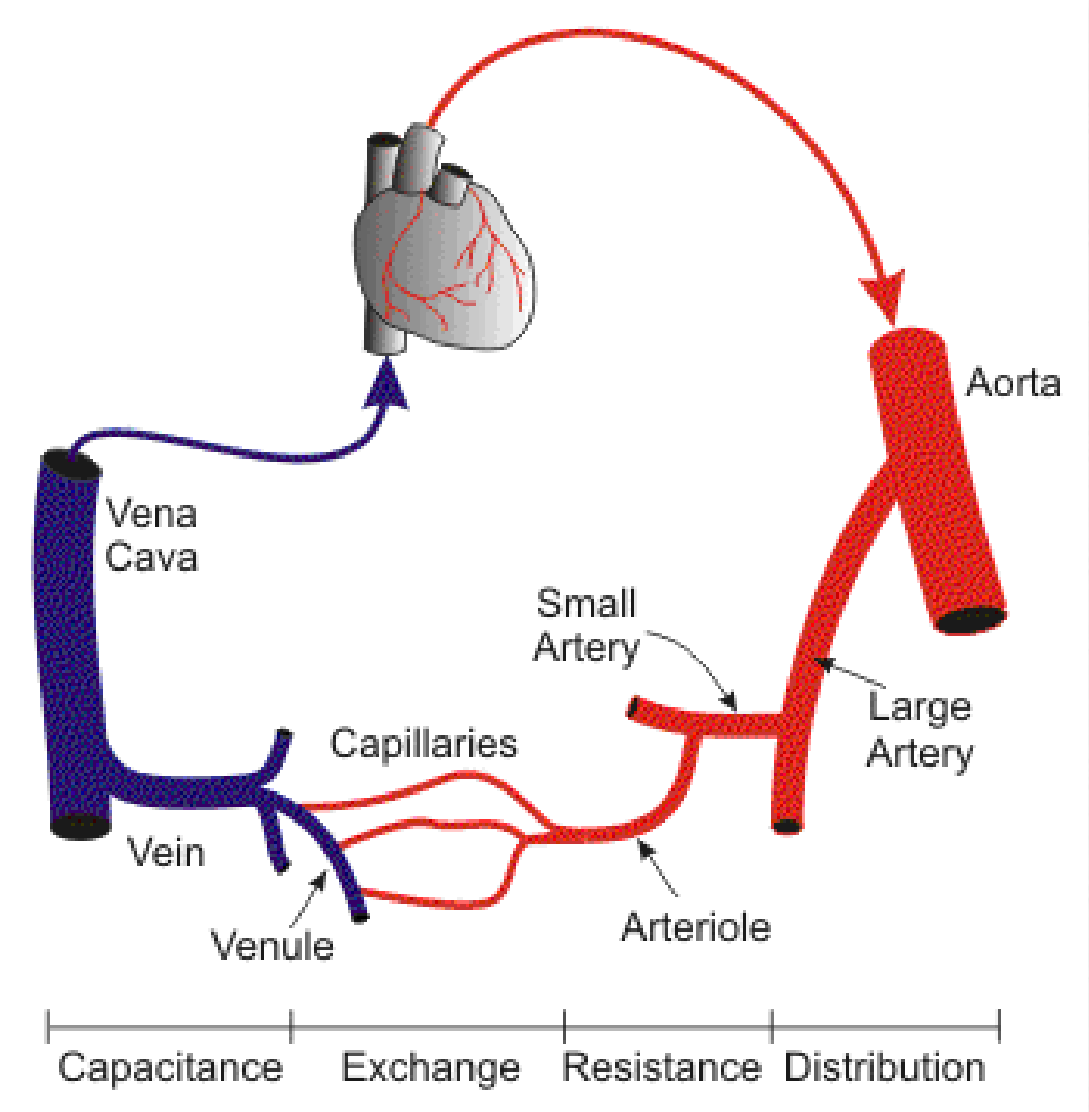
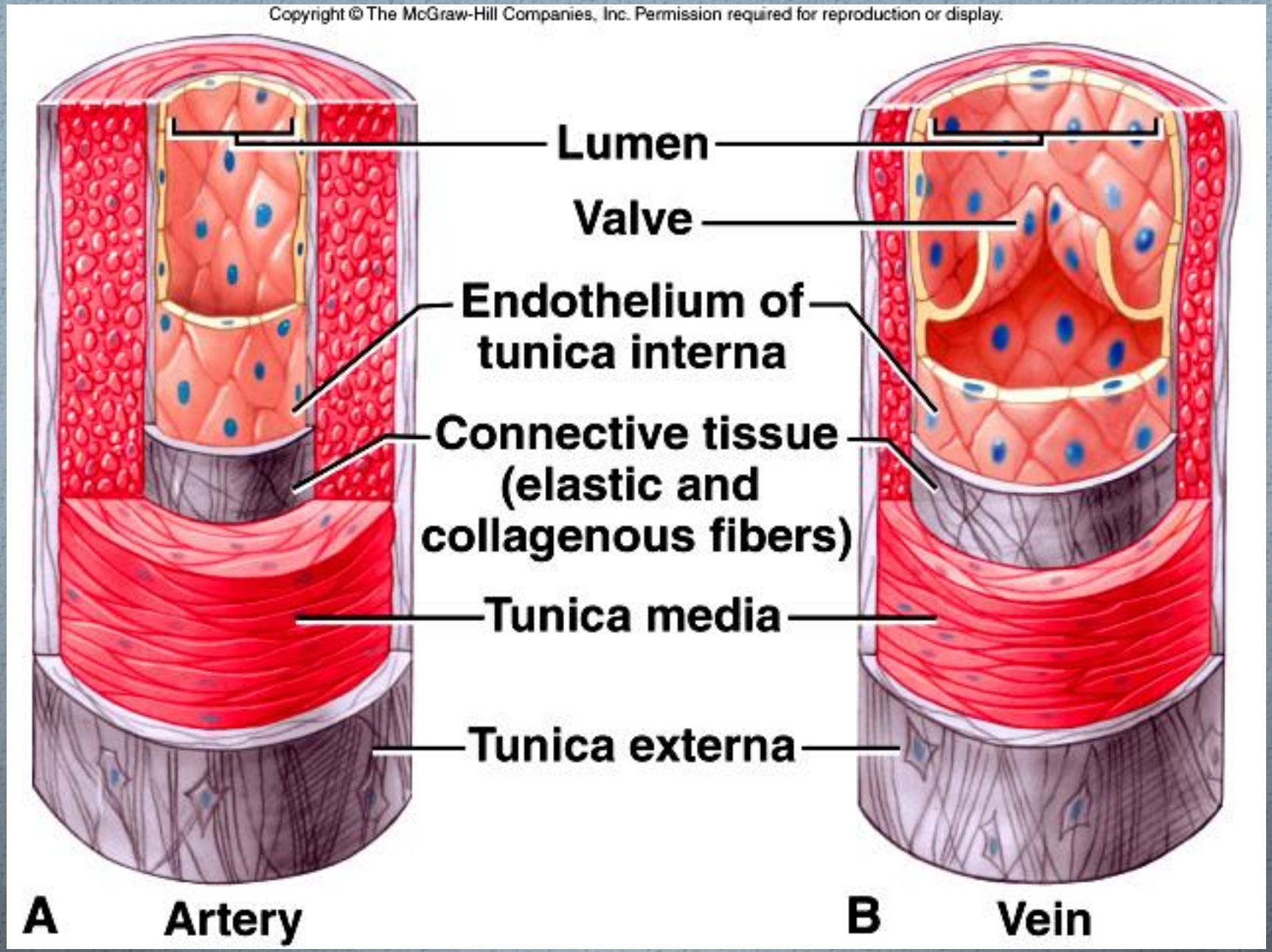


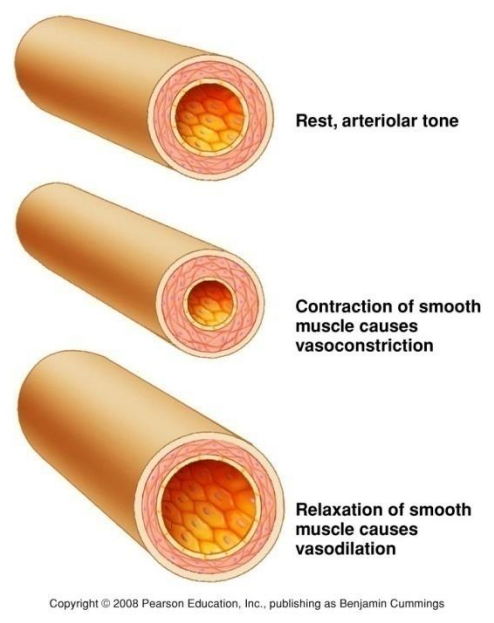
Figure 15-4: Elastic recoil in the arteries


Aorta
Vena
Cava
Small
Artery
Large
Artery
Capillaries
Vein
Venule
Arteriole
Capacitance
Exchange
Resistance
Distribution



Regulation of blood flow in arteries

- It is important to adjust blood flow to organ needs → Flow of blood to particular organ can be regulated by varying resistance to flow (or blood vessel diameter)
- Vasoconstriction of blood vessel smooth muscle is controlled both by the ANS and at the local level.
- Four factors control arterial flow at the organ level:
  - change in metabolic activity
  - changes in blood flow
  - stretch of arterial smooth muscle
  - local chemical messengers



Intrinsic control of local arterial blood flow

- Change in metabolic activity
  - Usually linked to CO_2 and O_2 levels (↑ CO_2 → vasodilation →↑ blood flow) intrinsic control
- Changes in blood flow

- decreased blood flow → increased metabolic wastes → vasodilation

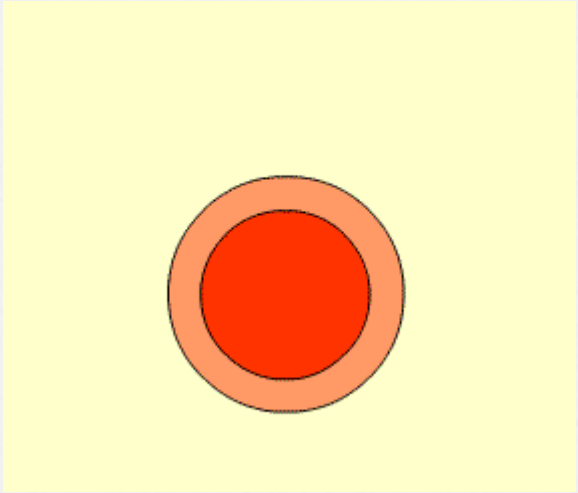
- Stretch of arterial wall = myogenic response

- Stretch of arterial wall due to increased pressure → reflex constriction

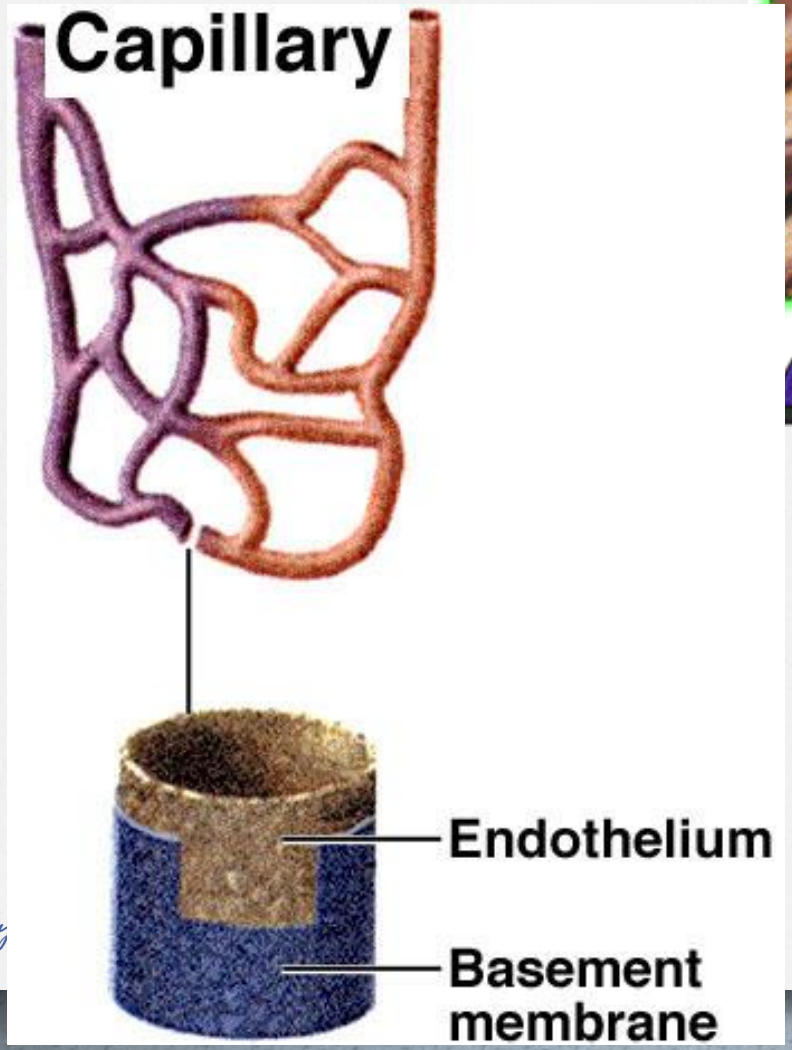
- Locally secreted chemicals can promote vasoconstriction or most commonly vasodilation

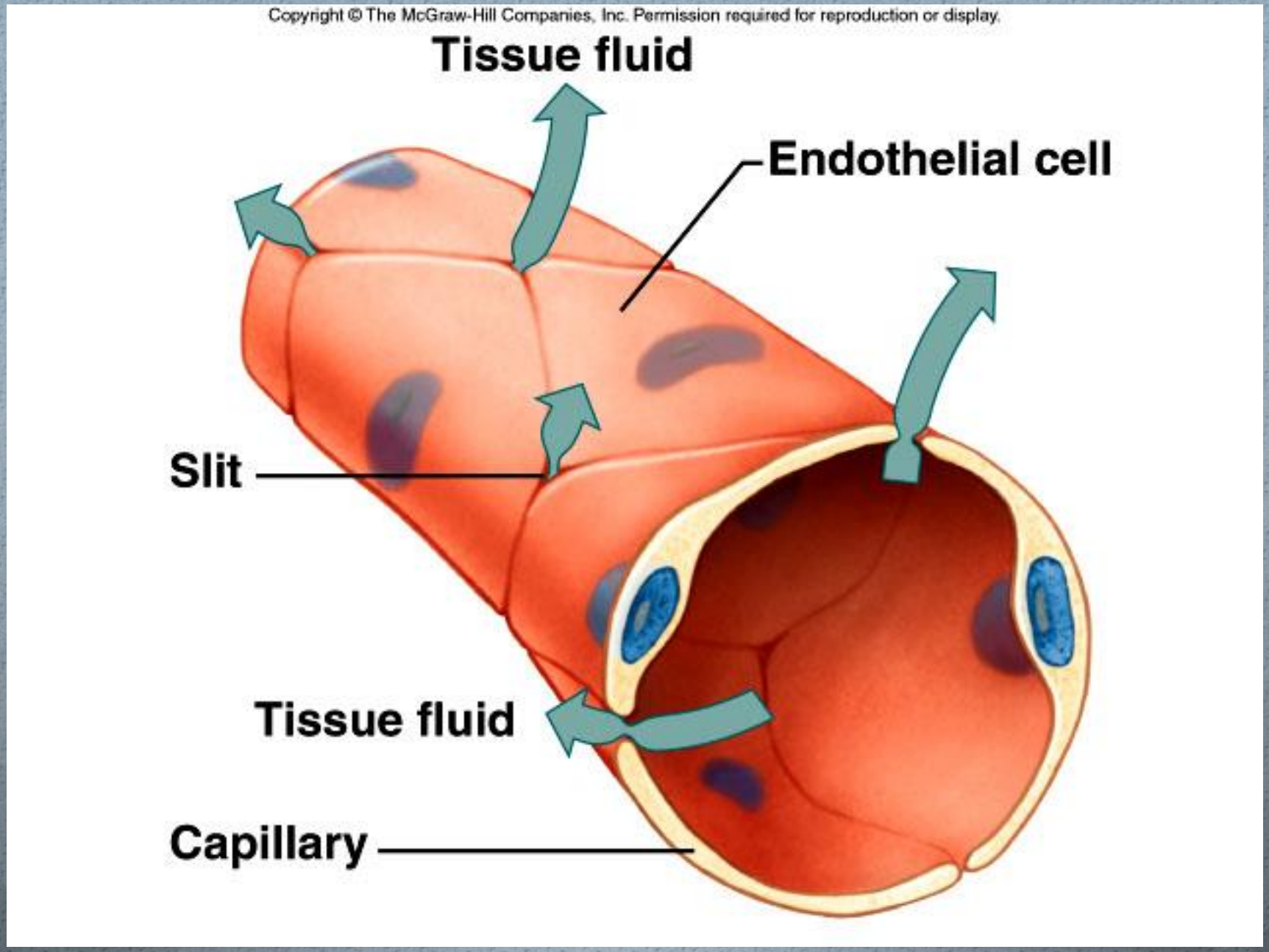
- inflammatory chemicals, (nitric oxide, CO_2)

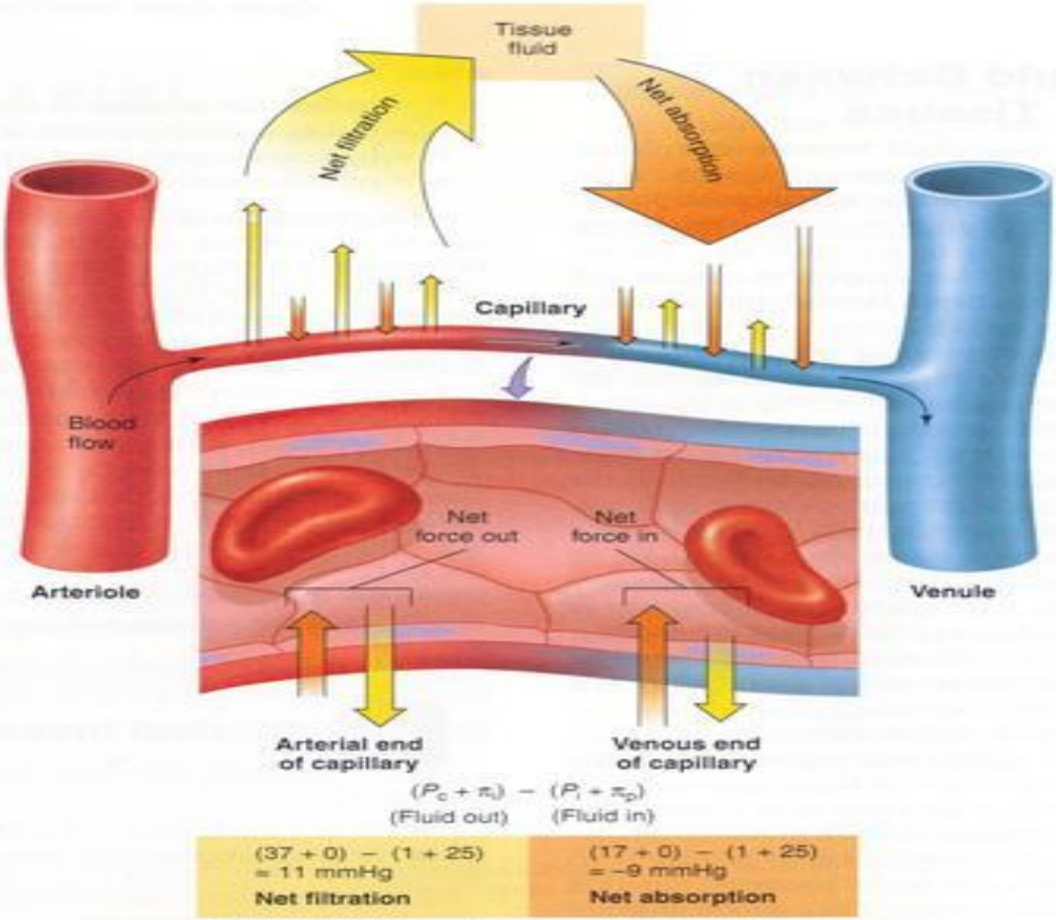
Artery in systole and diastole



Kapiler



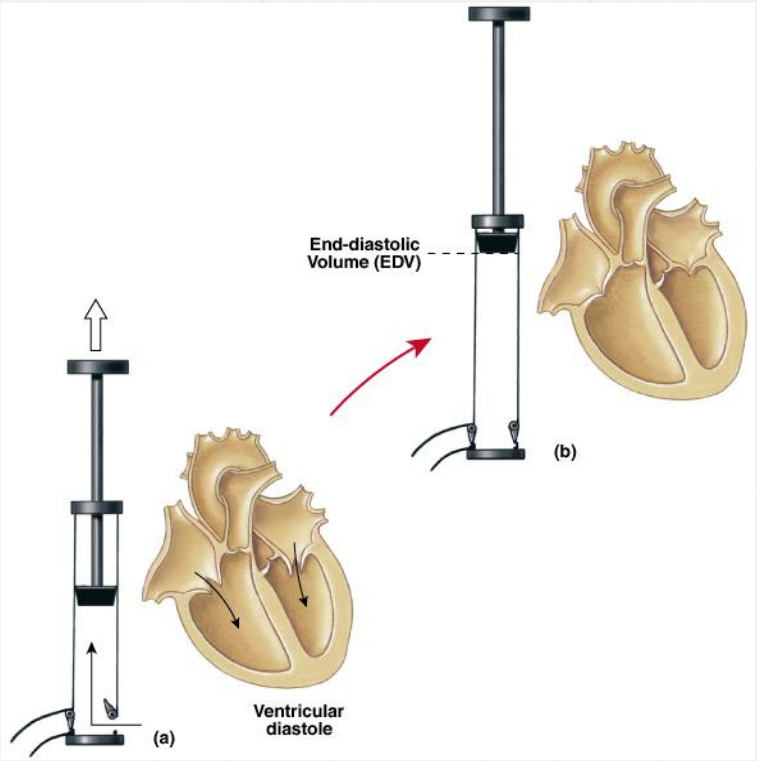


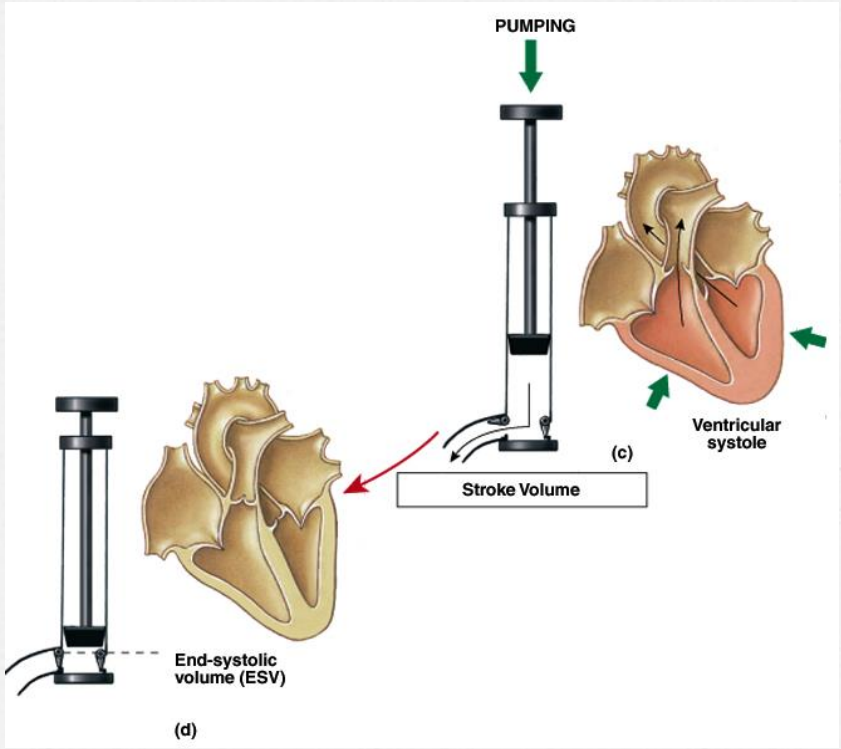

Tissue fluid
Net filtration
Net absorption
Capillary
Blood flow
Arteriole
Venule
Net force out
Net force in
Arterial end of capillary
Venous end of capillary
$(P_c + \pi_i) - (P_i + \pi_p)$
(Fluid out) (Fluid in)
(37 + 0) − (1 + 25) = 11 mmHg
Net filtration
(17 + 0) − (1 + 25) = −9 mmHg
Net absorption
Where P_c = hydrostatic pressure in the capillary
π_i = colloid osmotic pressure of interstitial fluid
P_i = hydrostatic pressure of interstitial fluid
π_p = colloid osmotic pressure of blood plasma

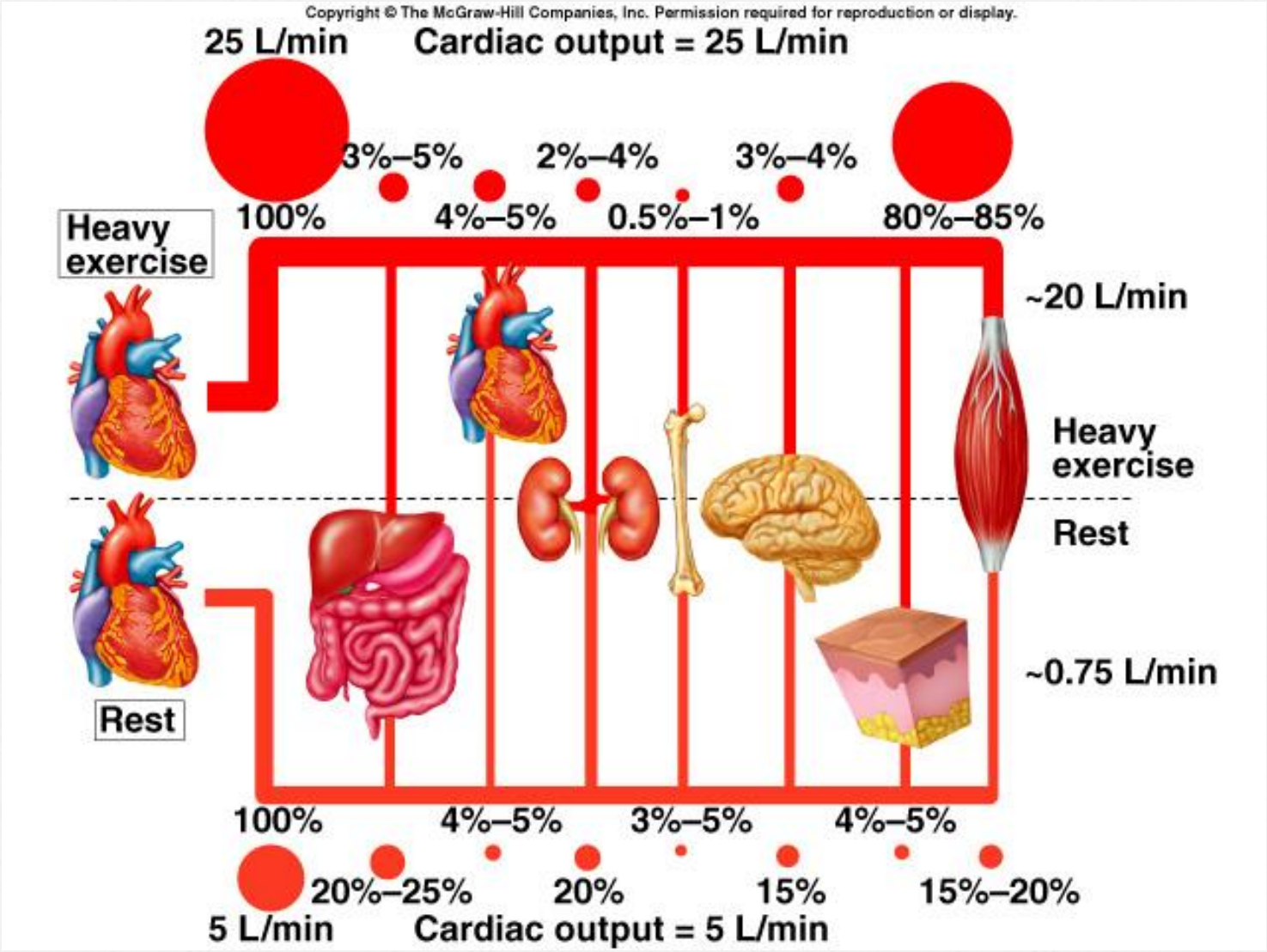
VOLUME DARAH

Stroke volume
End-diastolik volume
End-sistolik volume
Cardiac output
Ejection fraction

POMPA JANTUNG



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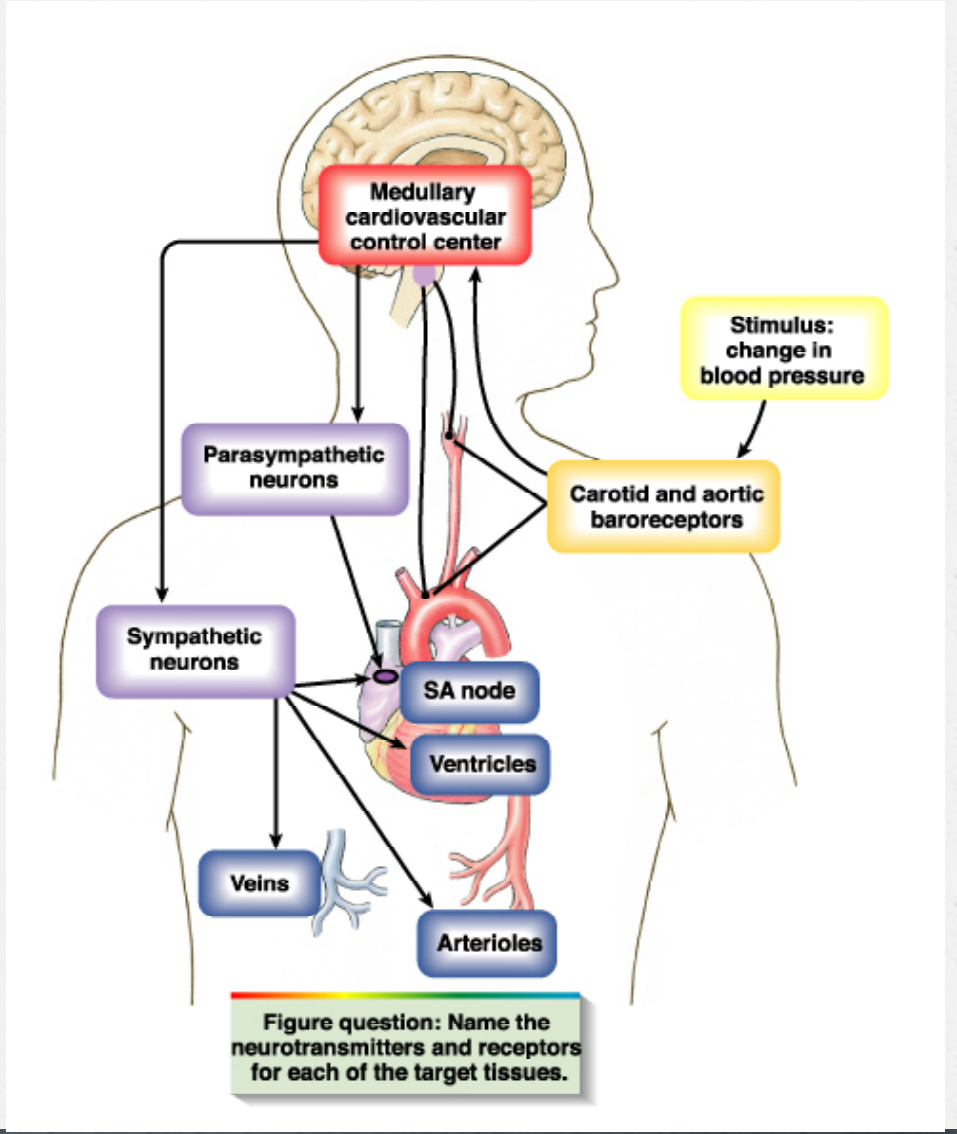
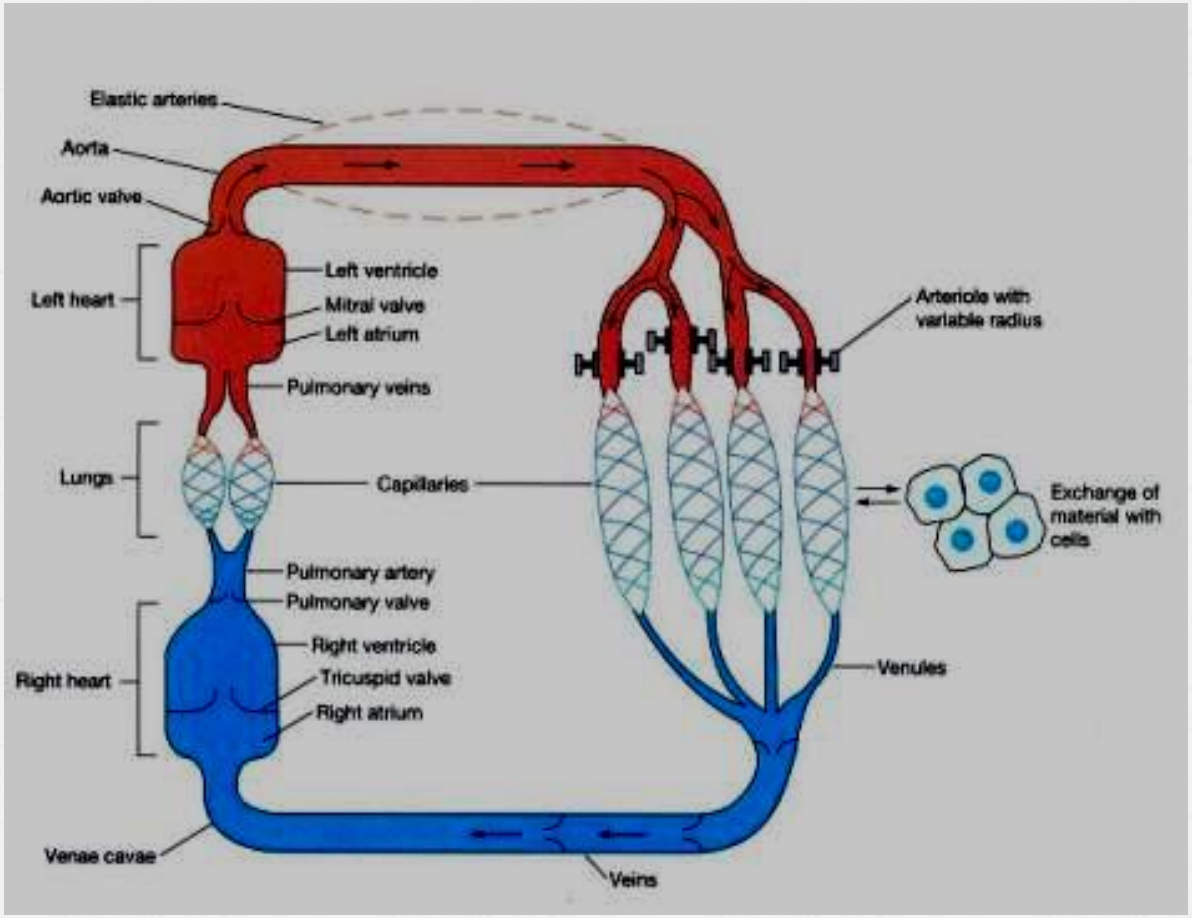
25 L/min
Cardiac output = 25 L/min
3%–5%
2%–4%
3%–4%
100%
4%–5%
0.5%–1%
80%–85%
Heavy exercise
~20 L/min
Heavy exercise
Rest
~0.75 L/min
Rest
100%
4%–5%
3%–5%
4%–5%
20%–25%
20%
15%
15%–20%
5 L/min
Cardiac output = 5 L/min

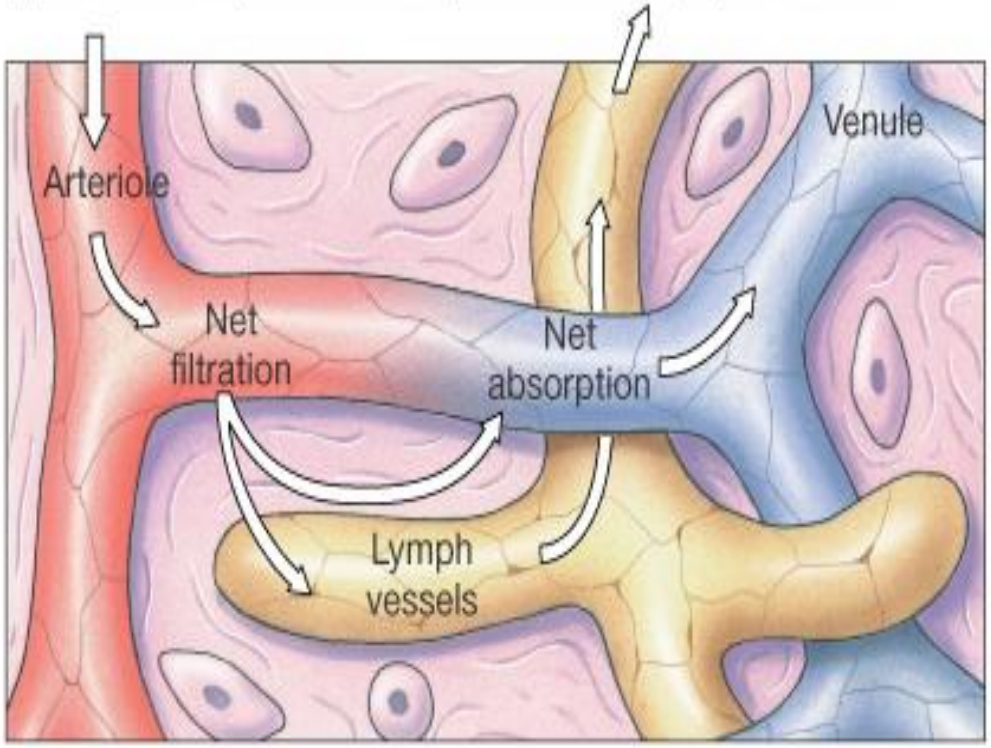
Regulation of Blood Pressure

- Main coordinating center is in the medulla oblongata of the brain; medullary cardiovascular control center
- Reflex control of blood pressure
  - Baroreceptor reflex




Elastic arteries
Aorta
Aortic valve
Left heart
Left ventricle
Mitral valve
Left atrium
Pulmonary veins
Lungs
Capillaries
Pulmonary artery
Pulmonary valve
Right heart
Right ventricle
Tricuspid valve
Right atrium
Venae cavae
Veins
Arteriole with variable radius
Exchange of material with cells
Venules

(b) Relationship between capillaries and lymph vessels



The excess water and solutes that filter out of the capillary are picked up by the lymph vessels and returned to the circulation.

fungsi

HEMODINAMIKA

- Variabel-variabel fisik yang berhubungan dengan bagaimana darah mengalir
- Prinsip-prinsip dasar fluida cairan
- Komponen dinamika cairan dalam tabung
  - Energi :
    - tekanan atau beda tekanan antara 2 tempat
    - Gaya per satuan luas
    - Densitas cairan
    - Gravitasi
    - Panjang tabung

ALIRAN CAIRAN MELALUI TABUNG

1. ALIRAN LAMINAR

- Sebagai arus yang paralel
- Arus yg tepat berdekatan dgn dinding pembuluh stasioner, yg mendekati pusat kecepatan lbh tinggi, maksimum di pusat tabung
  - Cairan Newtonian (mis. Air) berbentuk parabola dg ujung tajam,
  - Non-Newtonian (mis. Darah) ujung lbh tumpul
    - Sel-sel darah mengalir sejajar dgn arah aliran & bergerak ke tengah
    - Memudahkan masuknya darah ke arteriola

ALIRAN CAIRAN MELALUI TABUNG

2. ALIRAN TURBULEN

- Ketika kecepatan mencapai nilai kritis (Reynolds)
  - Angka Reynolds (Re) = $(vD\rho)/\eta$
    - V-kecepatan, D-diameter, ρ-densitas, η-viskositas
  - Re mencapai > 200-400 terjadi turbulen saat di percabangan arteri kmd hilang ketika sdh lurus
  - Re kritis aliran turbulen pd pembuluh darah lurus 2000
  - Aliran ini menyebabkan kehilangan energi sbg bunyi & panas

ALIRAN CAIRAN MELALUI TABUNG

- Keadaan2 yg menyebabkan aliran turbulen
  - Kec aliran yg tinggi (aorta proximal dan a. pulmonaris)
  - Pulsasi arteri
  - Perubahan diameter mendadak
  - Pembuluh darah dg diameter besar

3. ALIRAN *SINGLE-FILE*

- Aliran dgn perubahan btk SDM (aliran berbentuk bolus)

PENGUKURAN ALIRAN DARAH (FLOWMETER)

- ELECTROMAGNETIC FLOWMETER
  - Tdk invasif
  - Dpt merekam perubahan aliran <1/100 per detik
  - Dpt merekam aliran pulsatil maupun stabil
  - Tradisional:
    - Menempelkan elektroda di pembuluh darah yg dikelilingi oleh medan magnet kuat
    - Kec aliran darah proporsional dg arus listrik yg dihasilkan antara 2 elektroda dan direkam dg voltmeter
  - Modern:
    - Menggunakan probe yg ditempelkan disekeliling pembuluh

PENGUKURAN ALIRAN DARAH (FLOWMETER)

- ULTRASONIC DOPPLER FLOWMETER
  - Keuntungan sama dg elektromagnetik
  - Menempelkan kristal piezoelektrik kecil di dinding pembuluh darah
    - Ketika diberi aliran listrik akan memancarkan ultrasound dg frekuensi bbrp ratus ribu siklus/detik ke arah darah yg mengalir
    - Bunyi akan dipantulkan oleh SDM yg mengalir dg frekuensi yg lbh rendah
    - Kecepatan merupakan selisih frekuensi antara yg dipancarkan dg yg dipantulkan kembali

Viskositas

- Pada Newtonian fluid viskositas tdk tergantung dimensi tabung dan kecepatan aliran ok memenuhi aliran laminar.
- Tahanan intrinsik thd aliran disebabkan krn adanya gesekan antara lapisan-lapisan yg berdekatan yg akan menentukan viskositasnya

Viskositas

- Non-Newtonian Fluid (DARAH)
- Punya sel-sel dlm cairan, shg viskositas dan tahanan aliran tergantung :
  - Kecepatan aliran, hematokrit, diameter pembuluh darah kecil, sumbu SDM dan kemampuan SDM utk berubah bentuk
- Pengukuran dgn Viskometer Rotasional yg dpt menganalisis sifat-sifat rheologis darah

Viskositas

- Viscositas air pada 20°C adalah 1mPascal.s & hanya ~0·69mPa.s pada 37°C
- Viscositas plasma ~1·2mPa.s pada 37°C (krn albumin & globulin)
- Viskositas darah keseluruhan didominasi oleh hematokrit (jika 47% adalah ~2·8mPa.s)
  - Jk hematokrit naik sampai 60 atau 70 (polisitemia) mk viskositas akan naik 10x lipat
- Saling bertabrakan antara SDM menyebabkan viskositas mkn tinggi.
  - Tergantung fleksibilitas SDM

Efek Fahraeus - Lindqvist

- Jika darah dialirkan melalui tabung kaca, maka viskositas nyata akan konstan pada diameter tabung > 1 mm, jika diameter diturunkan hingga < 1mm maka viskositas akan menurun
  - Diduga krn perubahan orientasi SDM saat melewati diameter kecil tsb
  - SDM bergerak dg axis panjang paralel thd arah aliran, terjadi migrasi axis, perubahan bentuk dan rotasi membran yg akan mengubah darah menjadi emulsi dan menurunkan viskositas

Formasi Rouleaux

- Jika kecepatan aliran rendah maka shear rate rendah akan menimbulkan kecenderungan SDm membentuk agregasi (rouleaux) shg kecepatan akan meningkat.
- Pembentukan rouleaux ini tergantung pd konsentrasi protein molekul besar di plasma khususnya fibrinogen

Deformabilitas SDM

- Viskositas darah berbanding terbalik dgn deformabilitas SDM
- Btk SDM adalah bikonkaf dgn diameter 7 mikron
- Jika masuk kapiler yg berdiameter lebih kecil (3-7 mikron) berubah menjadi seprti peluru / parasut
- Perubahan btk tergantung pd konsentrasi Ca2+ dlm plasma
  - Jk O2 rendah, Ca2+ banyak masuk SDM, mejadi kaku shg viskositas naik

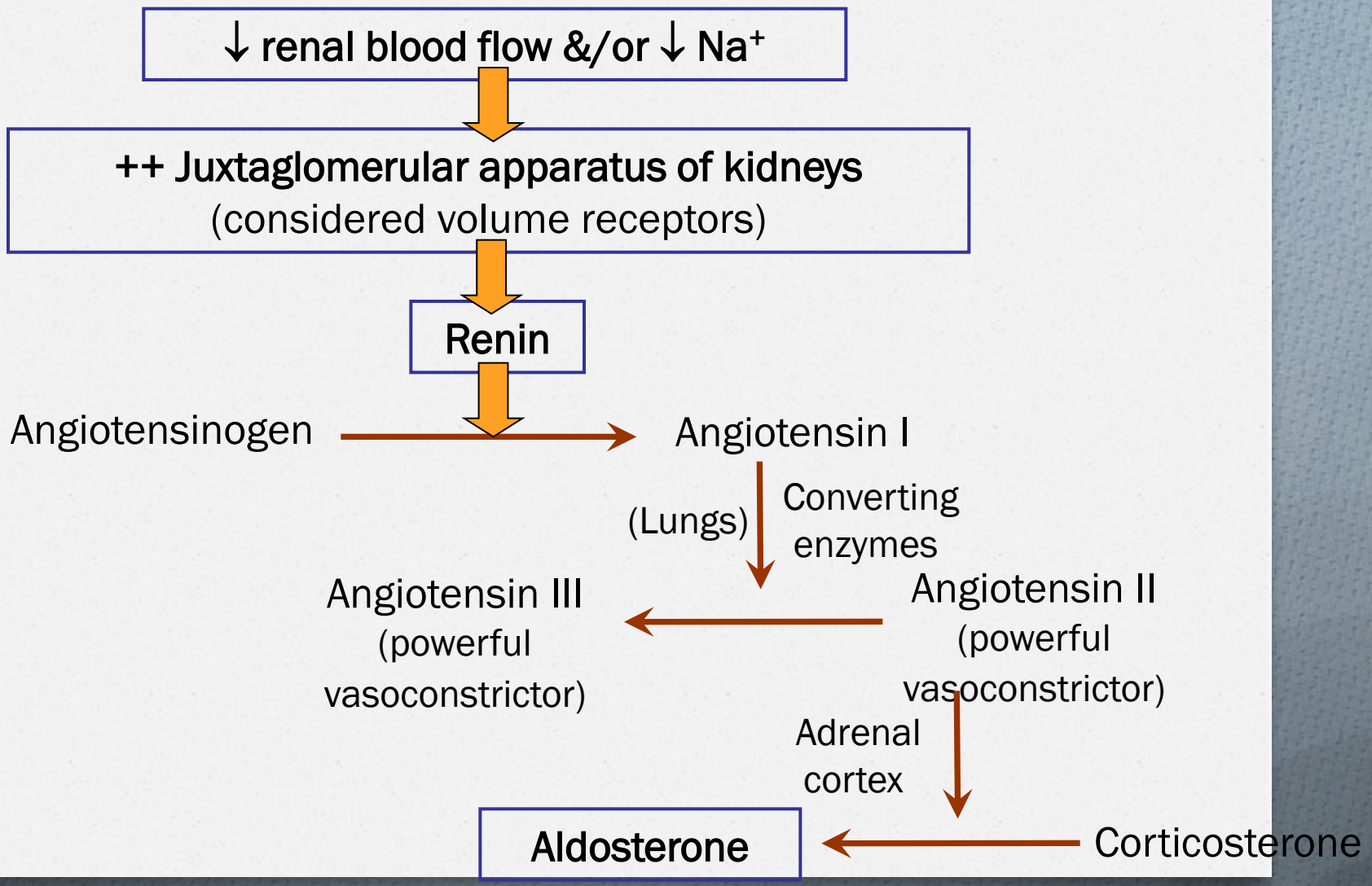
Regulation of Blood Volume:

- A long-term regulatory mechanism.
- Mainly renal:
  1. Renin-Angiotensin System.
  2. Anti-diuretic hormone (ADH), or vasopressin.
  3. Low-pressure volume receptors.

1. Renin-Angiotensin System:

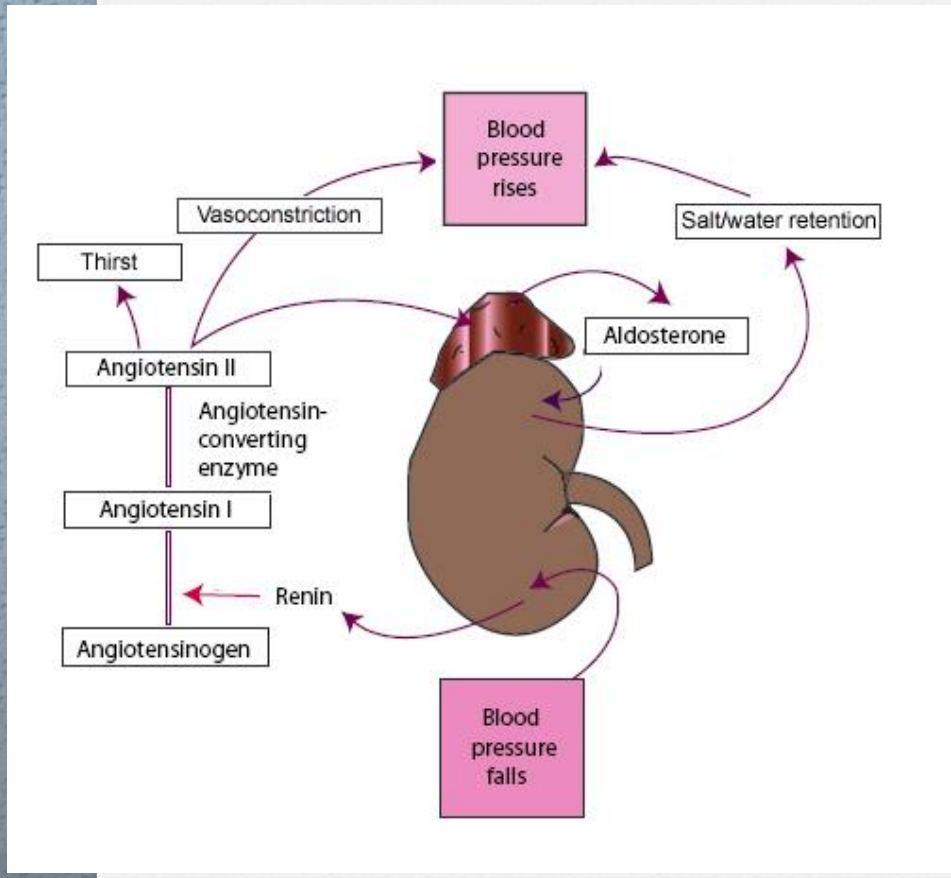
- Most important mechanism for Na^+ retention in order to maintain the blood volume.
- Any drop of renal blood flow &/or ↓ Na^+, will stimulate volume receptors found in juxtaglomerular apparatus of the kidneys to secrete **Renin** which will act on the **Angiotensin System** leading to production of **aldosterone**.

- # Renin-Angiotensin System:



- N.B. Aldosterone is the main regulator of Na^+ retention.

Control of blood volume



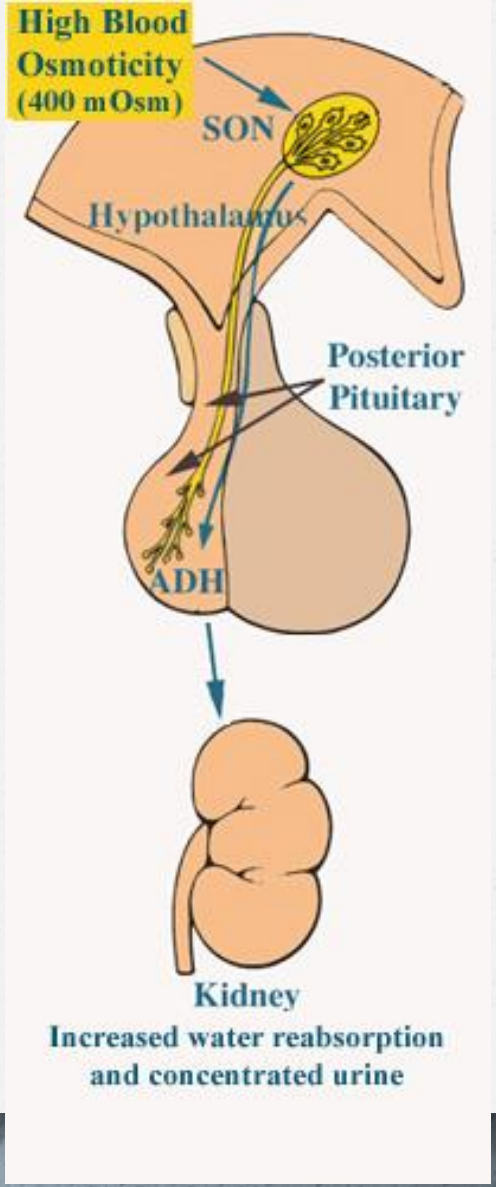
- Aldosterone:
  - Secretion by the adrenal cortex triggered by angiotensin II
  - Promotes sodium reabsorption by the kidney tubules (Na^+ moves back into the blood)
  - H_2O follows by osmosis
  - Whereas ADH promotes H_2O reabsorption only (in response to dehydration), aldosterone promotes reabsorption of both H_2O and salt (in response to ↓ BP)

2. Anti-diuretic hormone (ADH), or vasopressin:

- Hypovolemia & dehydration will stimulate the osmoreceptors in the hypothalamus, which will lead to release of ADH from posterior pituitary gland.
- ADH will cause water reabsorption at kidney tubules.

Control of blood volume

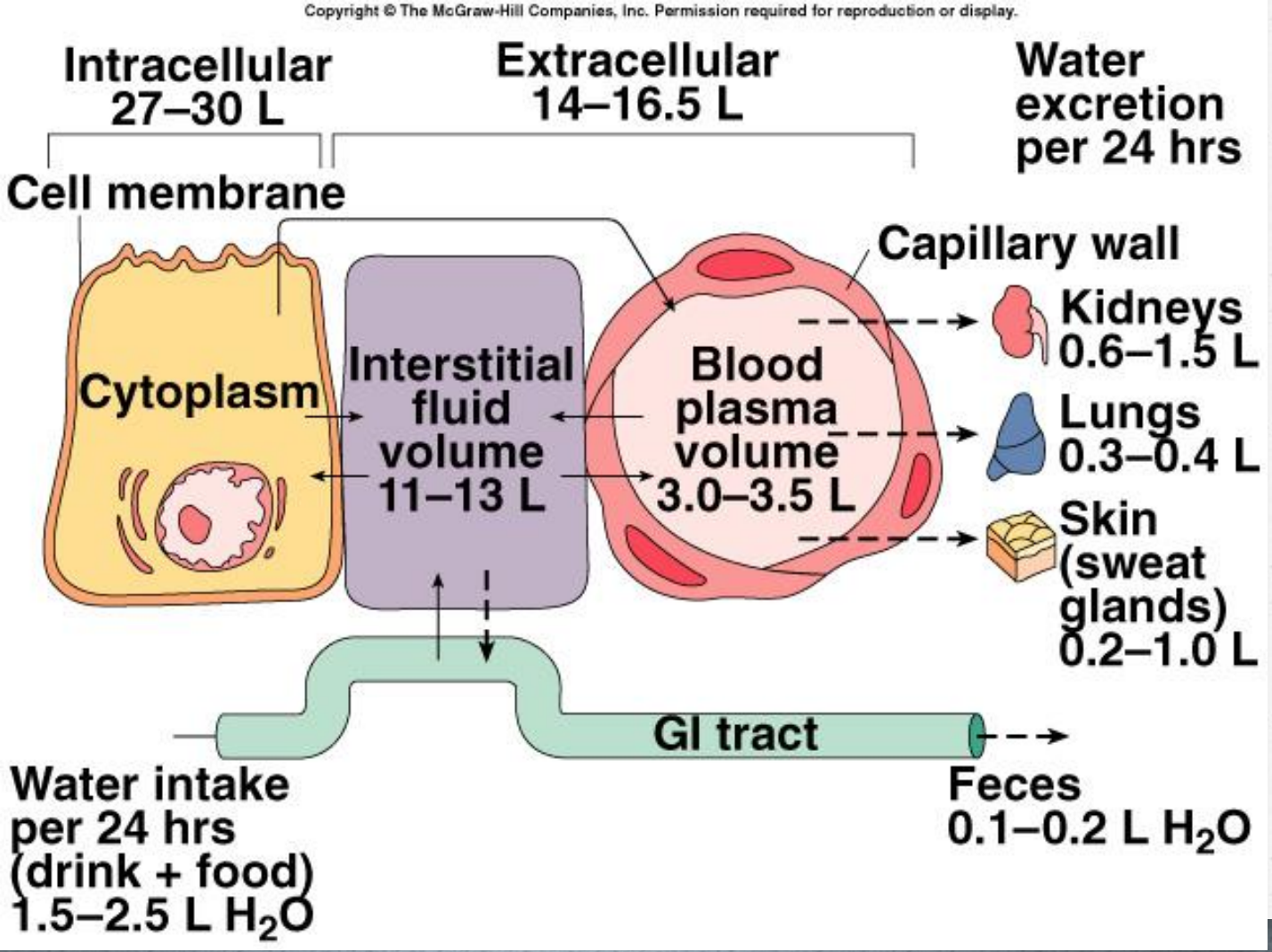
- Anti-diuretic hormone = ADH
- Secreted by the posterior pituitary in response to ↑blood osmolarity (often due to dehydration)
- Promote water reabsorption by the kidney tubules → H2O moves back into the blood → less urine formed

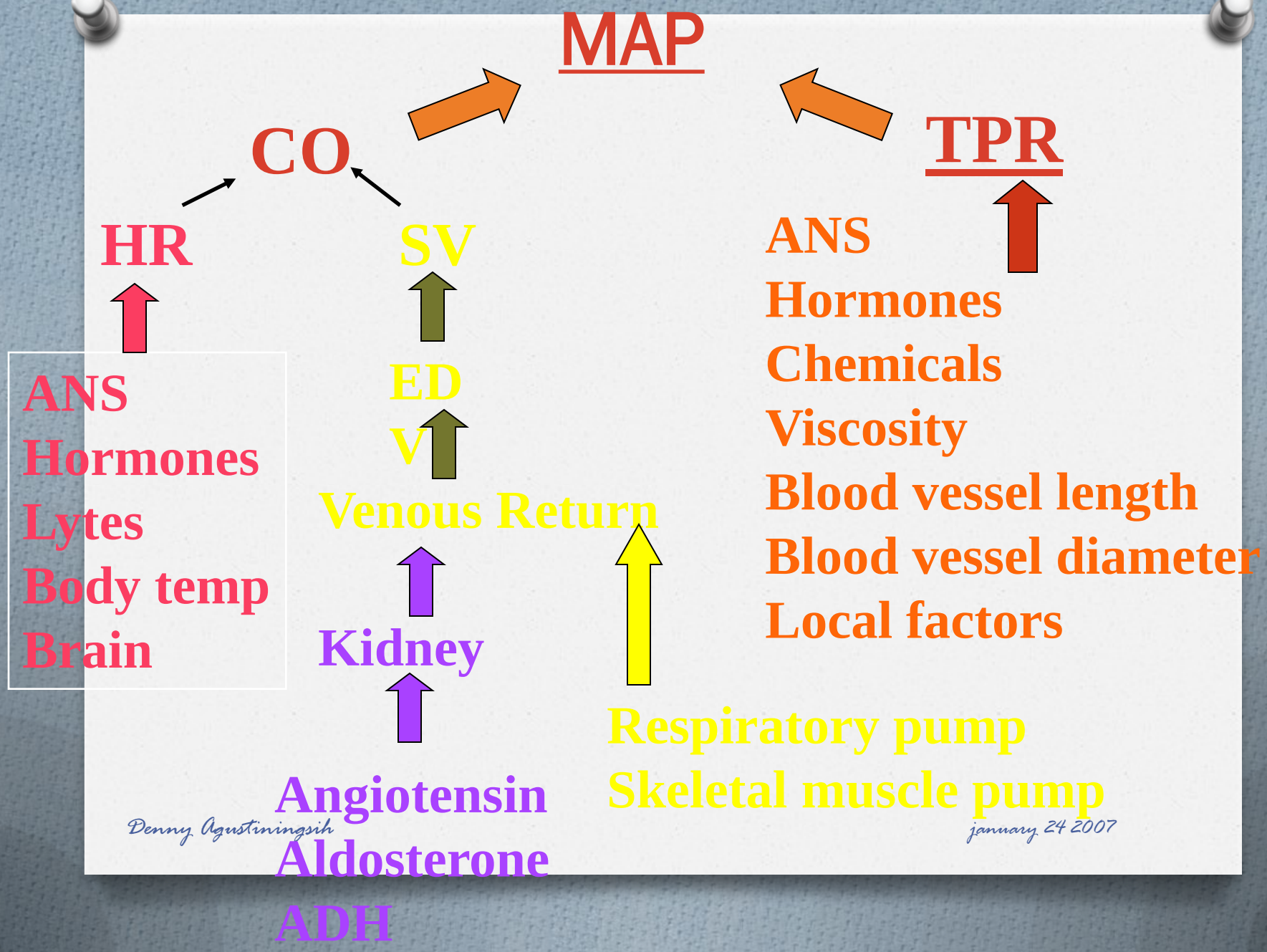


3. Low-pressure volume receptors:

- Atrial natriuritic peptide (ANP) hormone, is secreted from the wall of right atrium to regulate Na^+ excretion in order to maintain blood volume.

Blood Volume (continued)




MAP
CO
TPR
HR
SV
ANS
Hormones
Chemicals
Viscosity
Blood vessel length
Blood vessel diameter
Local factors
ANS
Hormones
Lytes
Body temp
Brain
ED
V
Venous Return
Kidney
Respiratory pump
Skeletal muscle pump
Angiotensin
Aldosterone
ADH
Denny Agustiningsih
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