Summer Pathophysiology Course 2001 – 2023
General medicine
Dentistry

Cardiovascular Pathophysiology 4
Hypertension and hypotension

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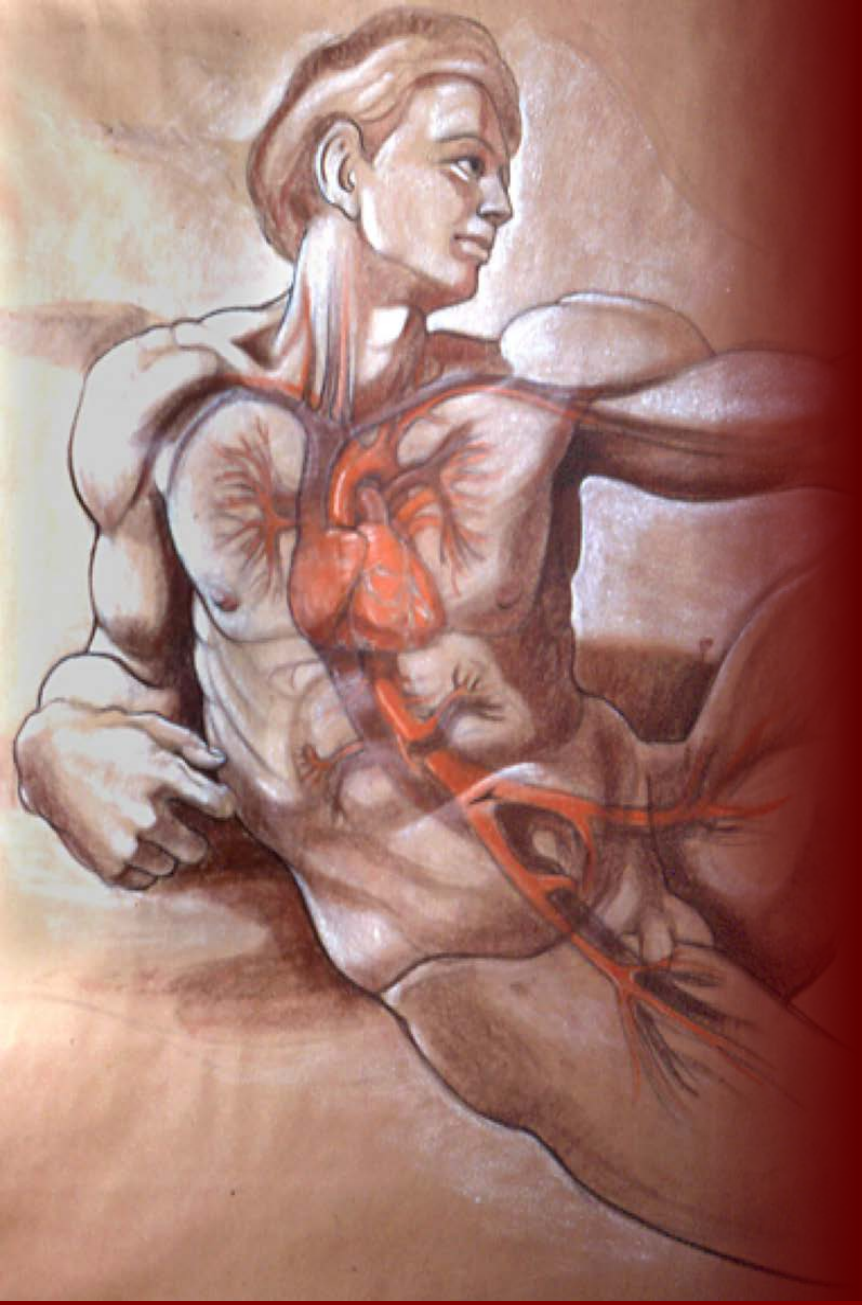
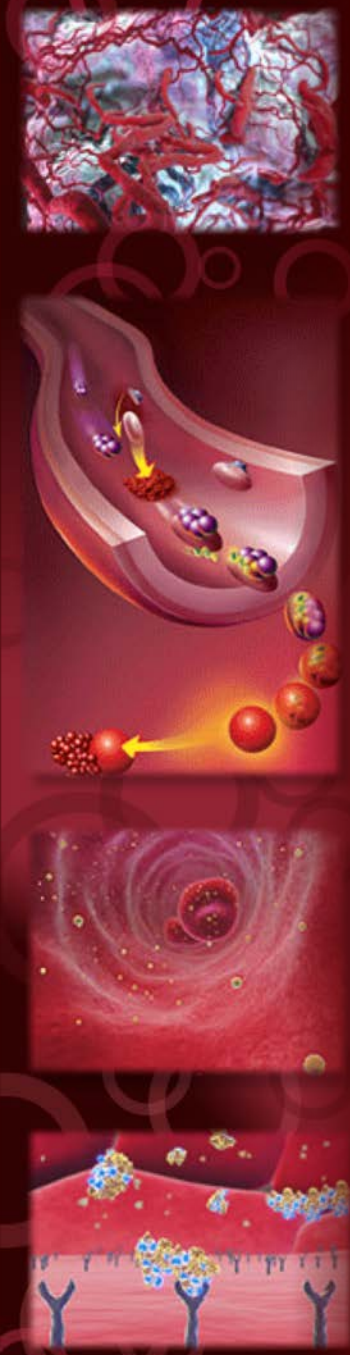
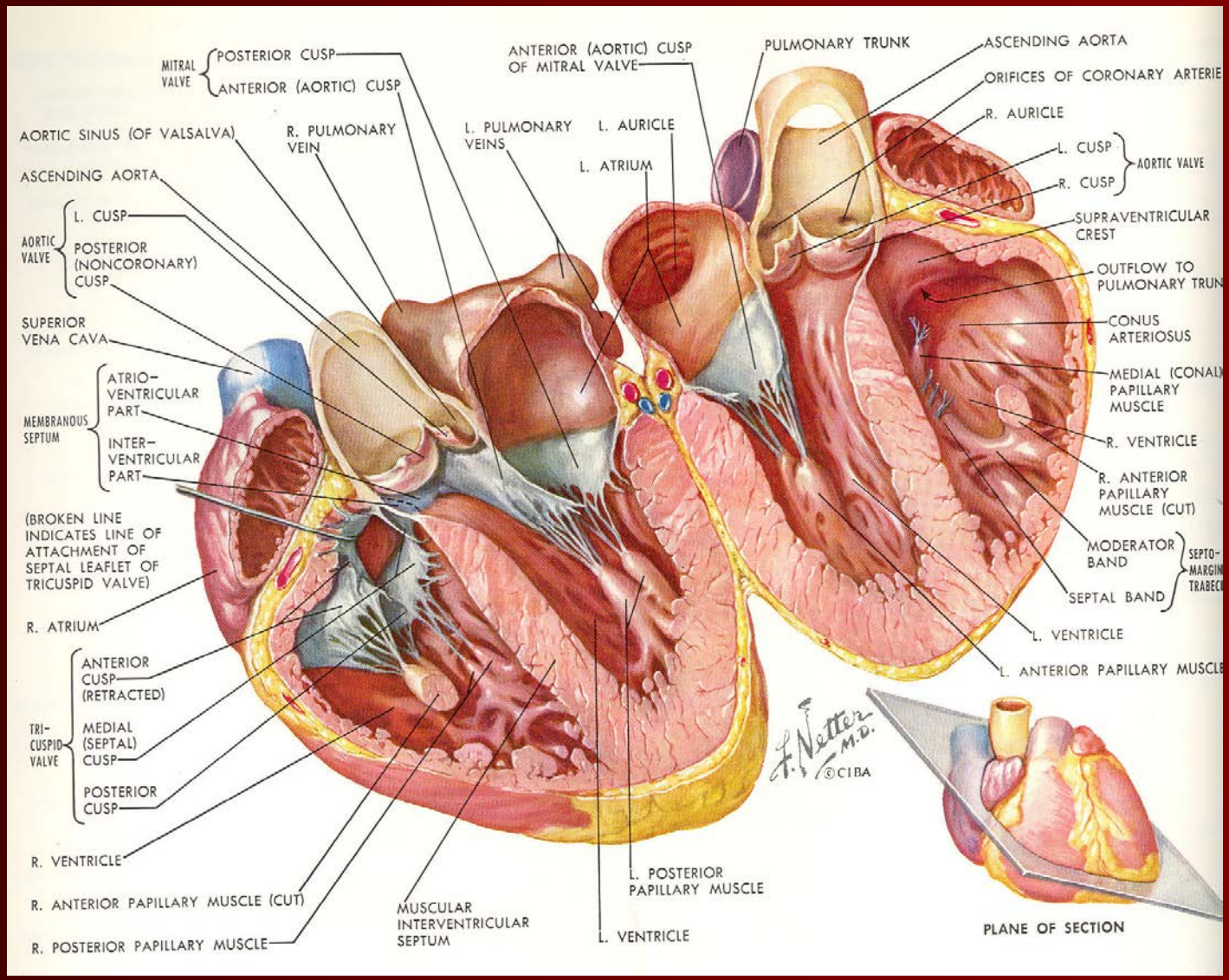
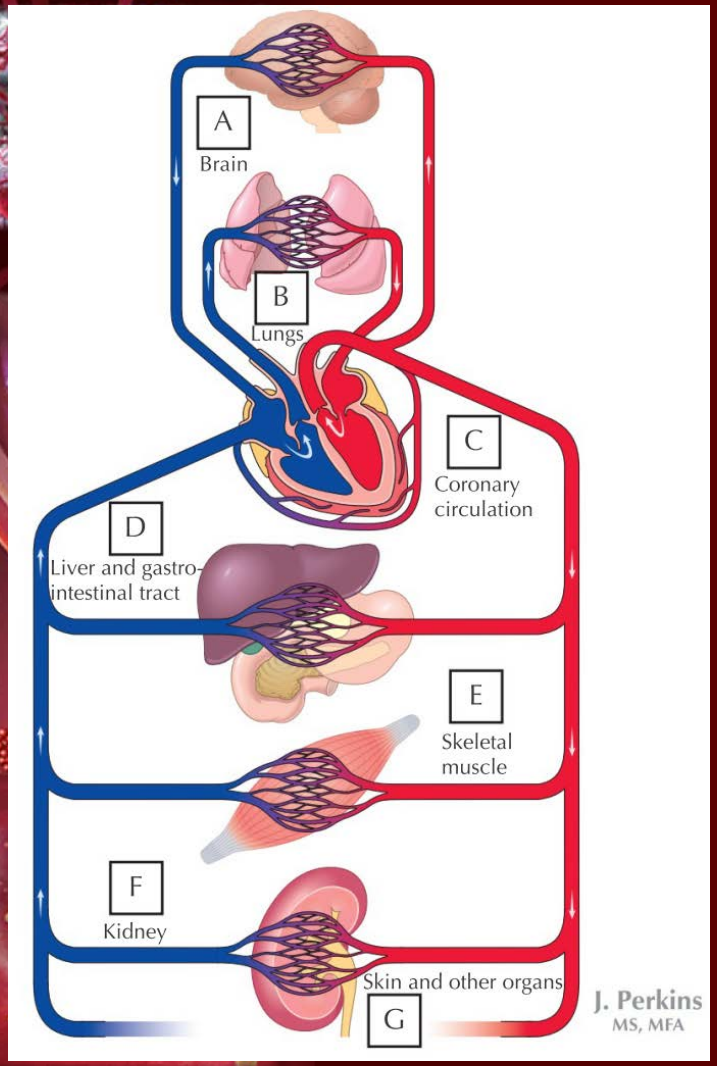


Physiology overview

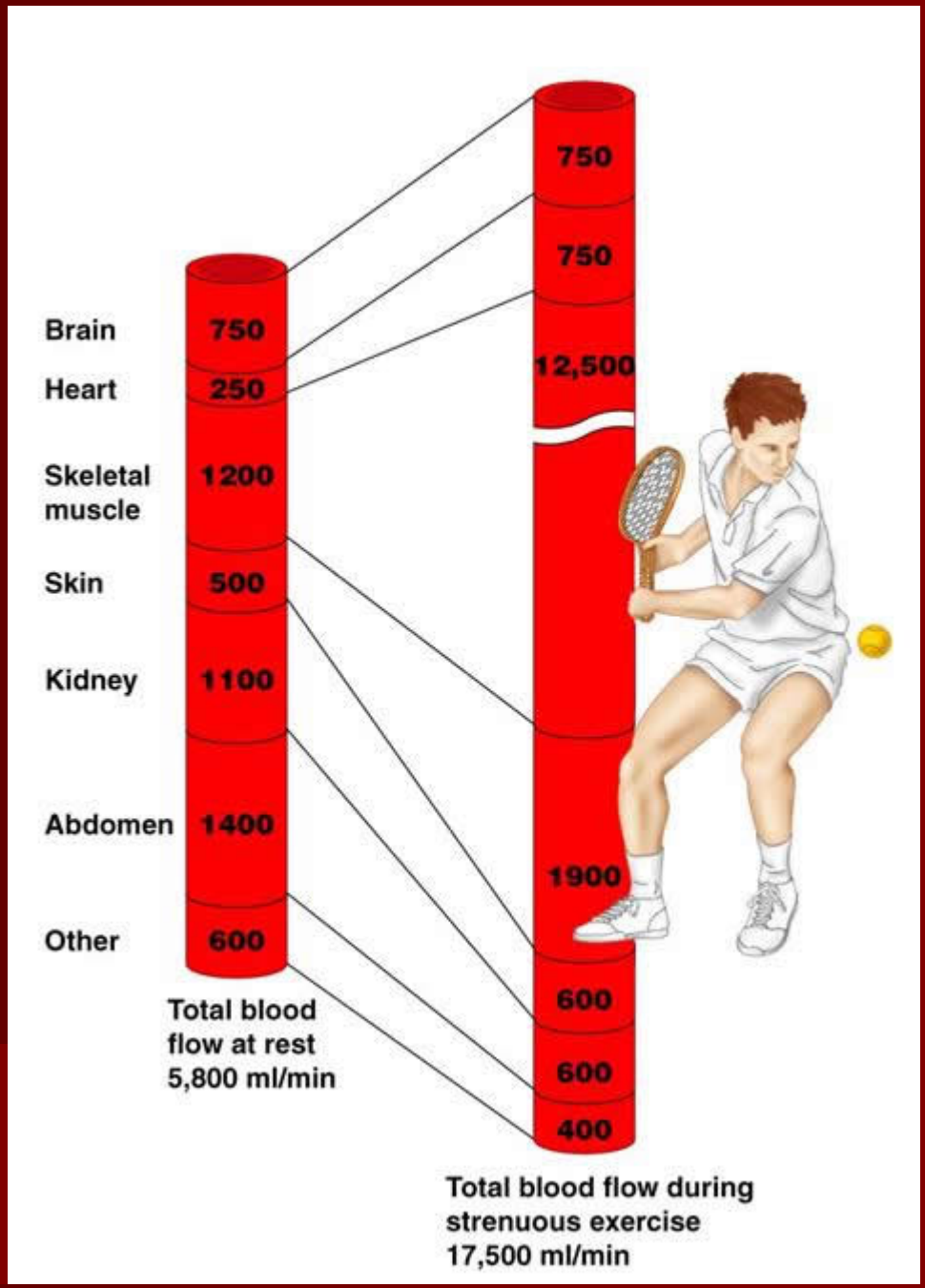
Cardiac pathology

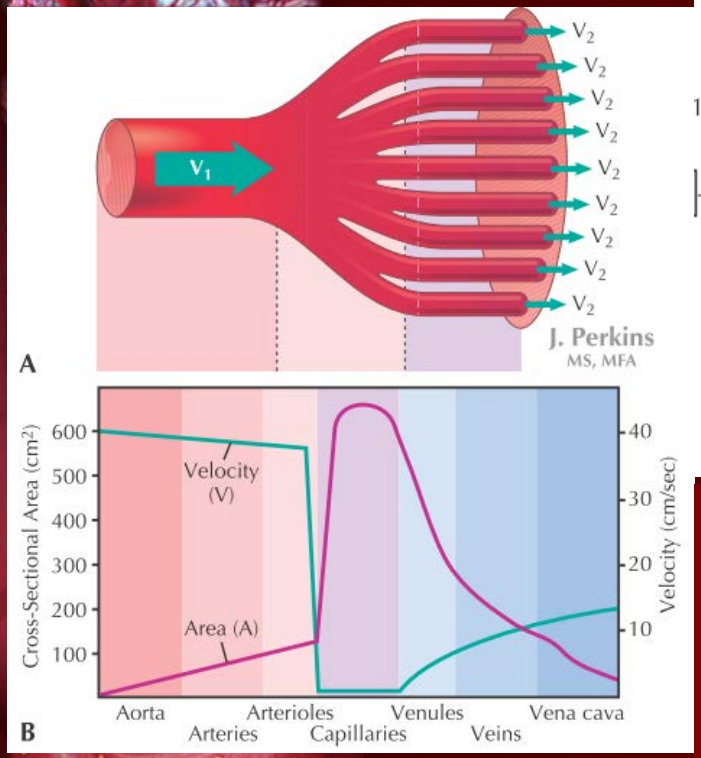






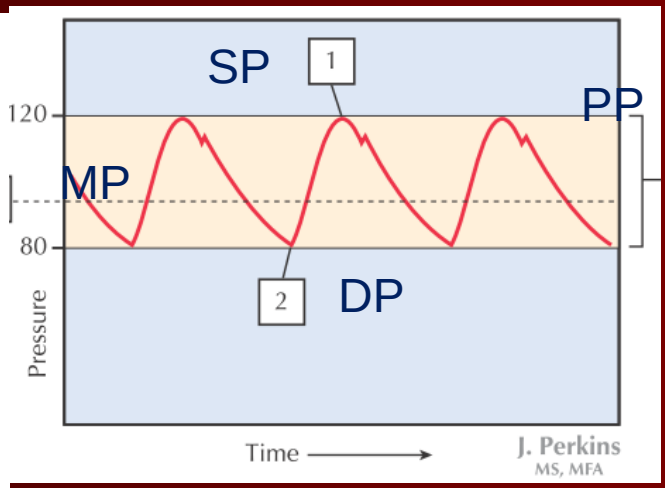
CO 5 L/min. A. Brain, 13%, B. Lungs, 100%
C. Coronary 4%, D. Liver + git 24%
E. Skeletal muscle, 21%, F. Kidneys, 20%
G. Skin and other organs, 18%



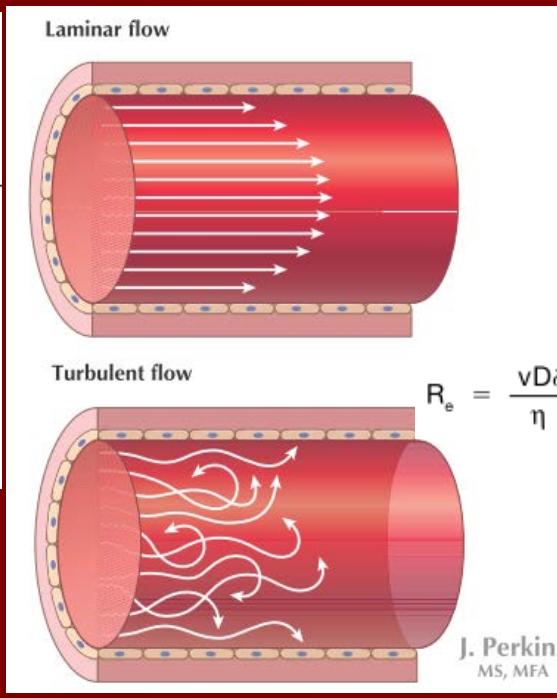


Velocity of flow in the large tube (V1) is the same as velocity of flow in each of the small tubes (V 2)

Q = vA or v = Q/A.

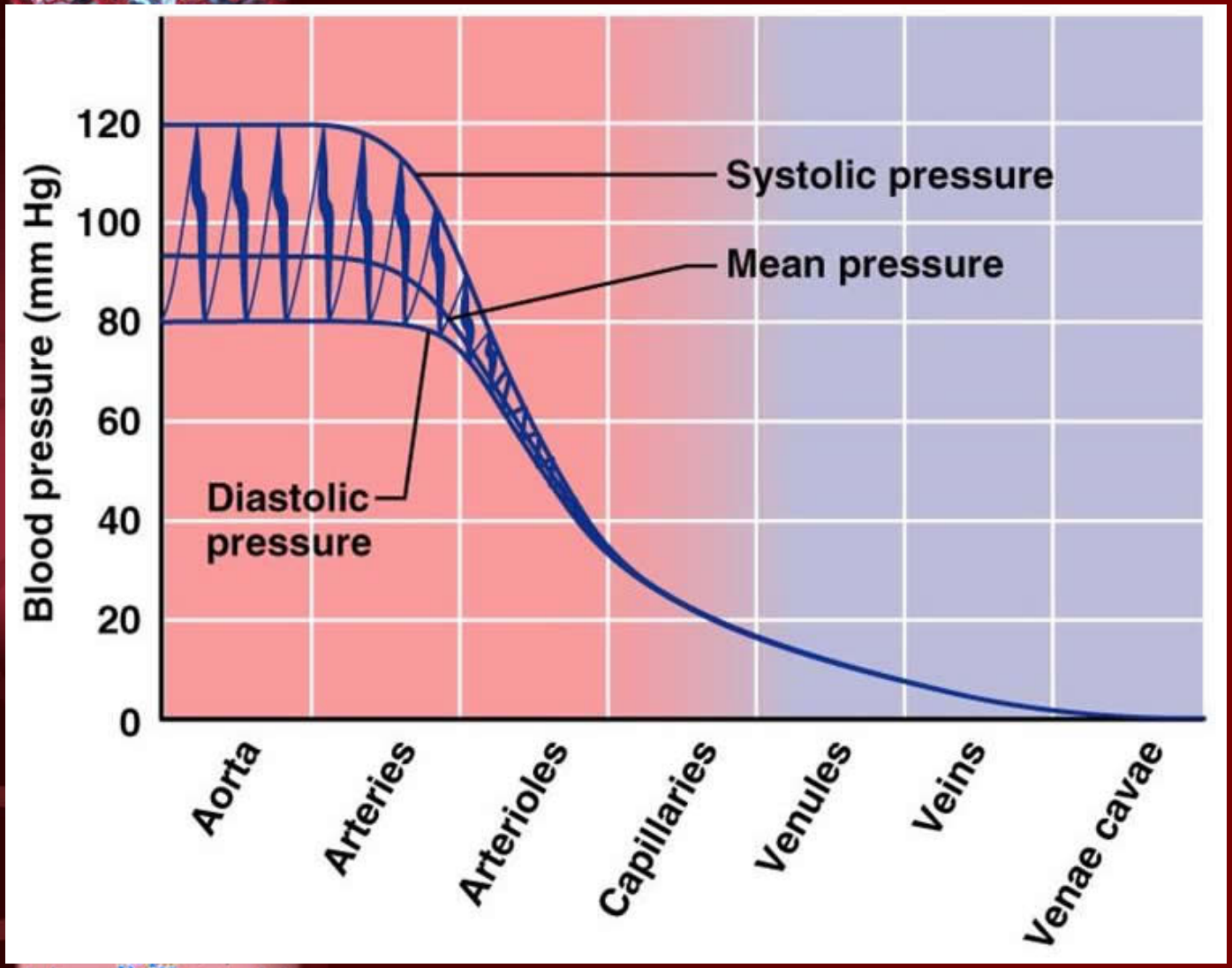


Systolic pressure, 120 mm Hg
Diastolic pressure, 80 mm Hg
Pulse pressure, 40 mm Hg
PP=SP-DP
Mean arterial pressure (MAP), 93 mm Hg,
MAP = DP + 1/3 PP



Reynold's number (Re) whether flow in a tube will be laminar or turbulent (v velocity, D diameter density of the fluid, viscosity of the fluid).

Pressure gradient



▶ Large arteries
systolic expansion elastic recoil -> diastolic wave;
↑I S/D fluctuations

▶Muscular arteries
↓SBP

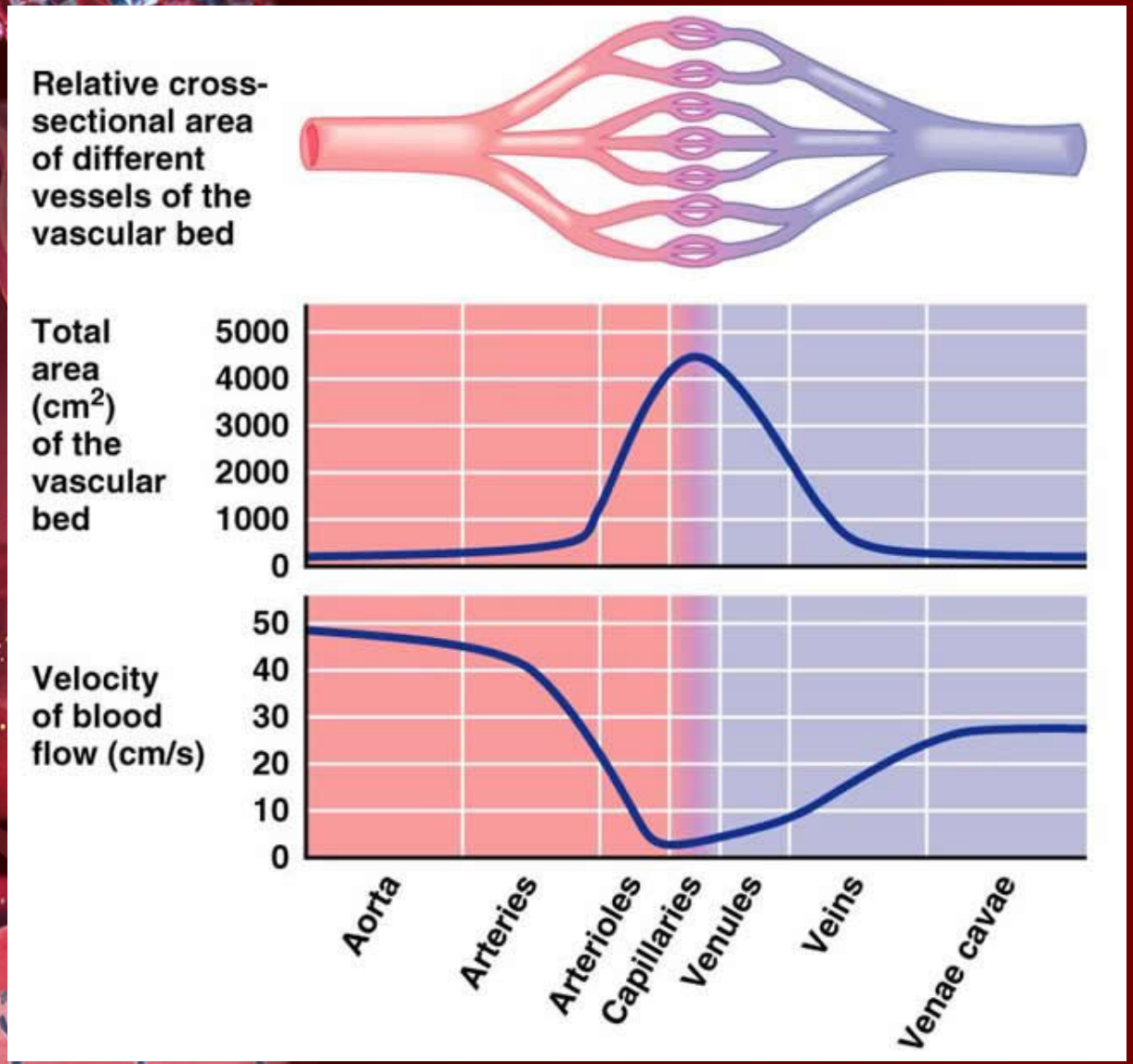
▶Arteriols
↓SBP / DBP

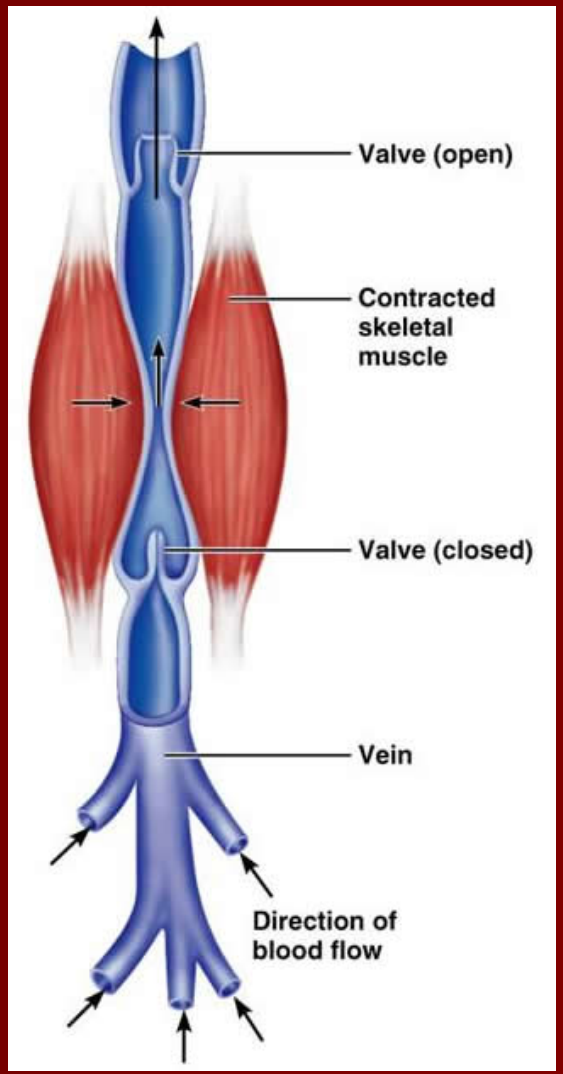
▶Capilaries 20 mmHg hydrostatic force driving fluid out

▶Venules
responsive to mediators

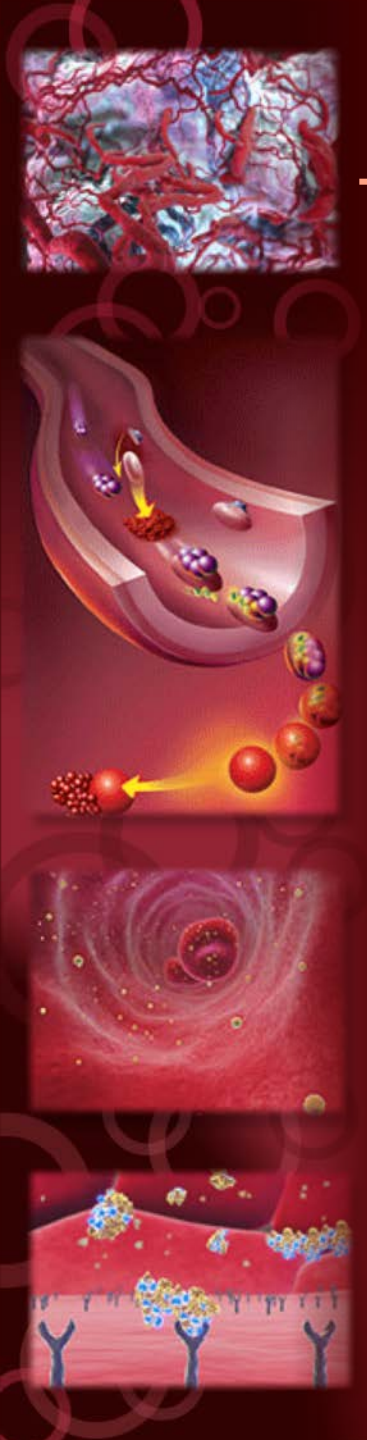
▶Veins
low prssure or underpressure

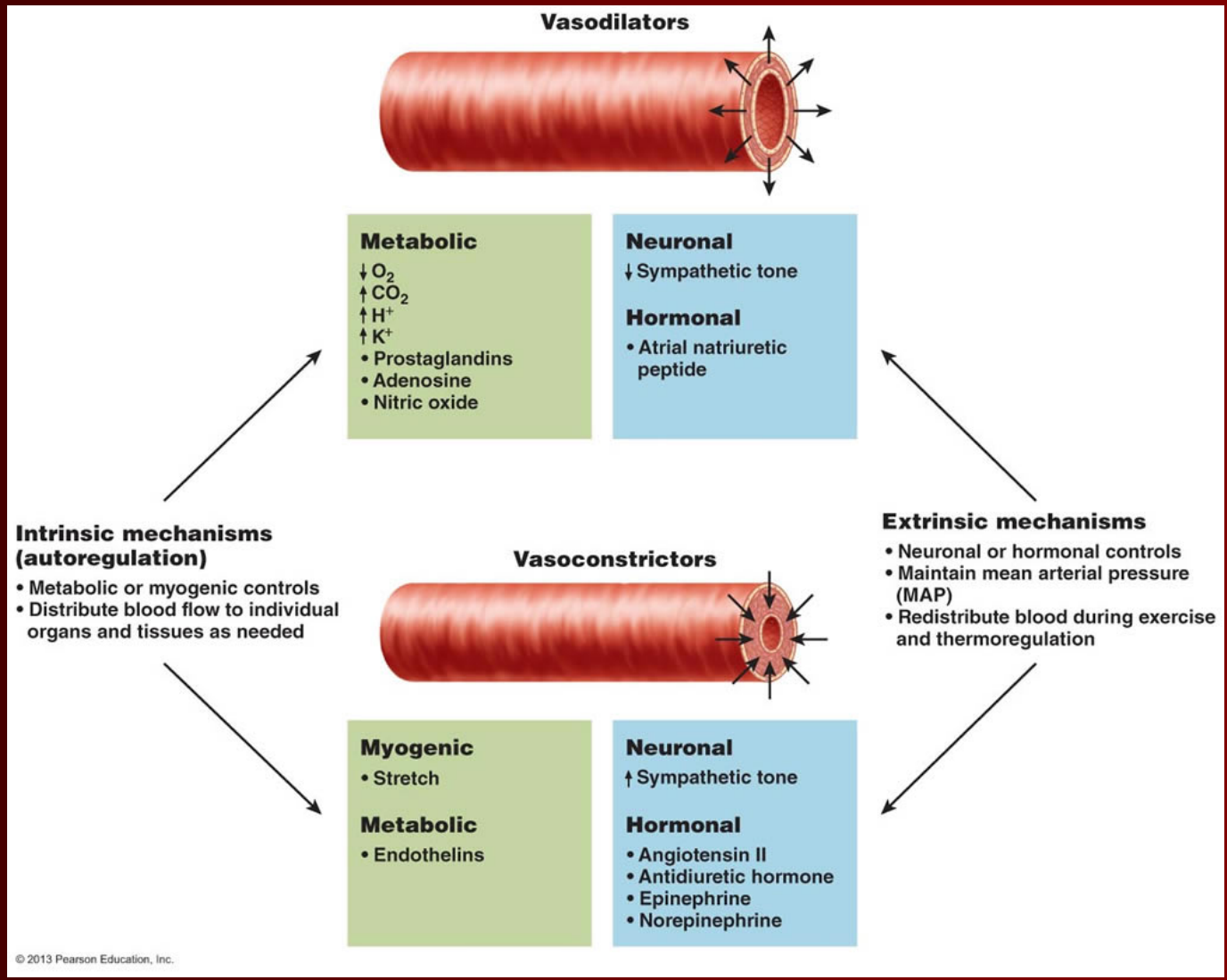
Cross area of cirulation



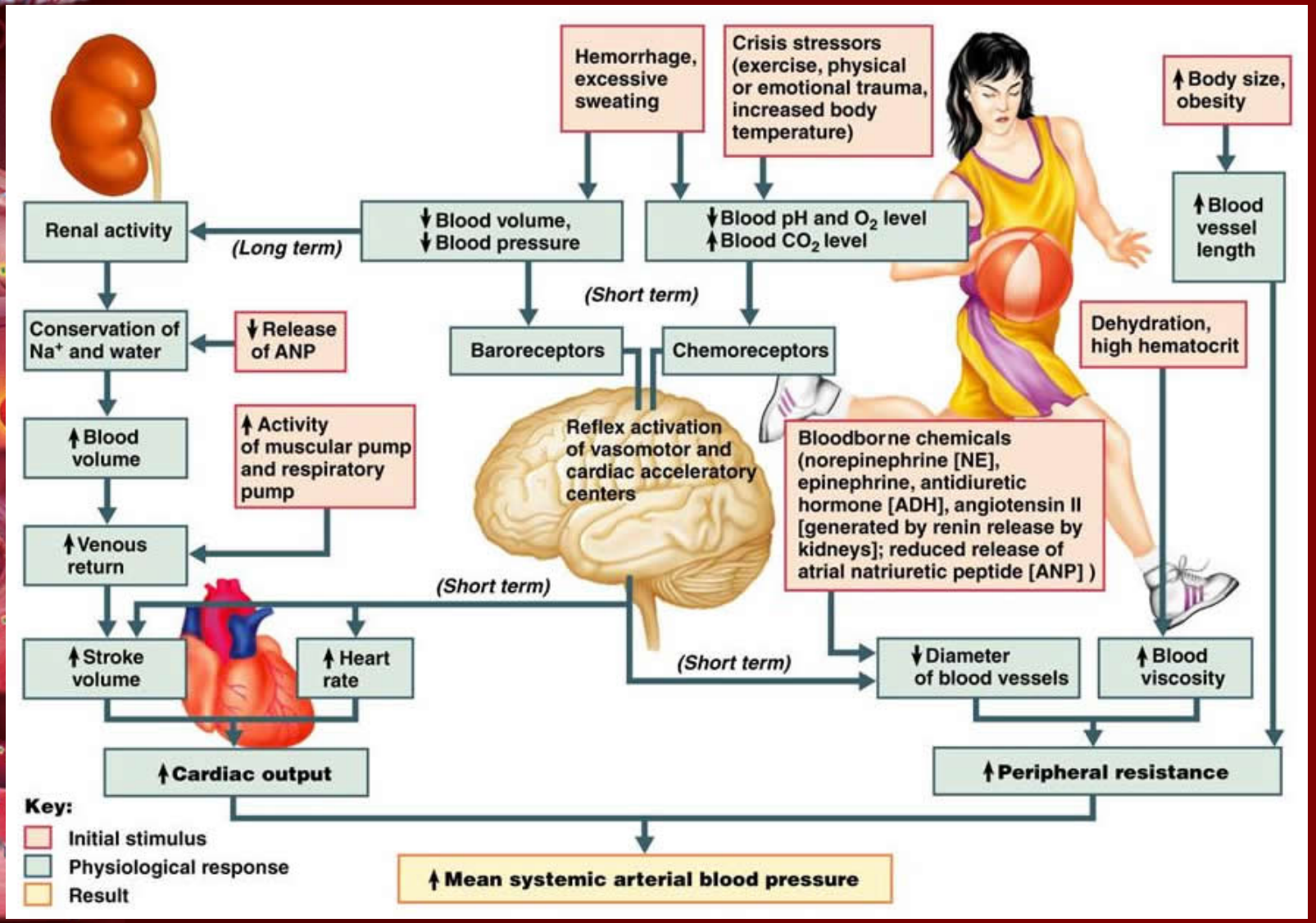


Response to mediators



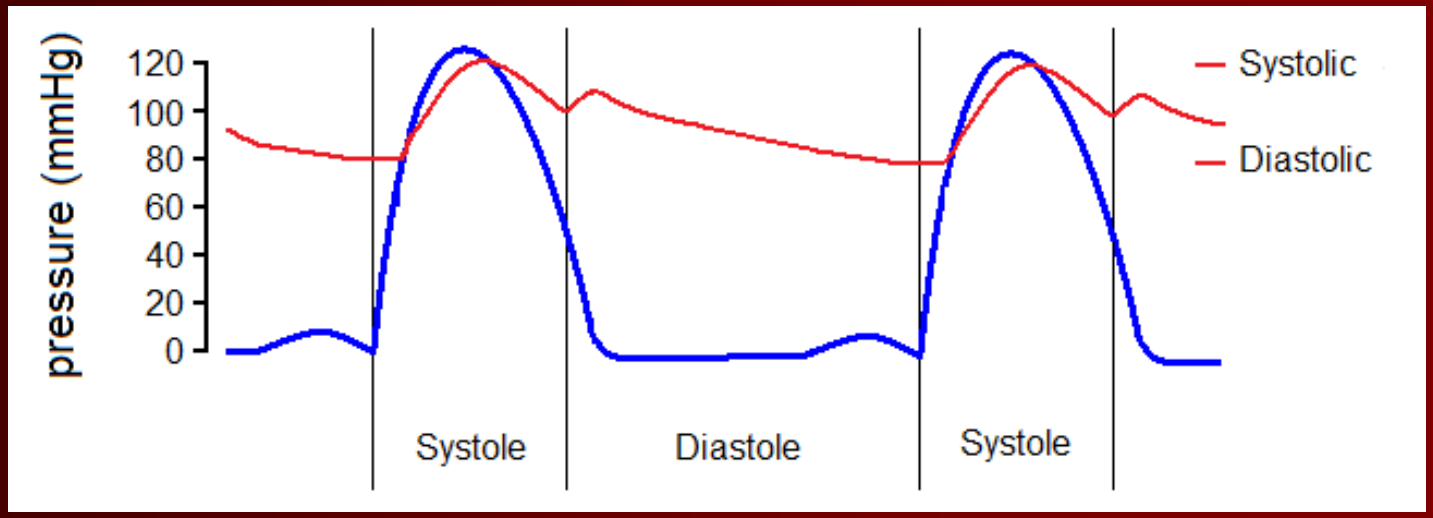


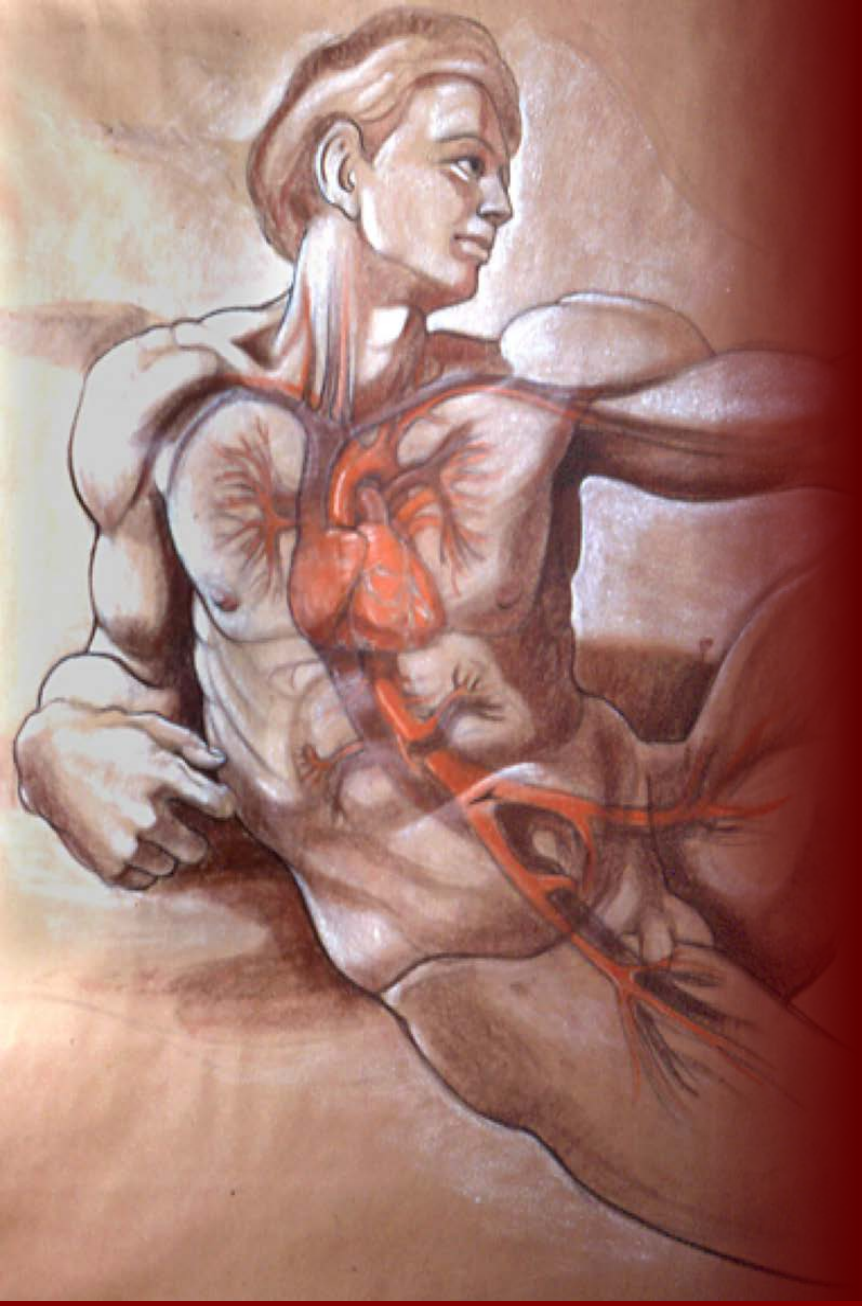
Control of blood pressure



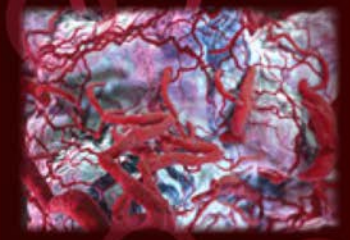
	Systolic BP		Diastolic BP	
Normal	90–119 mmHg	12–15.9 kPa	60–79 mmHg	8.0–10.5kPa
Prehyper-tension	120–139 mmHg	16.1–18.5 kPa	80–89 mmHg	10.8–11.9kPa

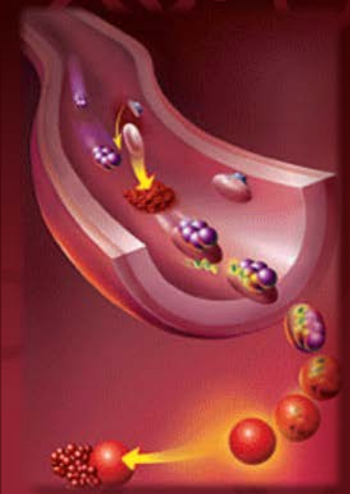
Joint National Committee (JNC-8), American College of Cardiology (ACC), American Society of Hypertension (ASH), European Society of Cardiology (ESC) and European Society of Hypertension (ESH).

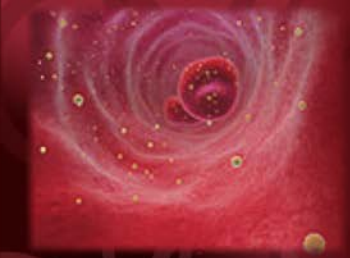


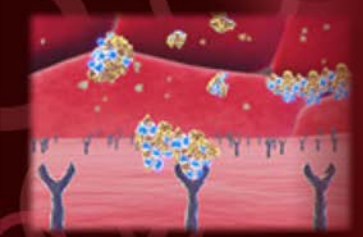


Hypertension









Hypertension

- Def: Hypertension (HT) is chronic, repetitive values of rest arterial systolic blood pressure (BP) ≥140 mmHg and diastolic BP≥ 90 mmHg
- Hypertensive state (response) – momentary finding;
- Hypertensive disease – symptoms and complications of hypertension

- Epi: ~ 30% adults; M > F; low socioeconomic status, aged, negroid Americans, 0,2 to 3% of high risk newborns; 1 - 5% of children and adolescents (gestational age, postconceptional age and birth weight).

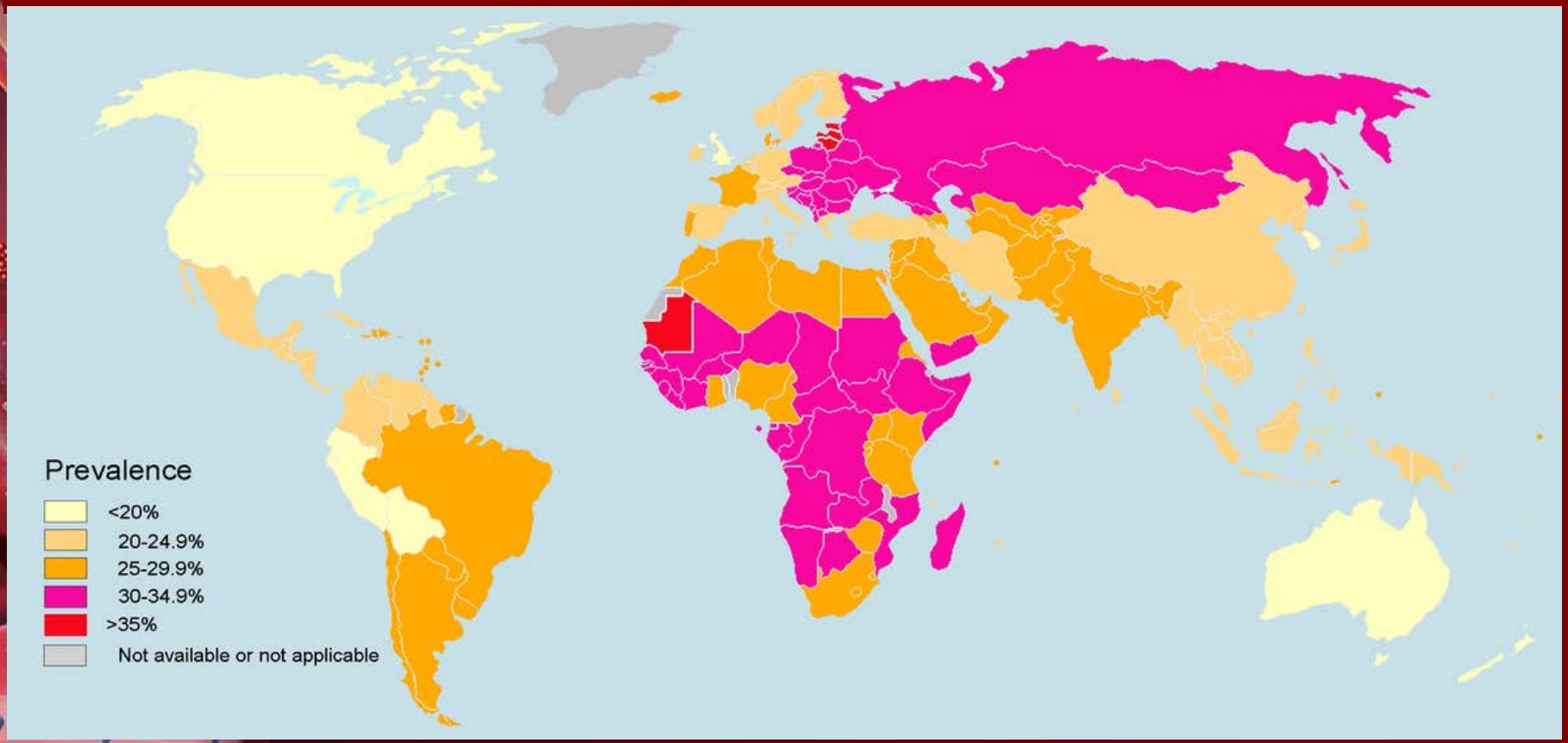
- Class: a) based on mechanisms; b)based on severity and complications

  A) Primary, Idiopathic (essential) = unidentified or unknown reasons Primary (Essential) (95%) - onset between age 20 - 50. Positive family history, no features of diseases causing secondary hypertension.

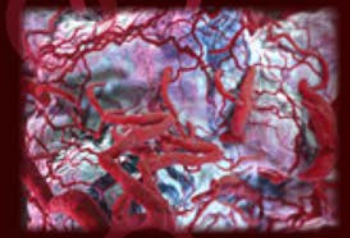
  B) Secondary = indentified organic or functional alteration in the organ and/or system (5%) - Onset age < 20 or > 50 years, No family history.

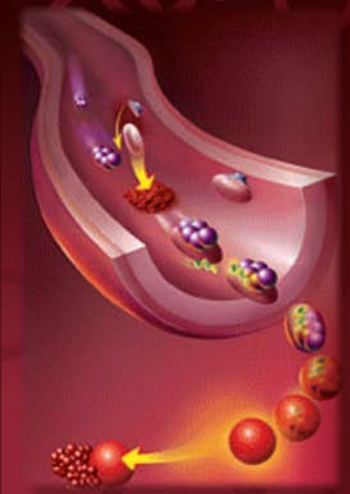
Hypertension - Epidemiology

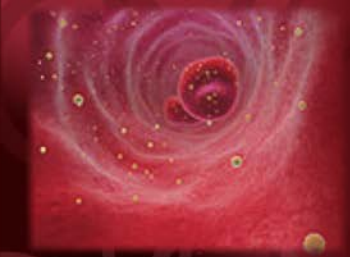
- 2014 (1 billion adults, 22% of the world population); 2013 Europe 30-45% of people
- 2004 - 2016 rates highest in Africa (30-45 % either sex), lowest in Americas (18%)
- Min: 3.5% (M)/ 7% (F) India ←→ Max: 69% (M) and 73% (F) in Poland
- 1995-2004-2017 24%, 29% 32% US (76 million US adults) 44% of African-American US

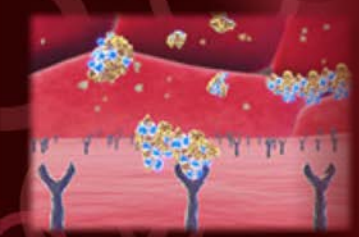


https://en.wikipedia.org/wiki/Hypertension#/media/File:Hypertension_World_Map_Men_2014.png



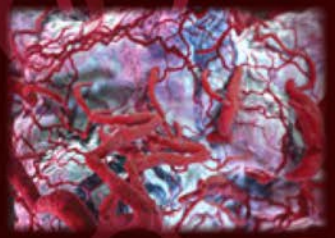






Hypertension - Classification

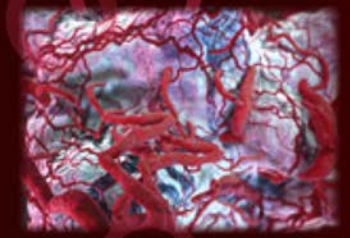
- In people 18 y or older: SP > 139 mmHg DP > 89 mmHg
- JNC7 - **prehypertension** (SP 120–139 mmHg) DP 80–89 mmHg, hypertension stage I, hypertension stage II, and isolated systolic hypertension (elderly)
- European Society of Hypertension (ESH) (2007)+ British Hypertension Society (BHS) IV (2004) use optimal, normal and high normal categories to SP <140 mmHg and DP <90.
- ESH-ESC Guidelines (2007) and BHS IV (2004): third stage (stage III hypertension) SP > 179 mmHg or SP > 109 mmHg.
- Hypertension "resistant" / if medications do not reduce BP
- AHA 2017 + ACC 2020 BP **≥140/90 mmHg** or home monitoring blood pressure **≥135/85 mmHg**, or 24-hour ambulatory BP **≥130/80 mmHg** (daytime av. ≥135/85 mmHg or nighttime average BP ≥120/70 mmHg)
- Children – SP or DP on 3 or more vists ≥ 95th percentile for the sex, age and height of the child.



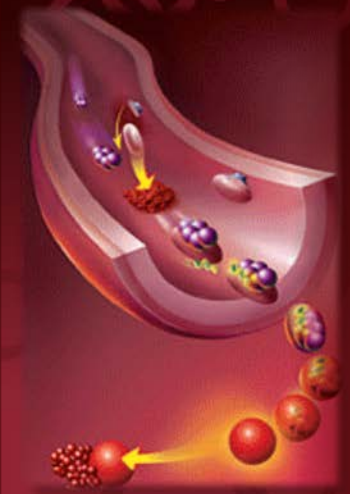
Hypertension - Classification

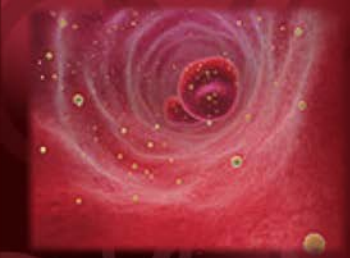
- European Consensus 2024

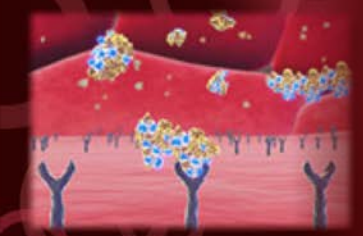
Category	Systolic, mmHg	Diastolic, mmHg
Hypotension	< 90	< 60
Normal	90–119 90–129	60–79 60–84
Prehypertension	120–129 130–139	60–79 85–89
Stage 1 hypertension	130-139 (ASA US) 140–159	80-89 (ASA US) 90–99
Stage 2 hypertension	>140 160–179	>90 100–109
Hypertensive crises	≥ 180	≥ 120
Isolated systolic hypertension	≥ 140	< 90
Isolated diastolic hypertension	< 140	≥ 90



Hypertension - Etiology

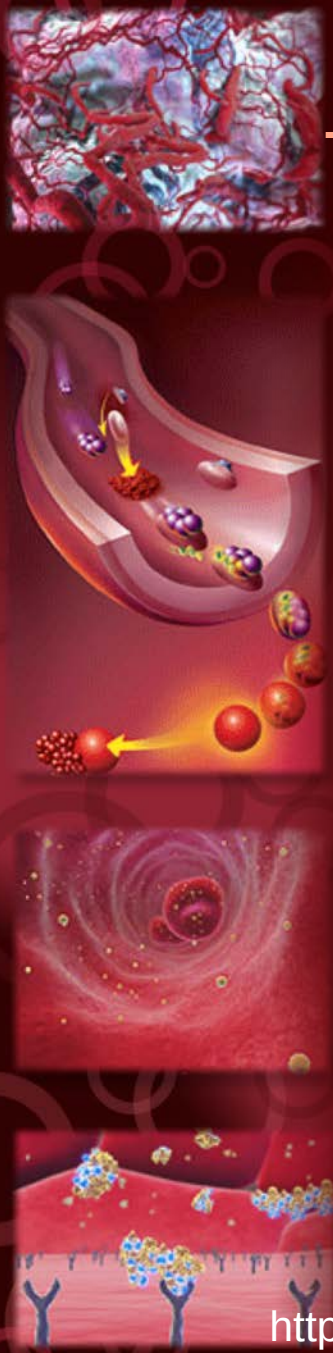


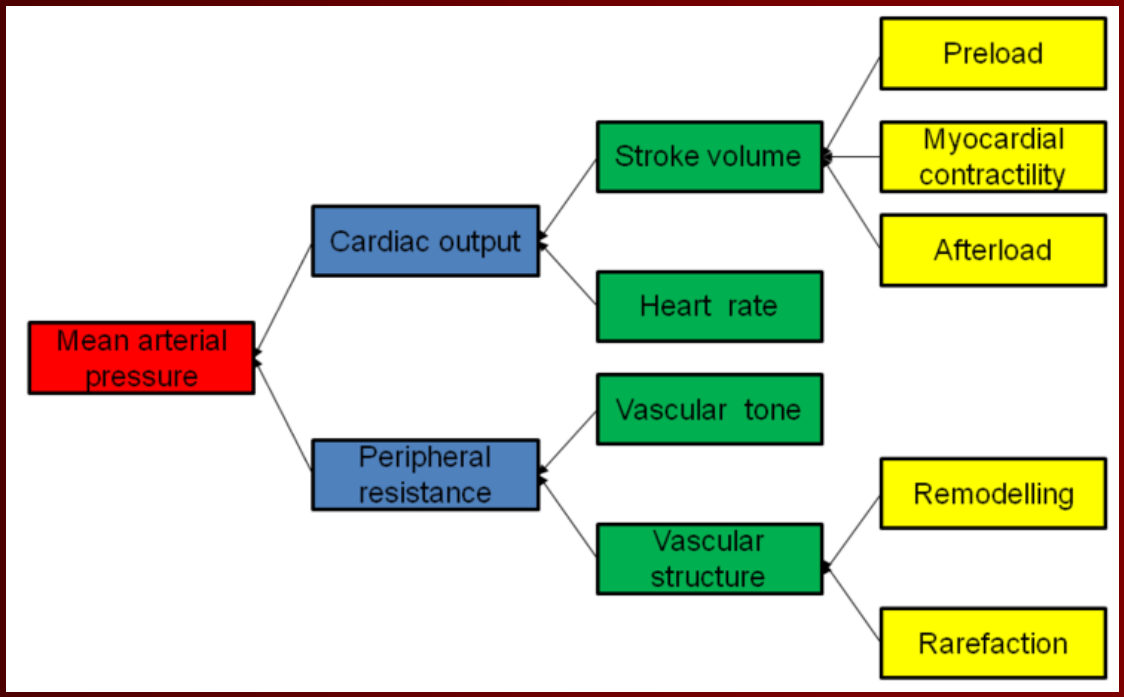




- **Etio:** a) Genetic factors, b) Environmental factors
- Genetic factors: common genetic variants with small effects + rare genetic variants with large effects on BP. genome-wide assoc. studies (GWAS):
  - 35 genetic loci related to BP genes;
  - 12 new genetic locus (epigenetic modifications) vascular smooth muscle + renal function <- SNP for each DNA methylation might affect in some way linking common genetic variation to multiple phenotypes
- Environmental factors: aging, diet, lifestyle
  - high salt intake, lack of exercise, central obesity, caffeine consumption ?, vitamin D deficiency ?. insulin resistance, syndrome X (or the metabolic syndrome)
  - early life events (risk factors) - low birth weight, maternal smoking, lack of breastfeeding (adult essential hypertension),
  - high blood uric acid in untreated people with hypertension
  - periodontal disease is also associated with high blood pressure seasonal (BP is higher in winter)

Hypertension- Pathogenesis





BP = tangential force on the vessel wall: product of pressure, diameter

1) **Heart** – pumping capability in terms of volume /time

2) **Vessels** – resistence

https://en.wikipedia.org/wiki/Hypertension#/media/File:Mean_arterial_pressure.png

Control of blood pressure 2

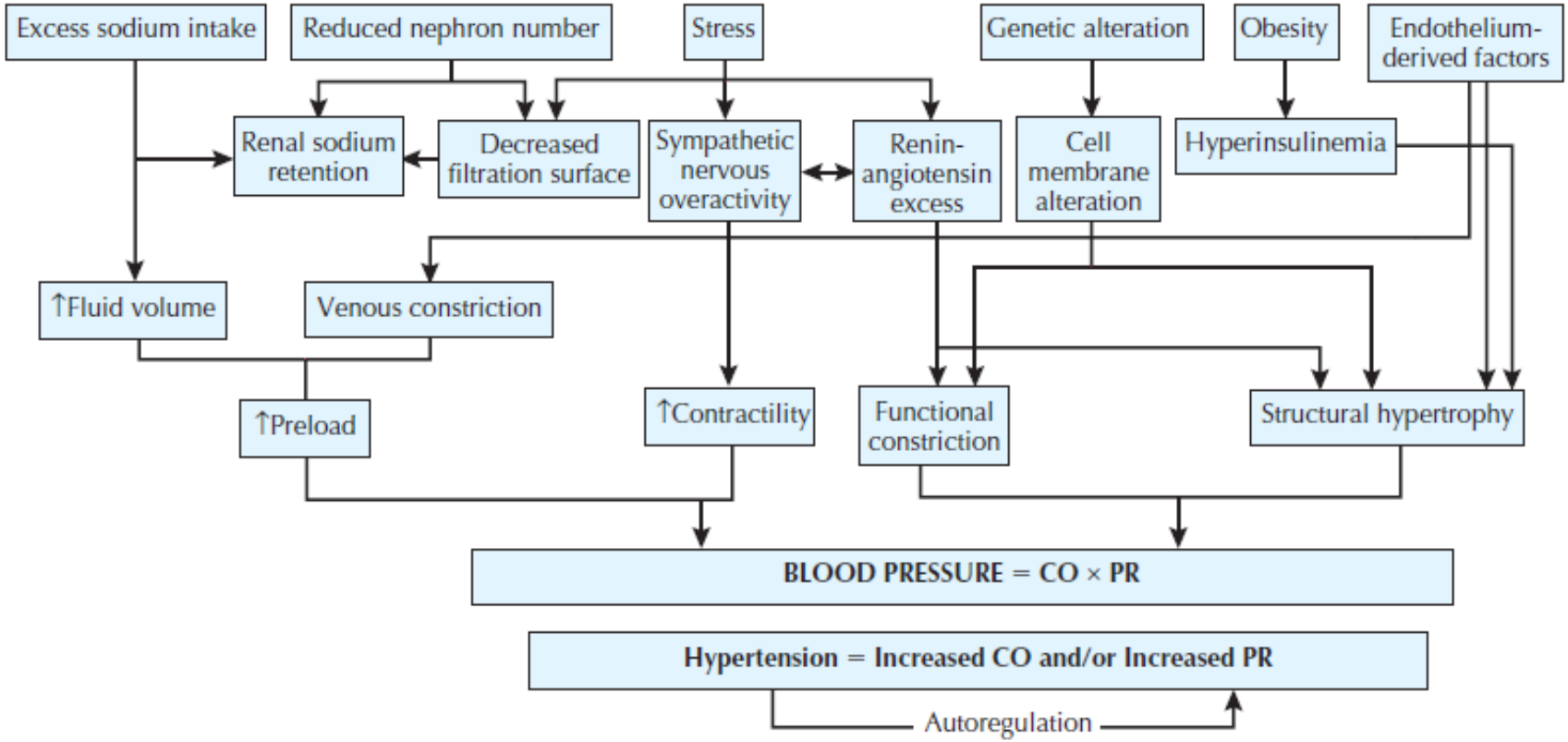
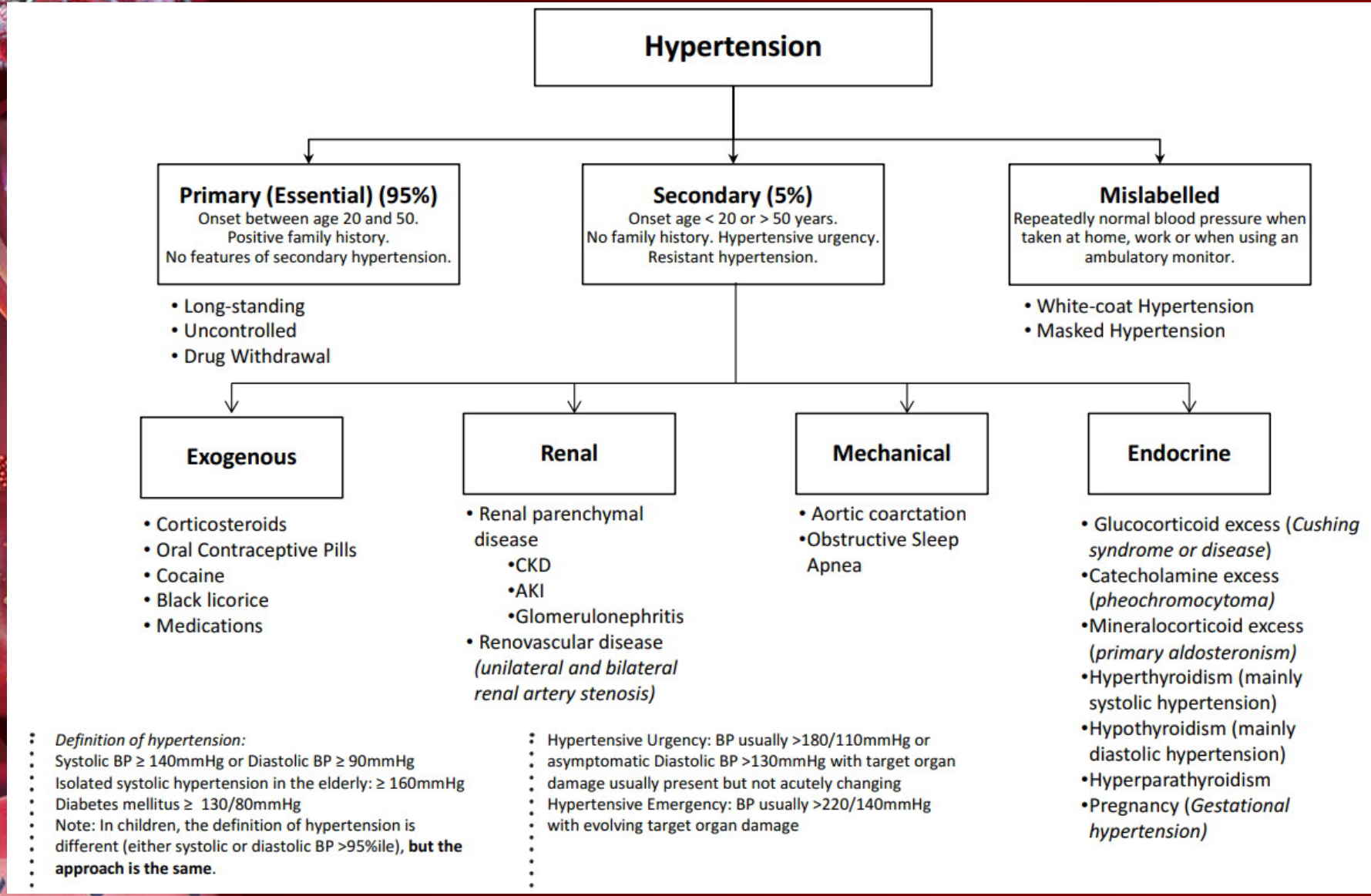
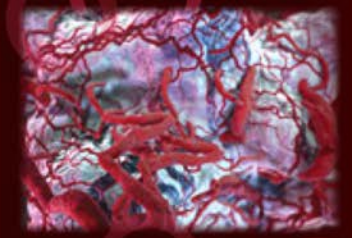


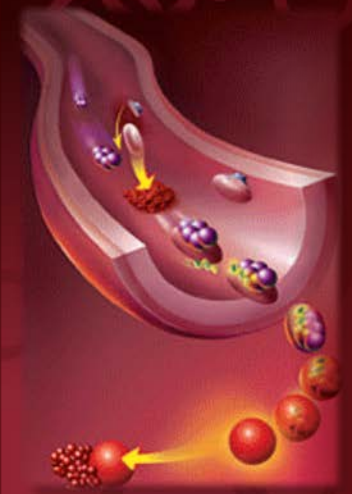
FIG 15.1 Factors Involved in the Control of Blood Pressure. *CO*, Cardiac output; *PR*, peripheral resistance. (With permission from Kaplan NM. *Kaplan's Clinical Hypertension*. 8th ed. Philadelphia: Lippincott Williams & Wilkins; 2002. p 63.)

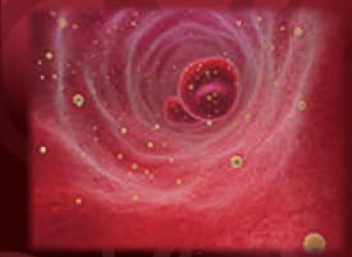
Classification of hypertension

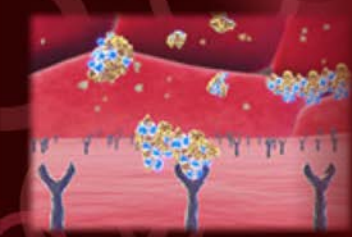


https://www.grepmed.com/images/8485/secondary-differential-algorithm-diagnosis-hypertension



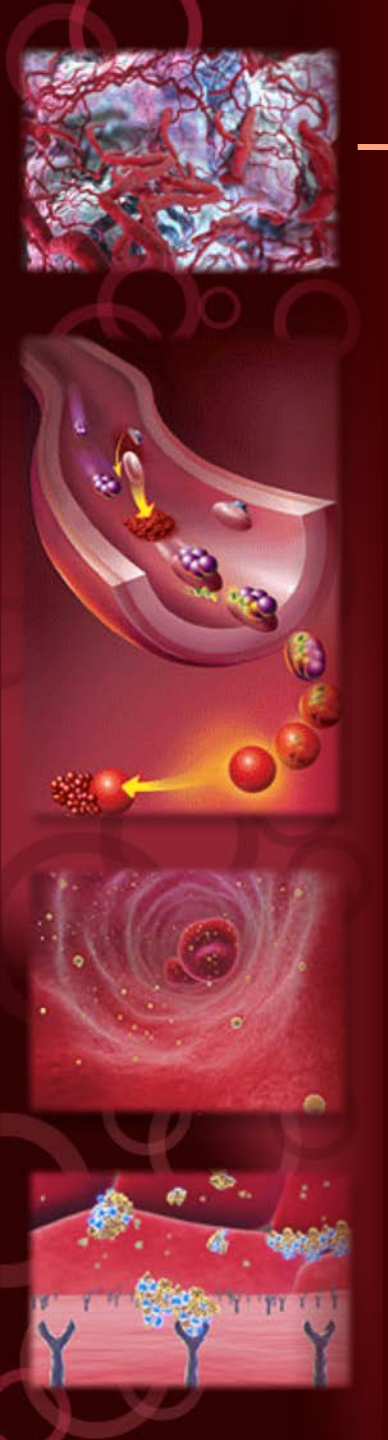






Etiology - Primary hypertension

- **Essential hypertension** (primary, idiopathic)→ no clear single causative factor; multifactorial → interaction of genetic & acquired (environmental) predisp. with subclinical multiorgan alterations; 85 – 97 % of cases
- Risk factors: Genetic variation, Aging, Obesity, Salt, Alcohol, Smoking, High renin, Diabetes, Vitamin D deficiency, Lack of exercise
- Prevalence increases with age
- Nephrogenic/ Endocrine PH – disturbances in RAA system (~ 40% of PH)
  - Reaction change with age > 50y mostly
  - High renin reactors vs. Low renin reactors
- Nephrogenic + volumometric PH – **handling with water and salt;** 50% to 60% of the patients are salt sensitive
- Vegetative PH – disturbances in vegetative ballnnce
  - sympathetic over-reactors – catecholamine surge



Secondary hypertension

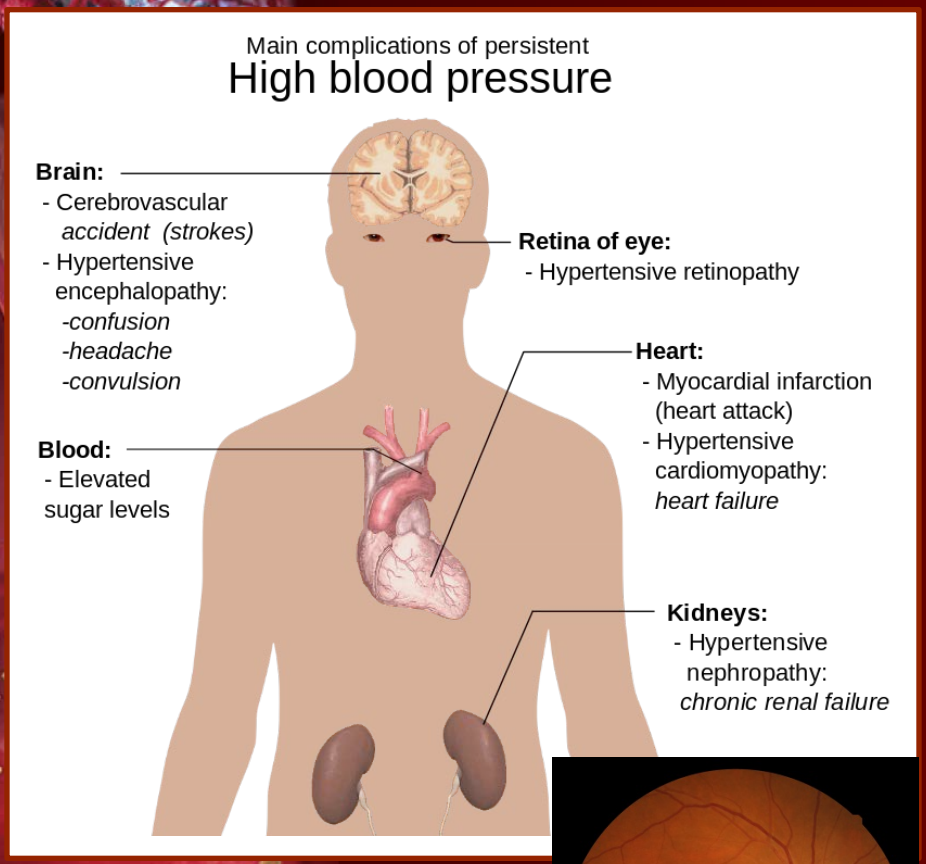
Diseases

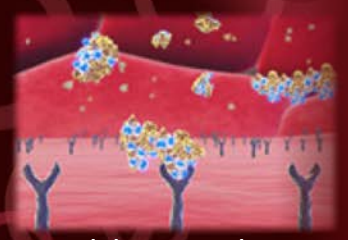
- **Cardiovascular (mechanical):** coarctation of aorta; obstructive sleep apnea
- **Renal:** • Renovascular disease (unilateral+bilateral renal artery stenosis),
  •Renal parenchymal disease - CKD, AKI, Glomerulonephritis
- **Endocrine:** Catecholamine excess (pheochromocytoma)
  - Glucocorticoid excess (Cushing syndrome or disease)
  - Mineralocorticoid excess (primary hyperaldosteronism)
  - Hyperthyroidism (systolic); Hypothyroidism (diastolic hypertension)
  - Hyperreninism, Hyperparathyroidism
- **Respiratory:** Pickwick syndrome, Obstructive sleep apnoea
  - **Neurological:** Intracranial hypertension, Guillain-Barré syndrome, Quadriplegia
  - **Other :** Pregnancy (Gestational) Acute stress: Perioperative,, Hypoglycemia

Various factors

- **Medications.** Corticosteroids, Oral contraceptives, methamphetamine, nasal decongestants overuse, Immunosuppressive agents (cyclosporine, tacrolimus), Nonsteroidal antiinflammatory agents
- **Exogenous substances:** cocaine, nicotine, excessive eating of liquorice, Alcohol withdrawal, herbal remedies, arsenic (drinking water)
- **Social:** Depression, loneliness

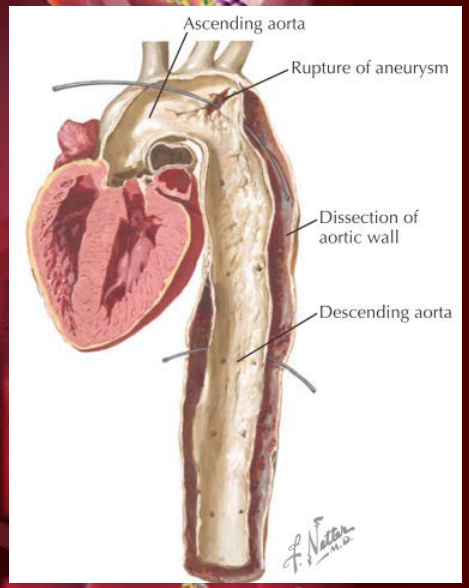
Hypertension - Complications

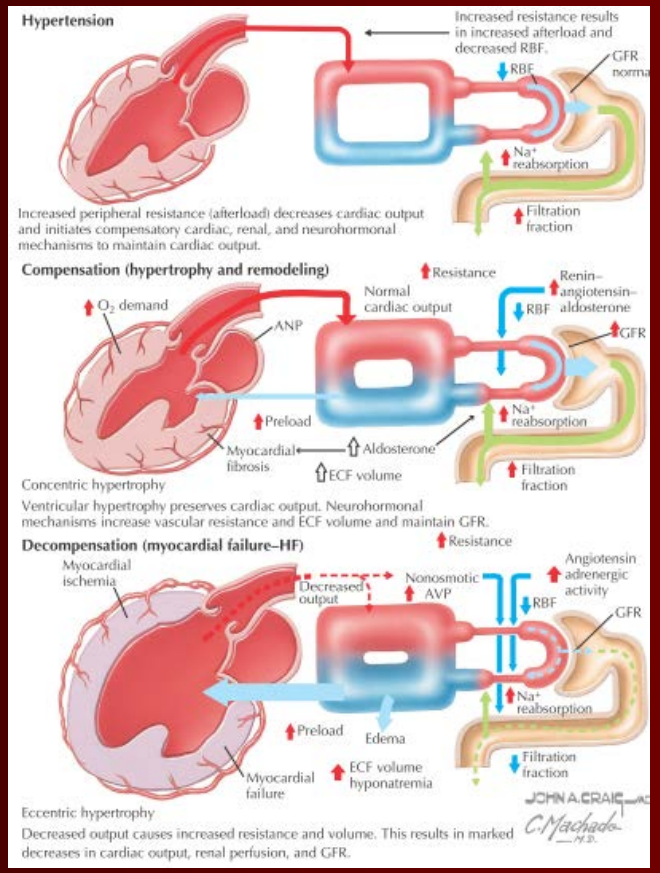


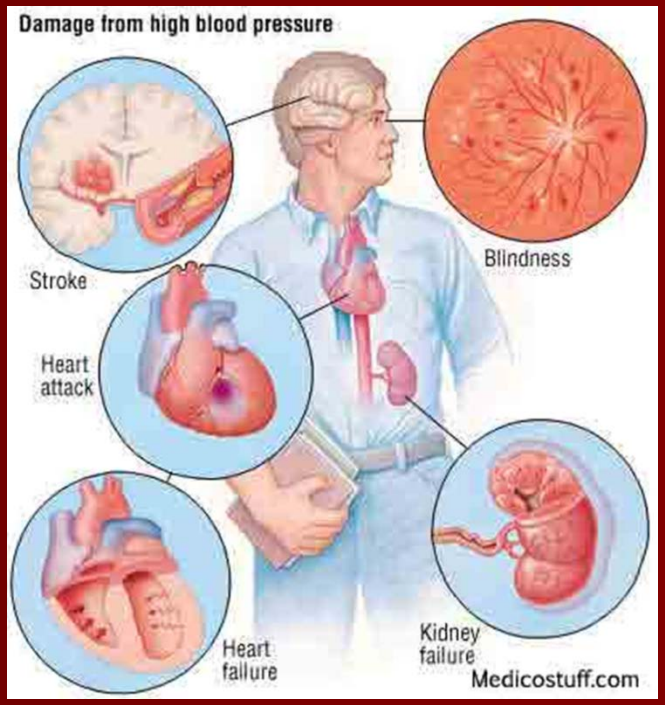


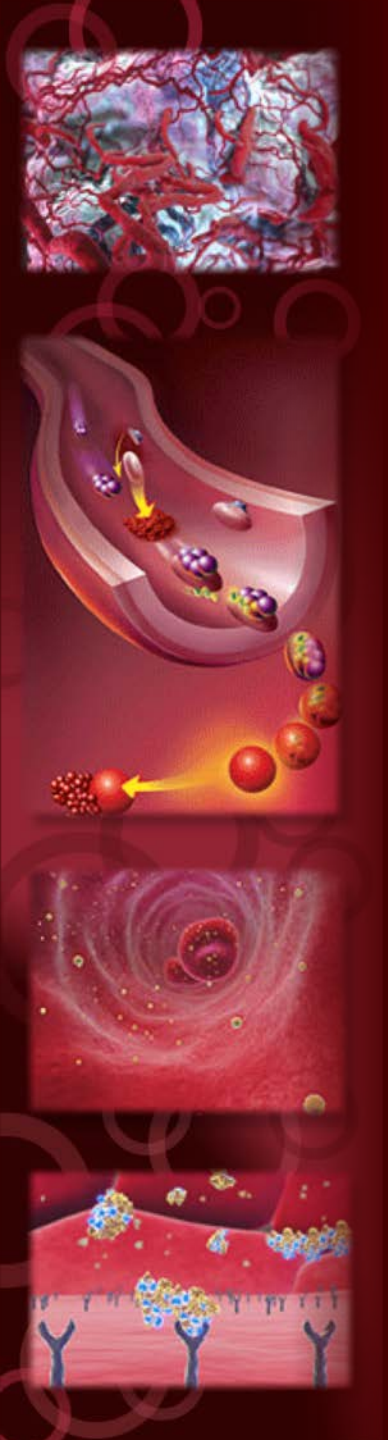
- Brain: Cerebrovascular ischemic strokes
  - Hypertensive encephalopathy:- confusion – headache – convulsion
  - Vascular (mutiinfarction) dementia.- memory & cognitive decline
- Heart = Hypertensive heart disease structural and functional adaptations (left ventricular hypertrophy) Infarction, aortal aneurysm & dissection
- Kidney removascvular sclerosis (fibrotized narrowed blood vessels)
- Extremities - peripheral arterial disease.[
- Retina - thickened, narrowed or torn blood vessels in the eyes,
- System - metabolic syndrome (together with obesity, hyperlipidemia)

- Hypertensive left ventricular hypertrophy – (25% HT) (Echo) are of 2 types: mechanical, leading to myocyte hypertrophy; neuro-hormonal, mainly resulting in a fibroblastic proliferation.
- Diastolic heart failure, common (60%HT) asymptomatic to heart failure, ventricular hypertrophy and ischemia.









aneurysm

An aneurysm forms after long-term damage to the artery walls from high blood pressure.

problems with memory and understanding

Trouble with memory and understanding could be an early sign that high blood pressure is affecting your brain.

sleep apnea

This sleep disorder has been linked to high blood pressure and may be triggered by it.

chest pain

Chest pain can be a sign of a heart attack or of reduced blood flow to the heart.

kidney damage or failure

Kidney damage happens when high blood pressure damages arteries leading to the kidneys and small vessels in the kidneys. Over time, the kidneys lose their ability to filter waste from the body.

artery damage

High blood pressure wears away at healthy artery walls, causing tears.

hardening of the arteries

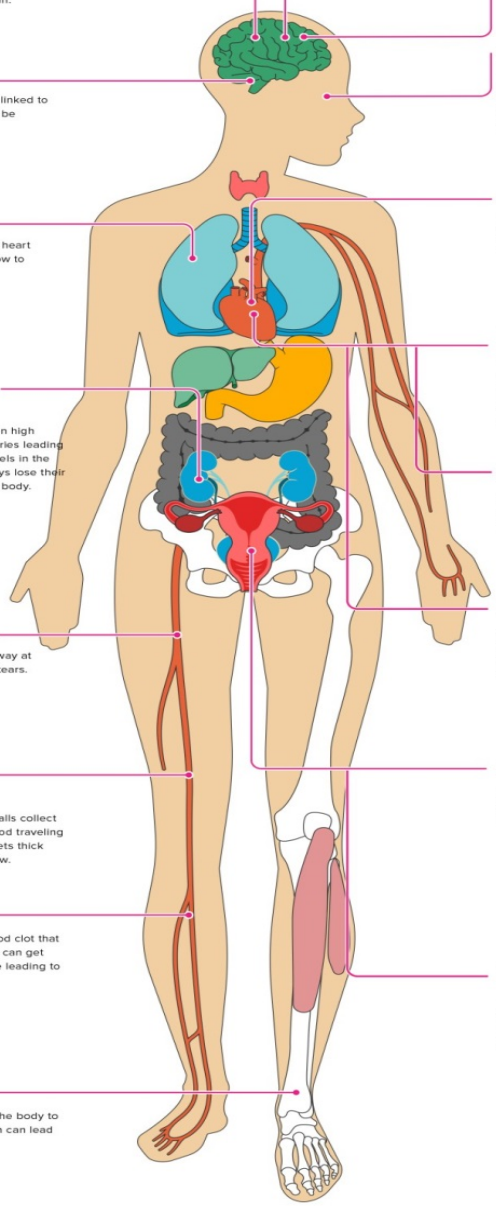
Over time, damaged artery walls collect cholesterol deposits from blood traveling through. When this buildup gets thick and hard, it reduces blood flow.

blood clot

If arteries are narrower, a blood clot that might normally travel through can get stuck. This causes a blockage leading to a heart attack or stroke.

osteoporosis

High blood pressure causes the body to eliminate more calcium, which can lead to osteoporosis.



dementia

Some forms of dementia may be directly related to a lack of blood flow to the brain.

choroidopathy or bleeding in the eye

Damaged blood vessels can burst behind the eye, causing fluid buildup known as choroidopathy.

blurred or loss of vision

Blurred vision or vision loss can result from damaged blood vessels behind the eyes.

arrhythmias

An irregular heartbeat, or arrhythmia, can be a sign of blocked arteries in the heart.

left ventricular hypertrophy

When the heart has to work harder to pump blood through the body it can lead to an enlarged left ventricle, called left ventricular hypertrophy.

heart attack or stroke

Untreated high blood pressure can lead to a heart attack or stroke when arteries become blocked.

heart failure

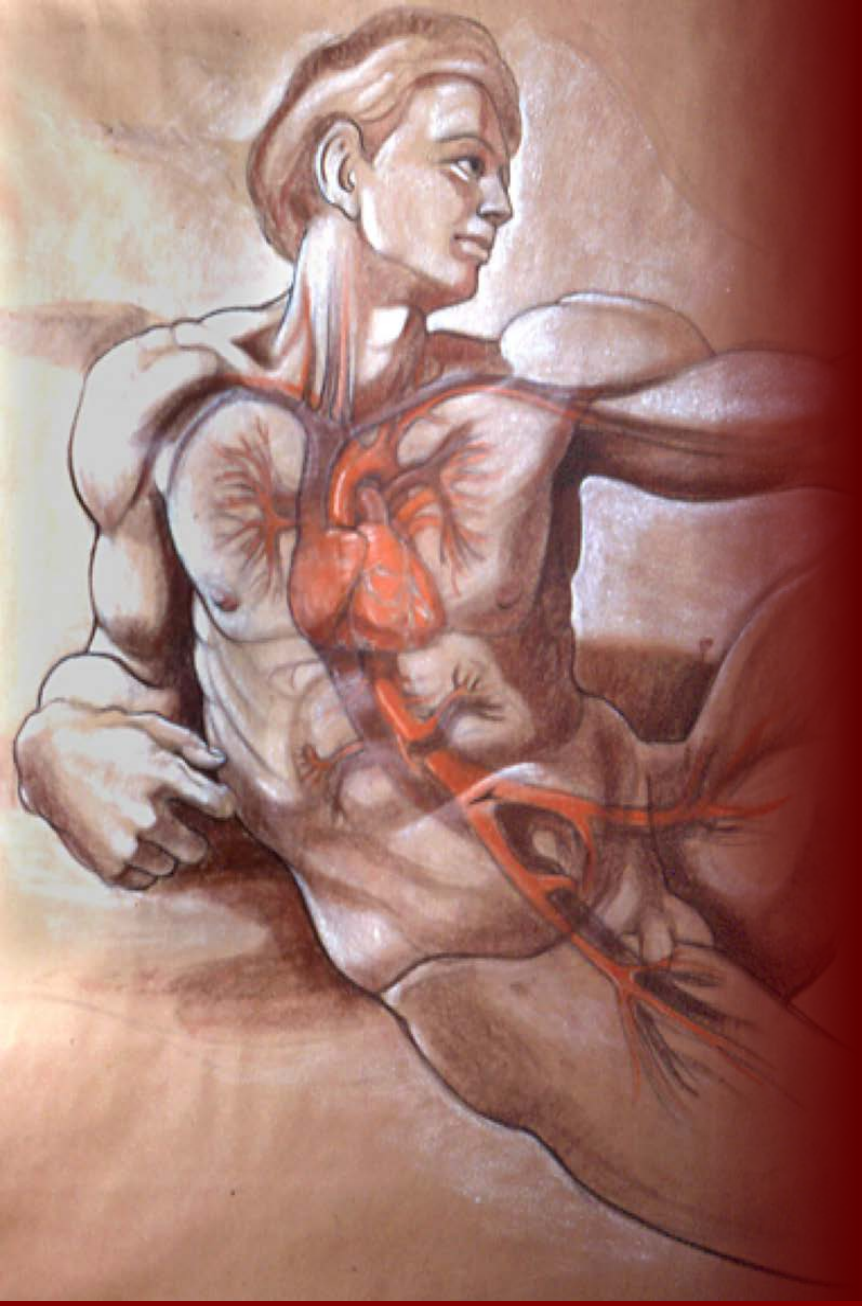
High blood pressure and narrowed arteries make the heart work harder over time, which can eventually lead to heart failure.

erectile dysfunction

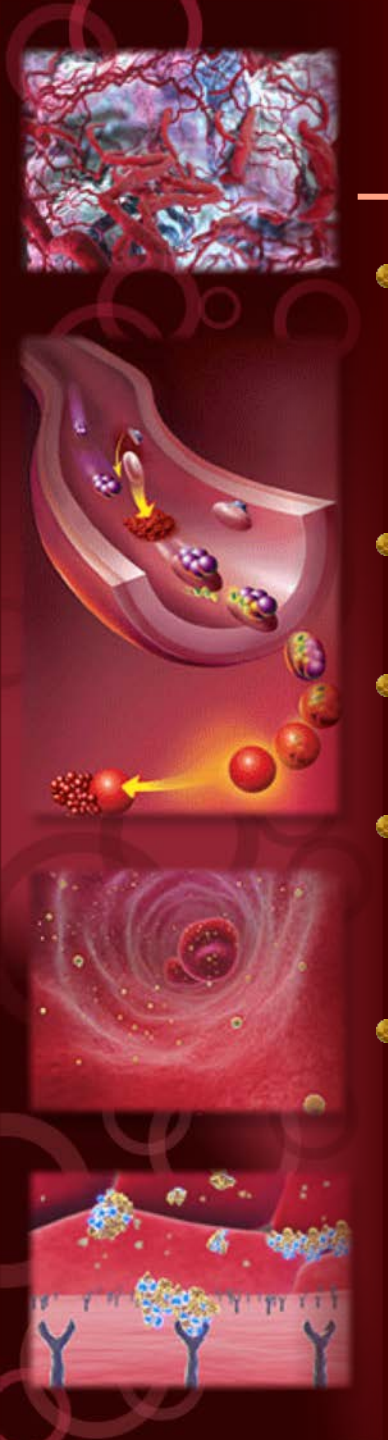
During arousal, the penis needs extra blood. Narrow blood vessels can prevent this and make it hard to get and keep an erection.

vaginal dryness or lowered sexual desire

The vagina relies on extra blood flow during arousal. Narrow blood vessels can contribute to lower sexual desire and dryness.

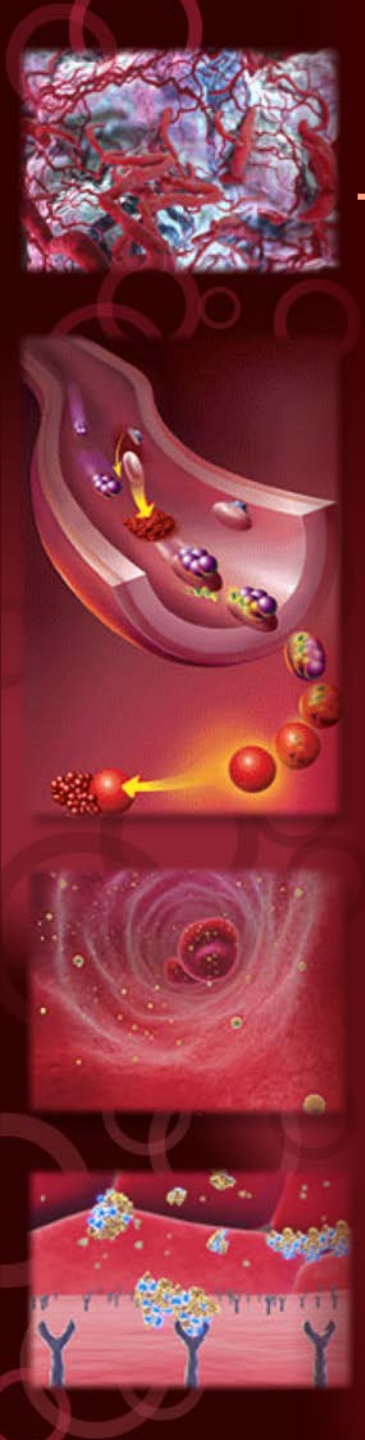


Hypotension



Hypotension - Description

- Def: Hypotensive state is set od symptoms caused by by episodes of low blood pressure (adults SP < 90 mmHg or DP< 60 mm Hg; MAP of < 75 mmHg children SP< 70 mmHg or DP < 40 mm); in practice, disease is considered if noticeable symptoms are present.
- Term hypotensive diasease is not used, nor chronic hypotension. In some sportsmen low blood pressure could be normal.
- Collapse = sudden attaclk of hypotension due to vascular paralysis (vasodilation)
- Shock = acute hypotension with sudden low blood pressure (SP < 50 mmHg) can deprive the brain and other vital organs of oxygen and nutrients, leading to a life-threatening condition
- Occ: Orthostatic hypotension (common in pregnant, ~ 30%) and older adults (35%). Postprandial hypotension - older people (37%)



Hypotension - Etiology

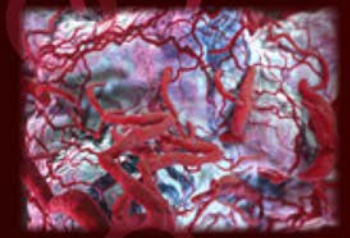
1) Low blood volume (hypovolemia) (diuretics), such as furosemide

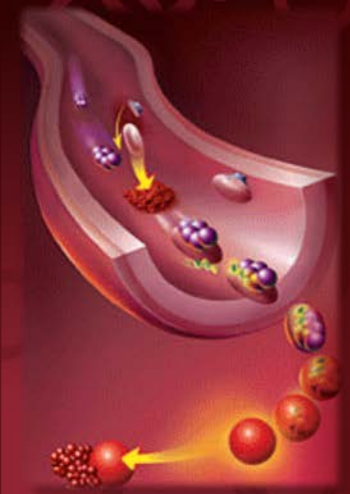
- insufficient fluid intake, protein intake (starvation), loss of water and solutes (diarrhea or vomiting), loss of blood (anemia, hemorrhage)

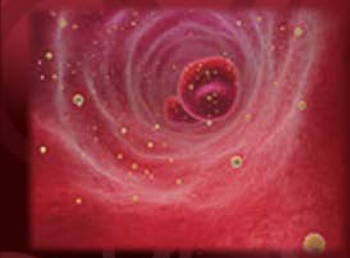
2) Low cardiac output -

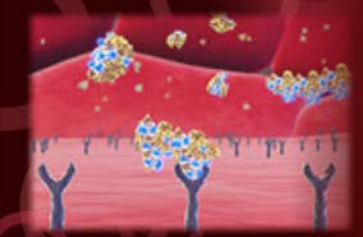
- congestive heart failure (cardiomyoathy, IHD, large infarction, heart valve problems)
- hormonal changes (hytpothyroidism, Addisson disease), bradycardia, low inotropy (side effects of chronic use of α- and β–blockers, antiarrhythmics), pregnancy
- parasympathetic overactivity (injury to the brain or spinal cord)

3) Vasodilation (vasoparalysis) – anaphylactic reaction, antihypertensive medications (insufficient constriction of arterioles, medications (antiparkinsonics levodopa , nitrates, Ca2+channel blockers, or AT1 receptor antagonists, anesthetic, (spinal anesthesia and most inhalational agents), herbal medicines theobromine (cacao) vasodilator and diuretic!, pregnancy, septic shock state, neurogenic shock, acidosis





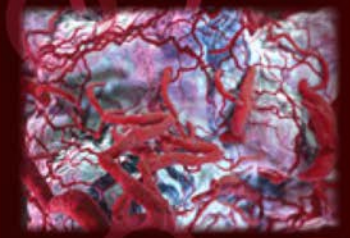




Hypotension - Manifestations

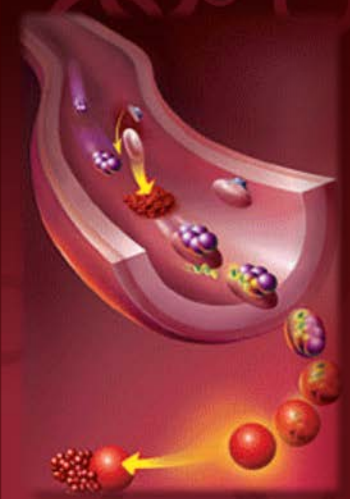
- headache, light headedness
- loss of consciousness
- temporary blurring or loss of vision
- stiff neck, severe upper back pain
- chest pain. shortness of breath
- irregular heartbeat
- fever (> 38.3 °C), seizures
- cough with sputum
- prolonged diarrhea or vomiting
- dyspepsia (indigestion)
- absence of perspiration
- dysuria (painful urination) dark colored urine
- profound fatigue
- black tarry stool

Class: 1) Primary hypotension (essential) unknownreasons
2) Autonomic failures + orthostatic syndromes
3) Secondary hypotension – reactive, diseases (reasons dentified)
4) Alergic reaction, sepsis

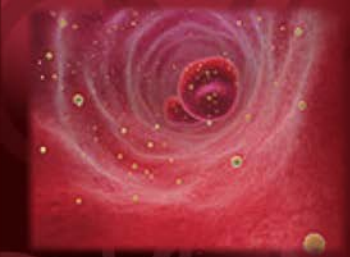


Hypotension - Specific units

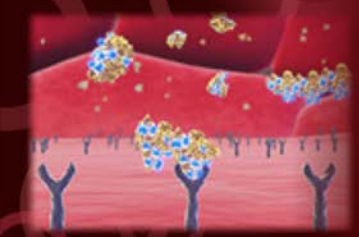
- Orthostatic hypotension hypotension after a change in body position (standing up, forward bend) is usually transient; drop of 20 mmHg in SP (and 10 mmHg DP) and a 20 b/min increase of HR

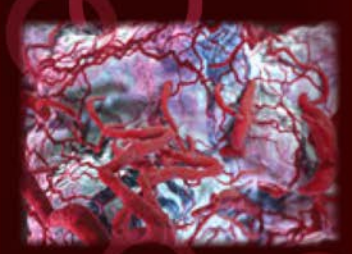


- Postural hypotension hypotension after long standing w/o movement (gard) mainly in hot weather and represents (failure of pressor reflex)
  - Cause = delay in the normal compensatory vasoconstriction in lower extremities by ANS due to hypovolemia – hot days, little hydrationmedicaments - psychiatric (antidepressants)



- Vasovagal syncope sundden fainting or drop attack (syncope) in the upright position (lightheadedness, sweating, changes in vision, a loss of consciousness)
  - Cause = increased activity of the vagus nerve (parasympathetic NS). Consciousness will often return rapidly once patient is lying down and the blood pressure returns to normal.





Hypotension - Specific units

- Postprandial hypotension sudden decline in BP that occurs 30 to 75 minutes after eating large bolus of meals due to failure of ANS- regulation
  - Cause = great volum of blood is diverted to the intestines (splanchnic blood pooling) to facilitate digestion and absorption, the body must increase cardiac output and peripheral vasoconstriction to maintain enough blood pressure to perfuse vital organs, such as the brain.
- Flammer syndrome: hypotension, peropheral vasocostriction (cold hands and feet) predisposes to normal tension glaucoma.
- Relative energy deficiency (Female athlete triad) (RED-S) h disordered eating led to amenorrhoea + osteoporosis+ hypotension
- Excercise-induced hypotension (water-based exercise)
- Intra-operative hypotension

  <65 mmHg risk of acute kidney injury (AKI), myocardial injury, post-operative stroke
- Hypotensive states in childhood

Age	Systolic Pressure
Term Neonates	<60 mmHg
Infants	<70 mmHg
Children 1 – 10y	<70+(age x 2)
Children >10 y	<90 mmHg