THE HEART

The Heart

12

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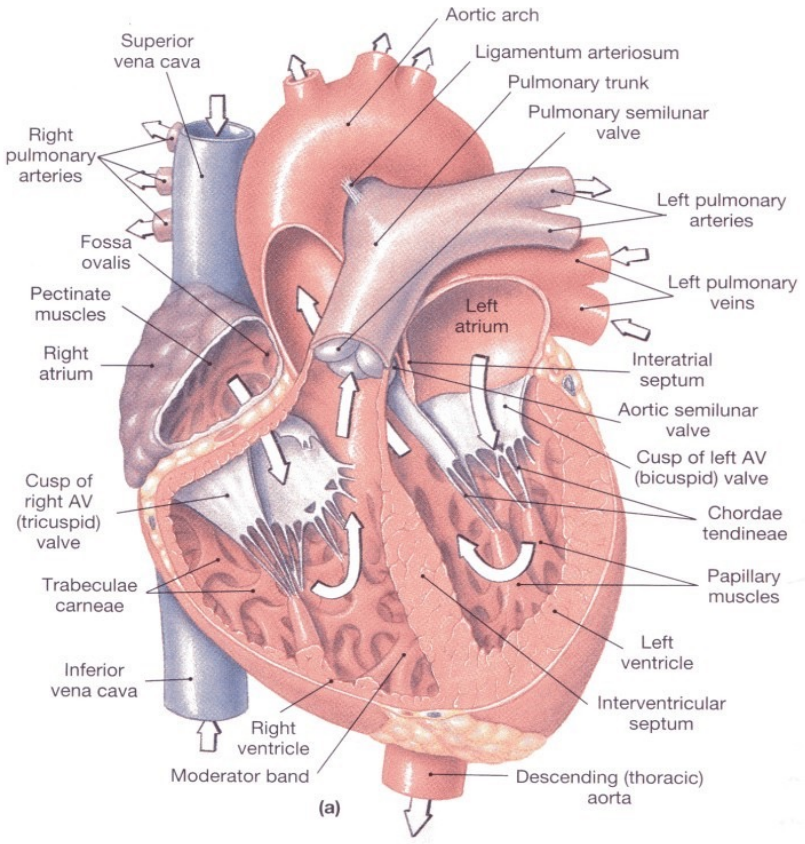
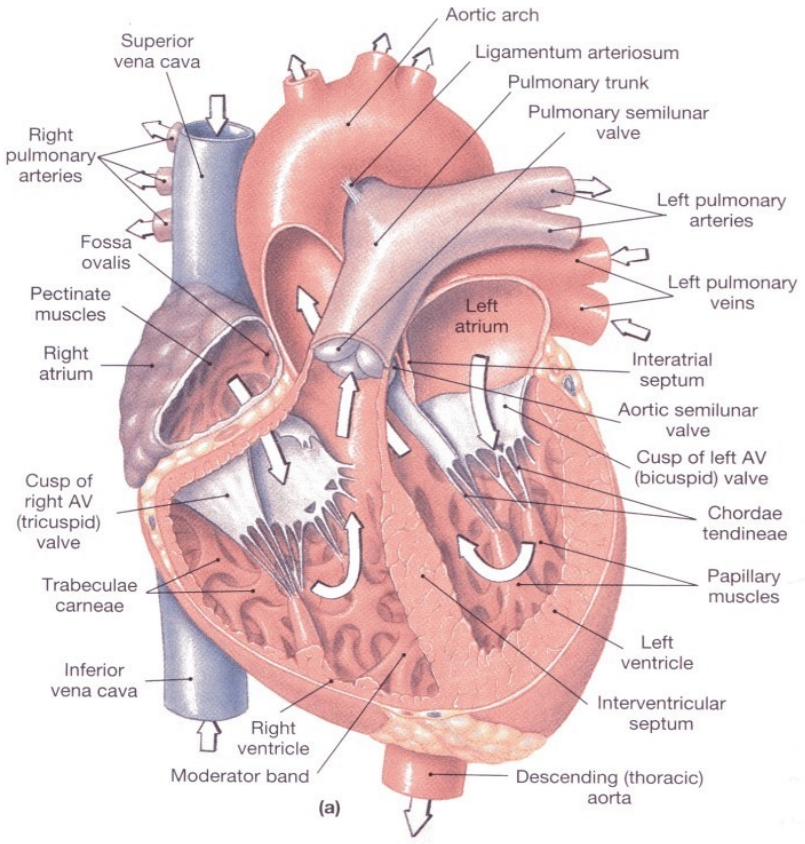
CHAPTER CONTENTS

The heart of the matter



- Muscular pump with one responsibility:
  - Provide adequate blood flow to all tissues of the body
- Located within mediastinum
- Encased in a fibrous sac (pericardium)
- Wall has three layers
  - Epicardium
  - Myocardium (muscle)
  - endocardium
- Beats >86,000x/d
- Circulates 6000 L of blood /d

The heart of the matter



- Four chambers separated by valves
- Two independent sides, but connected
- Right—
  - Low pressure system/ low O2
  - Flow to lungs
- Left—
  - High pressure system/ high O2
  - Flow to body
- Amount of blood pumped by both per unit time is equal.
- **<u>The heart can usually pump all of the blood it gets returned to it</u>**

The cardiovascular system

0_2

$C0_2$

waste

(Heart)

art.

"preload"

"afterload"

vein

Systemic circ.

Preload=
afterload

Cardiac Structure and Specializations

- Myocardium
- Valves
- Conduction System
- Blood Supply
- Cardiac Stem Cells

Effects of Aging on the Heart

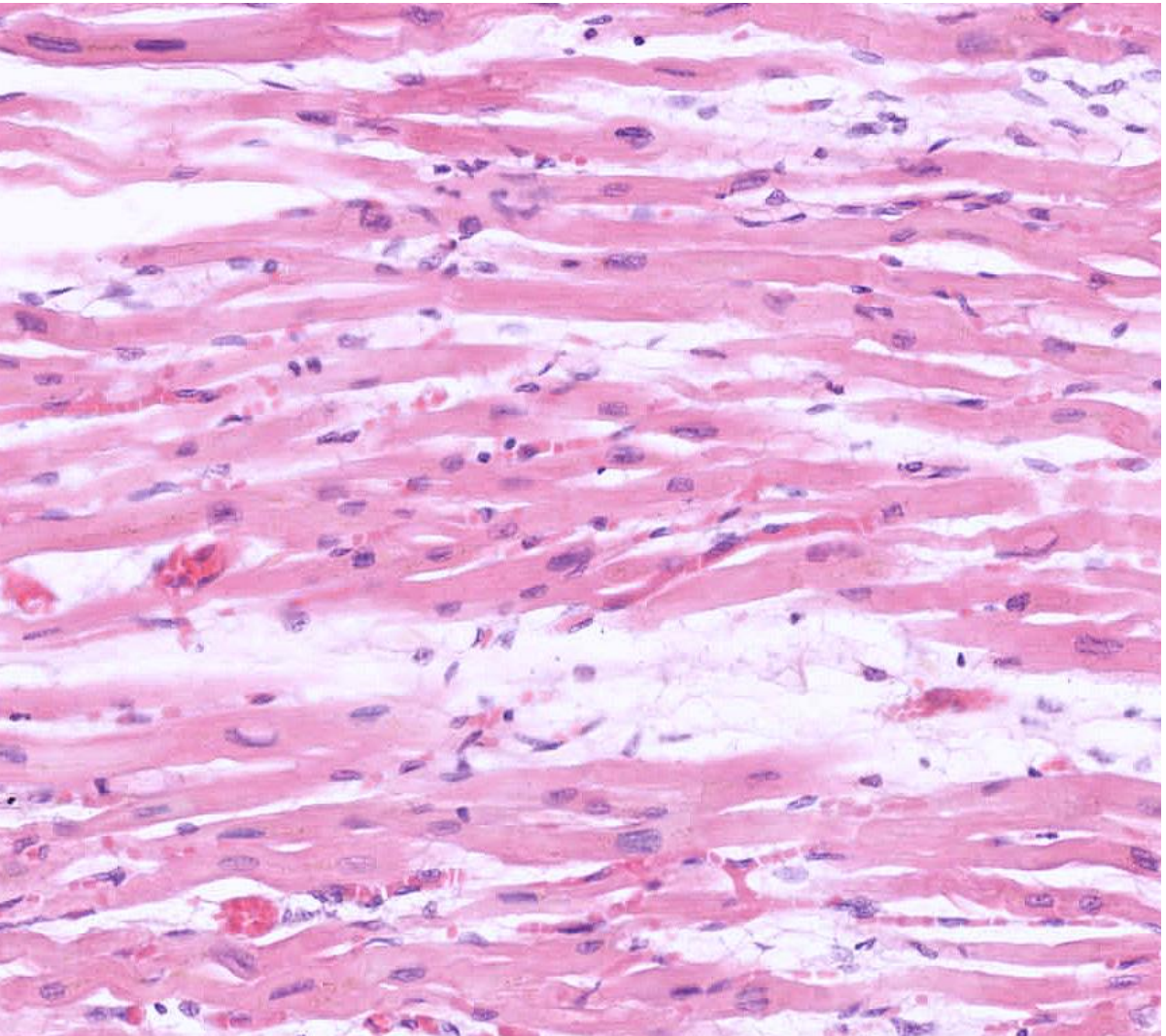
Overview of Cardiac Pathophysiology

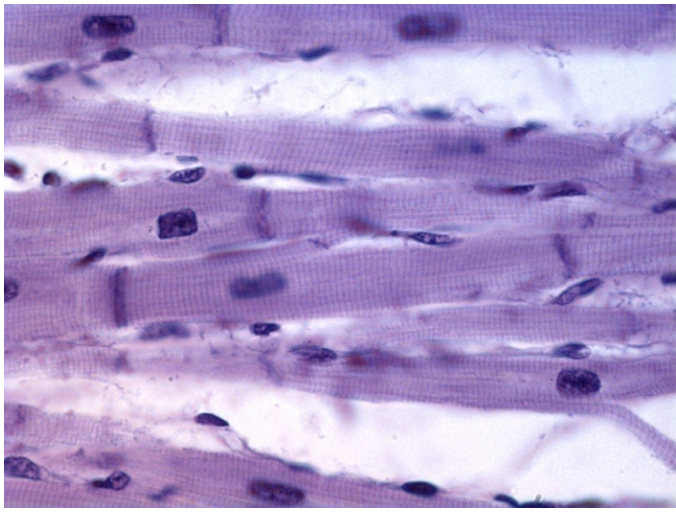
Heart Failure

- Cardiac Hypertrophy: Pathophysiology and Progression to Heart Failure
- Left-Sided Heart Failure
- Right-Sided Heart Failure

Cardiac Structure and Specializations

Myocardium





Cardiac Structure and Specializations

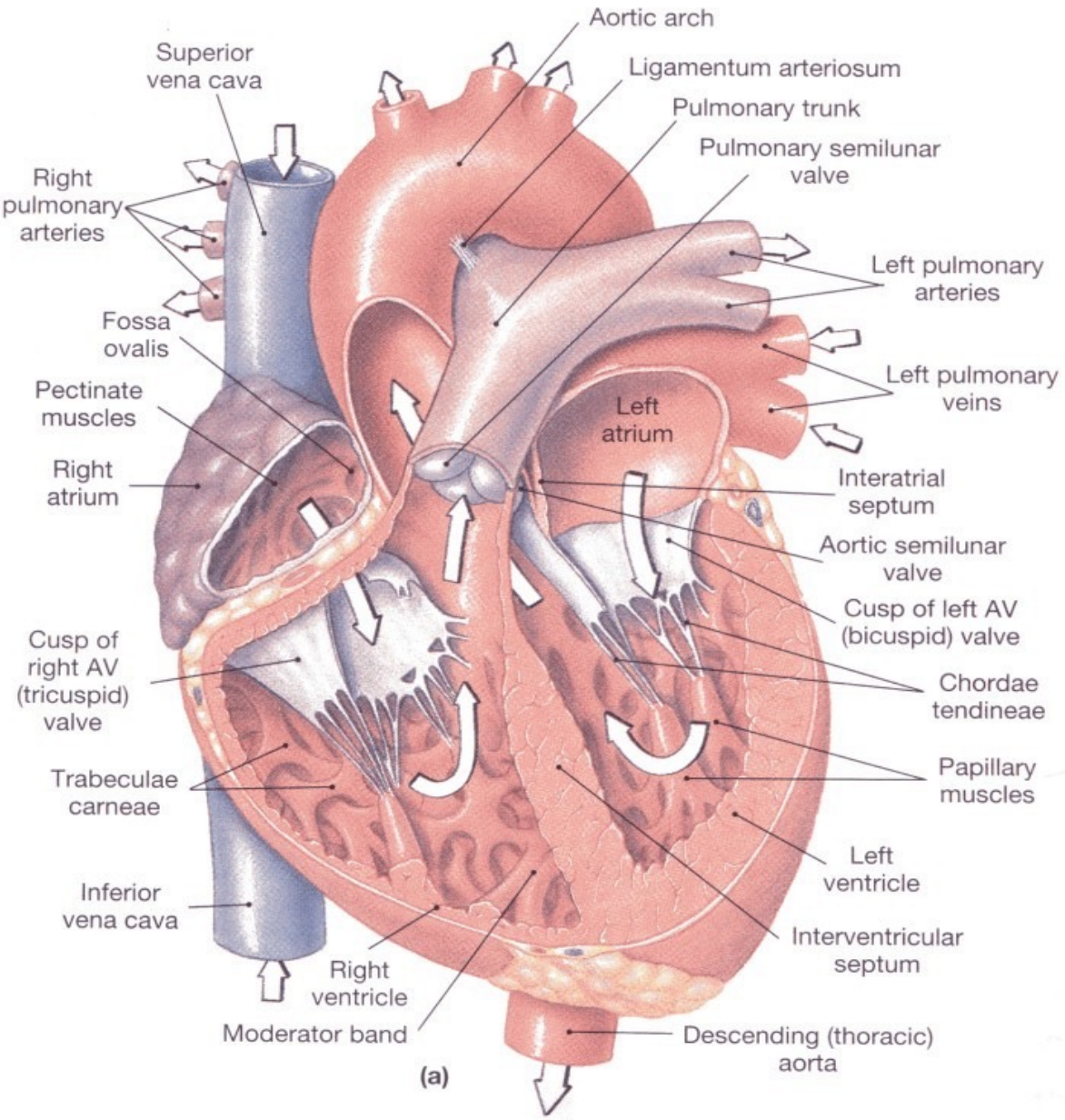
Valves

AV:

- **TRICUSPID**
- **MITRAL**

SEMILUNAR:

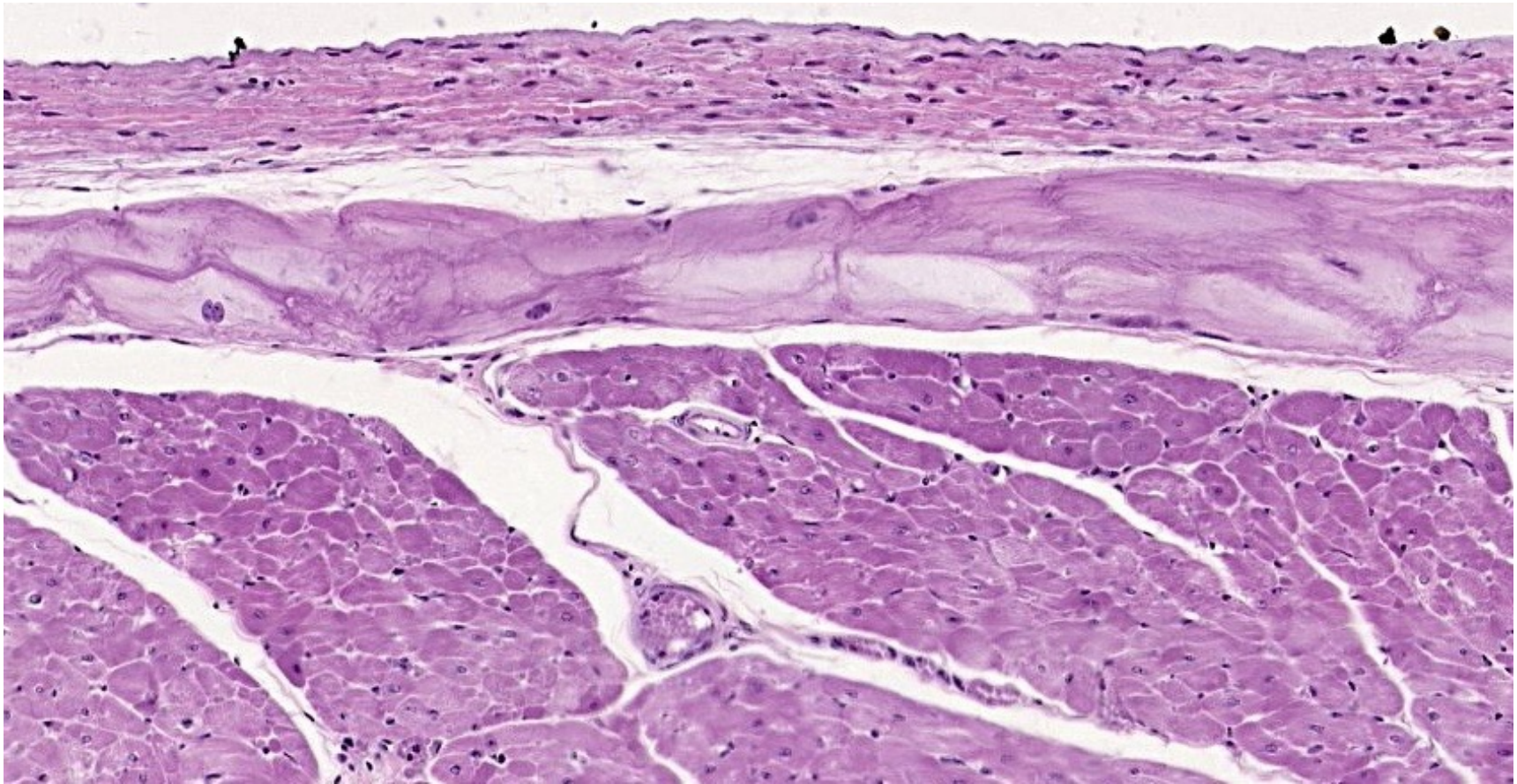
- **PULMONIC**
- **AORTIC**



Cardiac Structure and Specializations

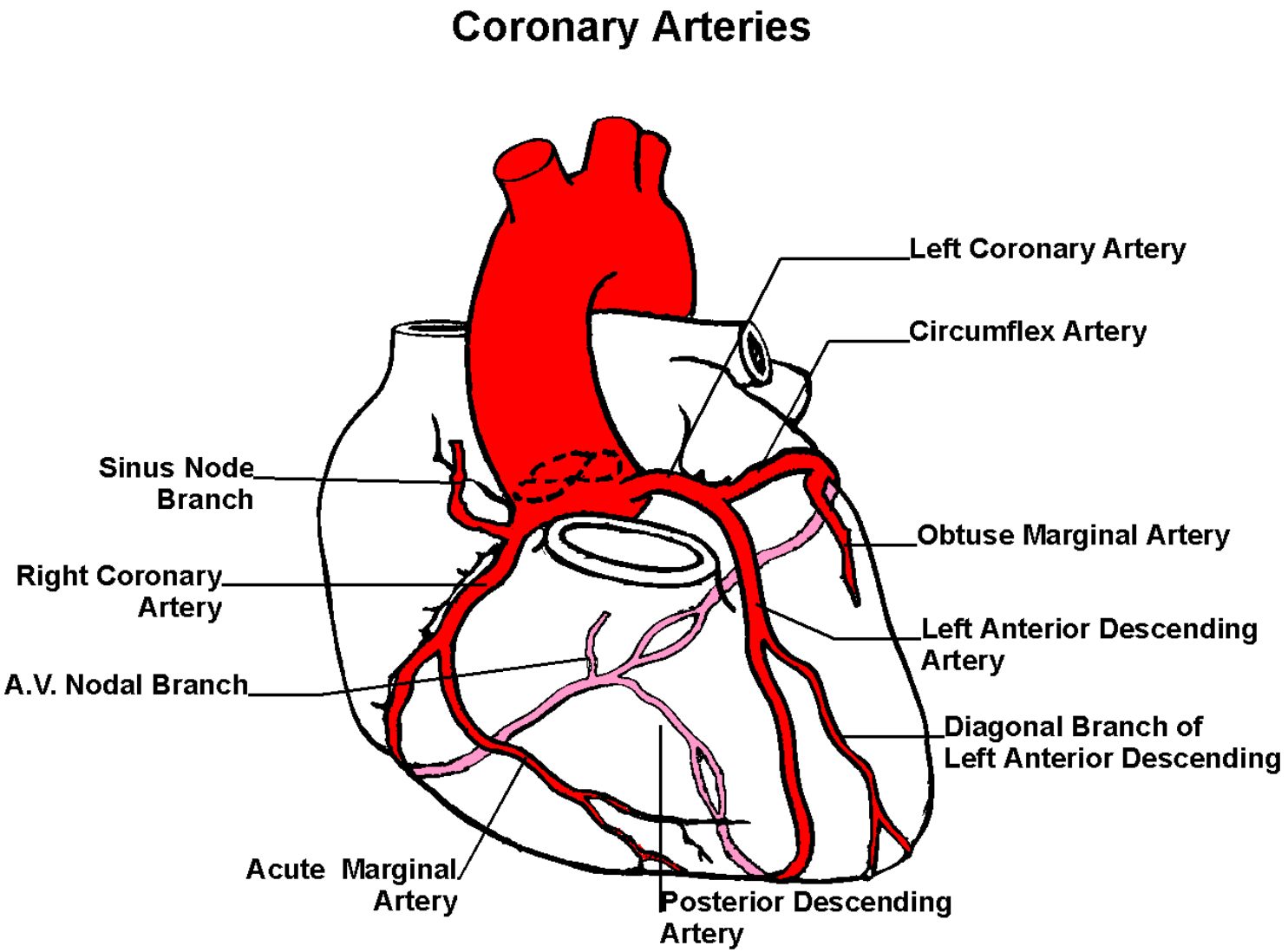
Conduction System

- **S.A. Node→AV Node→Bundle of HIS→ L. Bundle, R. Bundle**



Cardiac Structure and Specializations

Blood supply



Cardiac Stem Cells

- Myocardium depicted as a permanent cell population without replicative potential
- However, increasing evidence points to the presence of:
  - bone marrow– derived precursors
  - as well as a small population of stem cells within the myocardium
- generate all cell lineages seen within the myocardium.
- They constitute up to 5% to 10% of normal atrial cellularity,
- slow rate of proliferation, which is greatest in neonates, and decreases with age

Effects of Aging on the Heart

Chambers

Increased left atrial cavity size

Decreased left ventricular cavity size

Sigmoid-shaped ventricular septum

Epicardial Coronary Arteries

Tortuosity

Increased cross-sectional luminal area

Calcific deposits

Atherosclerotic plaque

Valves

Aortic valve calcific deposits

Mitral valve annular calcific deposits

Fibrous thickening of leaflets

Buckling of mitral leaflets toward the left atrium

Myocardium

Increased mass

Increased subepicardial fat

Brown atrophy

Lipofuscin deposition

Basophilic degeneration

Amyloid deposits

CARDIAC AGING

Aorta

Dilated ascending aorta with rightward shift

Elongated (tortuous) thoracic aorta

Sinotubular junction calcific deposits

Elastic fragmentation and collagen accumulation

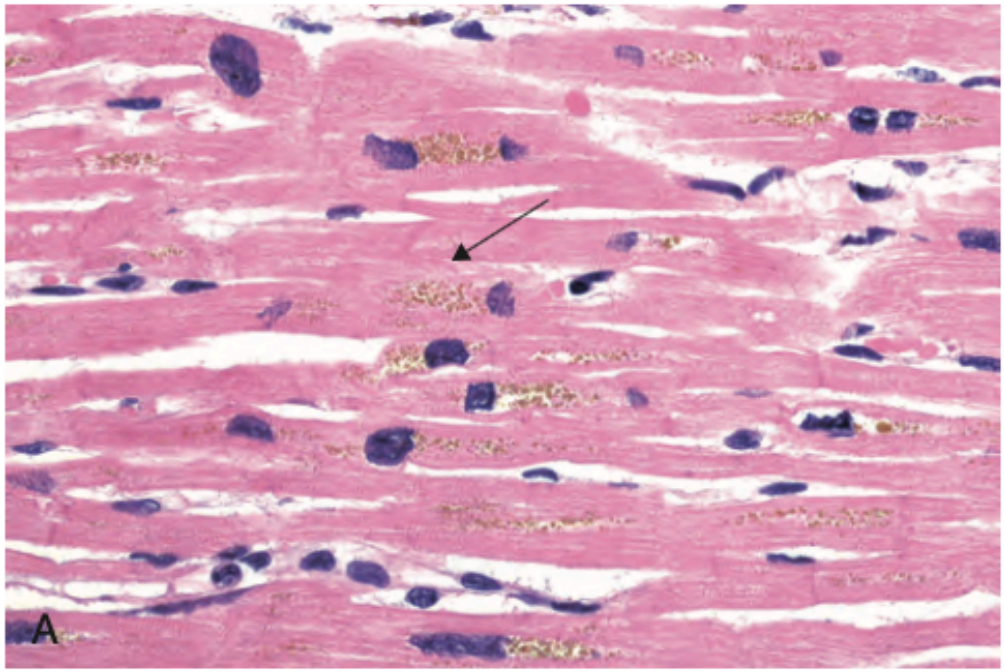
Atherosclerotic plaque

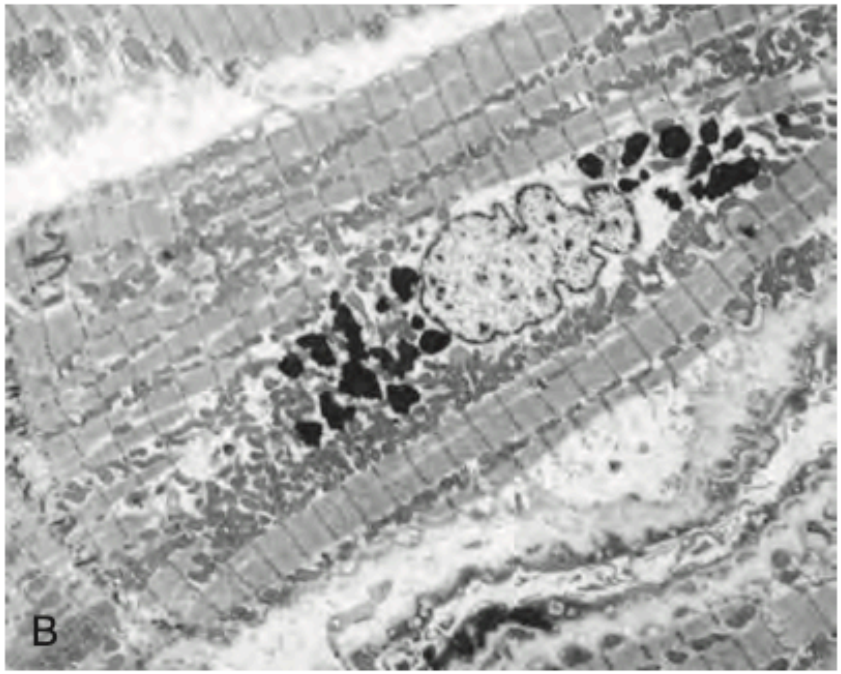
Table 12-1 Changes in the Aging Heart

Chambers
Increased left atrial cavity size
Decreased left ventricular cavity size
Sigmoid-shaped ventricular septum
Valves
Aortic valve calcific deposits
Mitral valve annular calcific deposits
Fibrous thickening of leaflets
Buckling of mitral leaflets toward the left atrium
Lambl excrescences
Epicardial Coronary Arteries
Tortuosity
Diminished compliance
Calcific deposits
Atherosclerotic plaque
Myocardium
Decreased mass
Increased subepicardial fat
Brown atrophy
Lipofuscin deposition
Basophilic degeneration
Amyloid deposits
Aorta
Dilated ascending aorta with rightward shift
Elongated (tortuous) thoracic aorta
Sinotubular junction calcific deposits
Elastic fragmentation and collagen accumulation
Atherosclerotic plaque

BROWN

ATROPHY, HEART





LIPOFUCSIN

rules of cardiac pathology

- The harder the heart works (more pressure), the more blood supply it needs
- When subjected to increased volume or pressure for extended periods of time, cardiac muscle enlarges (like your biceps)
- In adulthood the heart may grow in size, but its blood supply does not
- A ventricle can only hypertrophy so much before it dilates and becomes dysfunctional
- Any structural disease to the heart makes it electrically unstable and prone to arrhythmias

Congestive heart failure

- Symptom complex (not a disease, itself)
  - "CHF" tells you nothing of the cause
- "Heart failure" means:
  - Heart cannot provide enough flow to meet the demands of the body

And/or

- Heart cannot pump all of the blood that is returned to it

Congestive heart failure

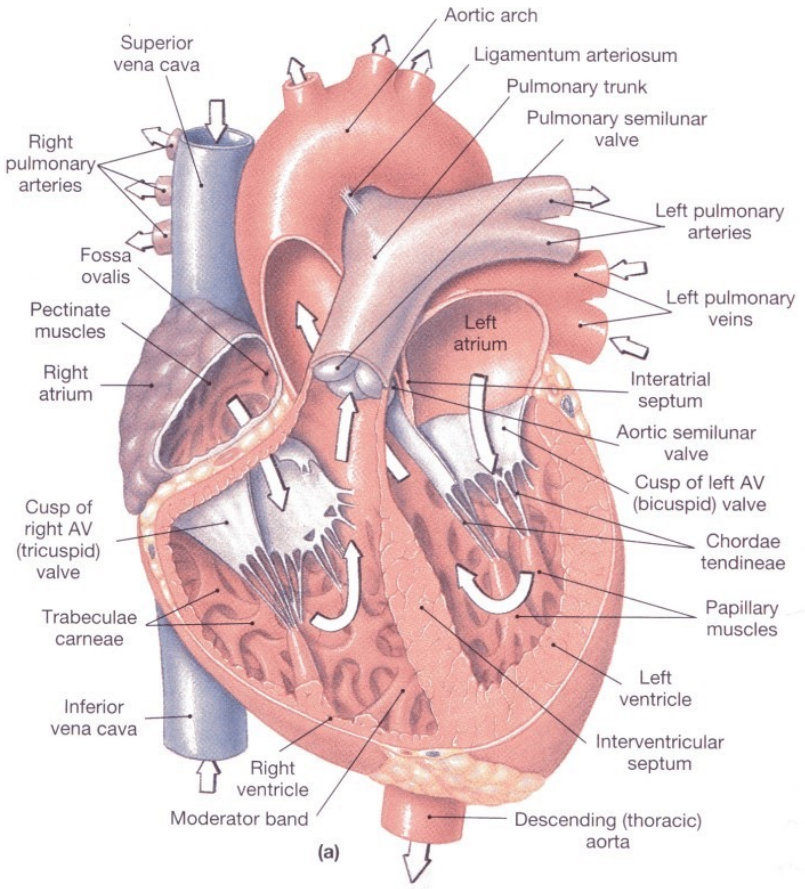
- Symptoms develop due to:
  - **Forward failure**: not enough blood flow to tissues
    - fatigue, renal insufficiency, tissue hypoxia/ damage, etc
  - **Reverse failure**: back up of venous return ("congestion") with expression of fluid into surrounding tissues
    - Edema of tissue

L: Lungs
R: Body tissues
(preload

heart

L: Body tissues
R: Lung
(afterload)

LHF vs. RHF



- Clinically divided into right heart failure(RHF) and left heart failure (LHF)
  - **RHF**: peripheral edema, ascites, pleural effusions, stasis dermatitis
  - **LHF**: pulmonary edema leading to dyspnea, cough, hemoptysis
    - "Paroxysmal nocturnal dyspnea, orthopnea"

Causes of CHF

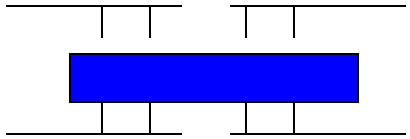
- Left heart failure
  - HTN
  - Valvular disease
  - Ischemic heart disease (coronary artery disease)
  - Cardiomyopathies
- Right heart failure
  - LEFT HEART FAILURE
  - Lung disease (“cor pulmonale”)
  - Congenital heart disease

Progression of CHF

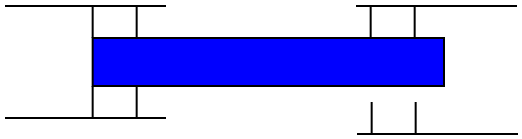
- Compensation– make the pump “better”
  - Increased sympathetic tone (Epi/NE)
    - Increased contraction force (“inotropic”)
    - Increased preload (venous return)
      - Stretch the muscle = more pumping power (for a while)
  - Aldosterone--increase amount of fluid in blood vessels
  - Hypertrophy
    - more muscle myofibrils = more pumping power
- Decompensation– (the above was not enough)
  - Ventricular dilation too much, heart becomes flabby
  - Dilation of the heart causes an extra heart sound (S3)
- A dilated heart is electrically unstable (see later)

Why does increasing preload work?

Normal

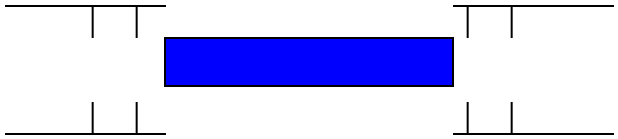


Compensated



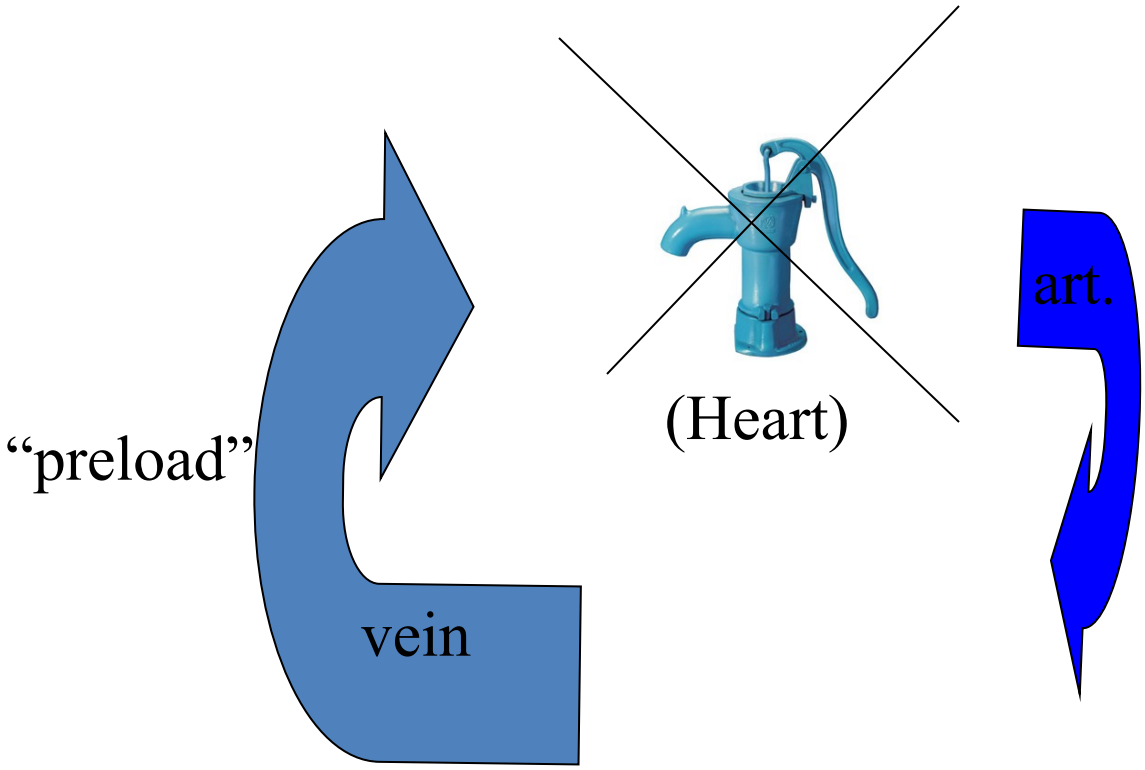
Increased preload
Increased stretch
Increased power

Decompensated



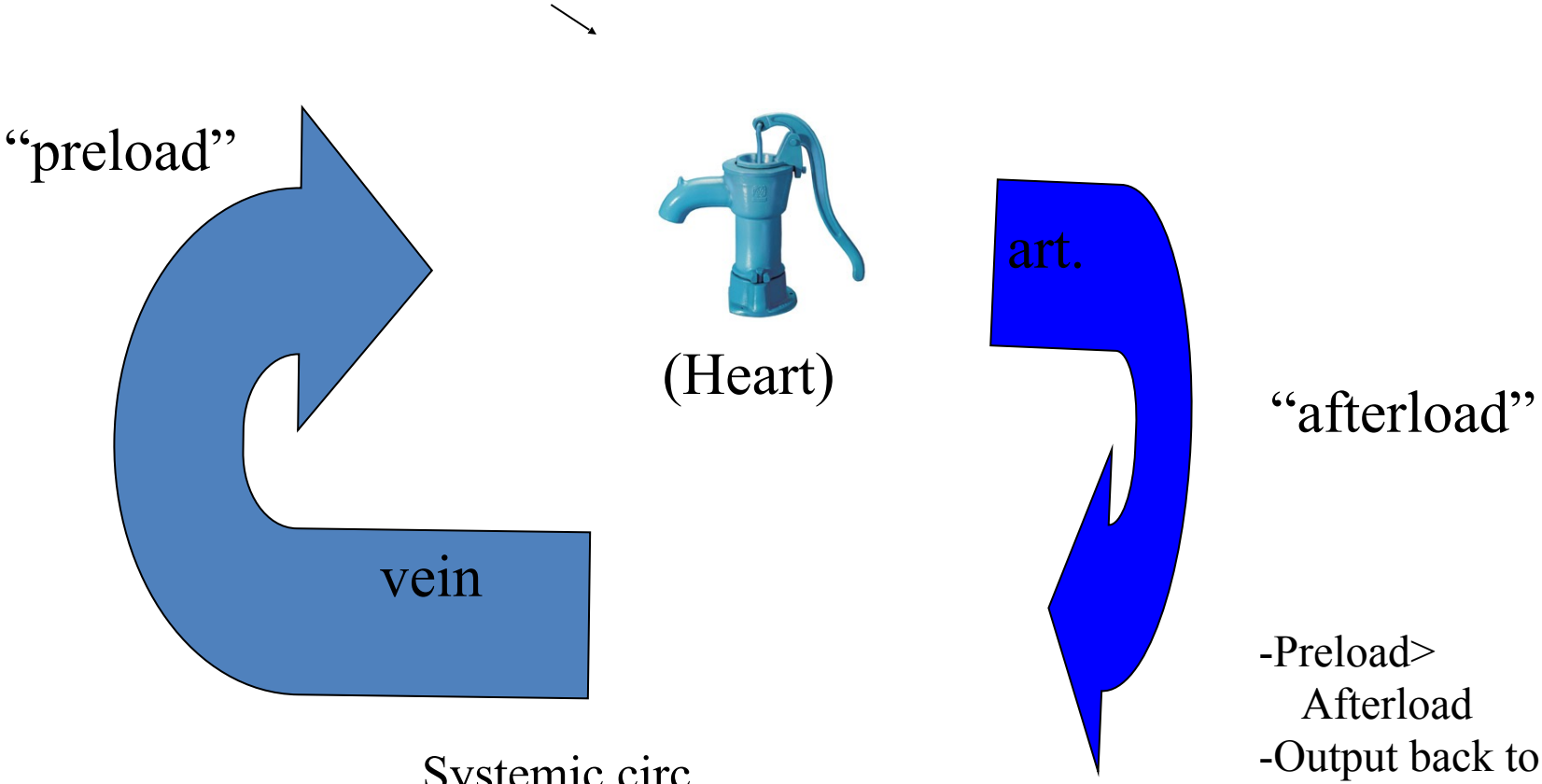
Too much stretch
Decreased power

Onset of CHF



Preload > afterload

Compensated CHF



Decompensated CHF

backward

0_2

$C0_2$ waste

(Heart)

art.

Forward

vein

Water out
in tissues

Systemic circ.

Preload > afterload,
Too much back up/
Stretch
Decreased output

Cor Pulmonale

- Heart disease caused by lung disease
  - Therefore, LV is usually not affected
- Elevations in pulmonary circulation pressure (right sided) lead to right ventricular hypertrophy, then dilation, then failure
- Disorders that predispose to cor pulmonale
  - diseases of the lung
  - diseases of pulmonary vessels
  - disorders affecting chest movement
  - disorders inducing pulmonary arteriolar constriction
- ***Most common cause is chronic obstructive lung disease***

Ischemic Heart Disease

Angina Pectoris

Myocardial Infarction

Chronic Ischemic Heart Disease

Arrhythmias

Sudden Cardiac Death (SCD)

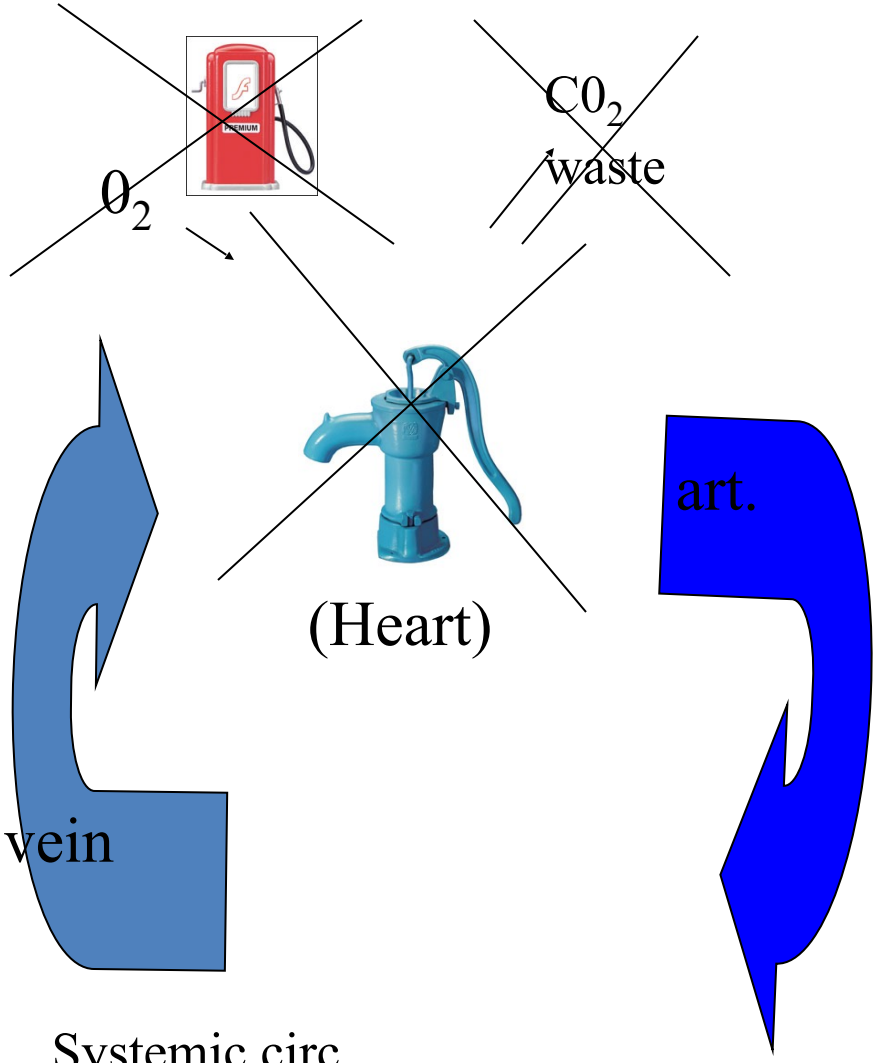
Hypertensive Heart Disease

- Systemic (Left-Sided) Hypertensive Heart Disease
- Pulmonary (Right-Sided) Hypertensive Heart Disease (Cor Pulmonale)

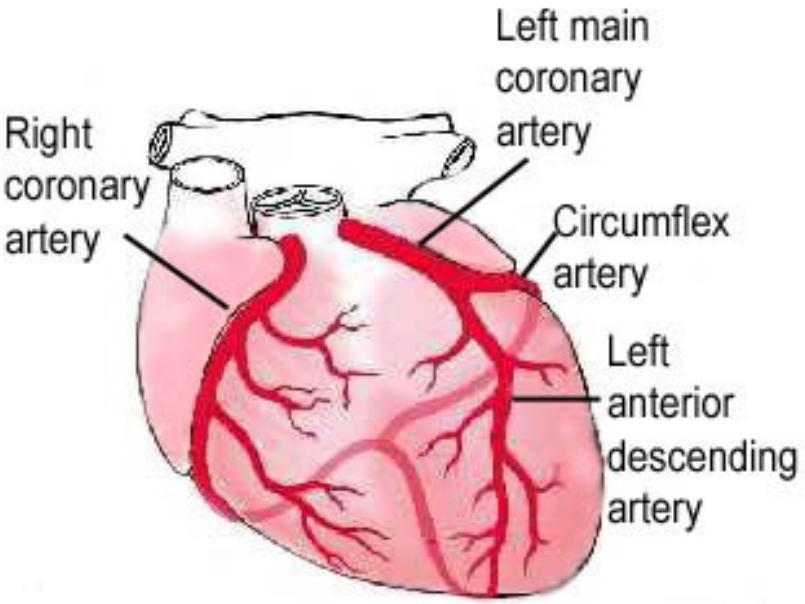
Ischemic heart disease

- Damage to myocardium caused when supply of blood not adequate to meet needs (demand > supply)
  - Most commonly caused by occlusion of coronary arteries, usually by atherosclerosis (90%)-- a.k.a.- “coronary artery disease”
  - Other causes– hypovolemia, emboli, drugs, infection, etc.

Ischemic heart disease



Coronary artery anatomy



- Heart supplied by three main coronary arteries:
  - LAD- anterior wall, anterior 2/3 of IVS, apex
  - LCX- lateral LVFW
  - RCA- RV, post. 1/3 IVS, conduction system
- The artery affected dictates damage location and presentation
- In atherosclerosis, often >1 artery affected

Ischemic heart disease

- Why do we care?
  - Leading cause of death for adult men and women
  - 1.5 M people have a myocardial infarction / y
  - 500,000 / y die of IHD
    - 250,000 / y die before reaching the hospital

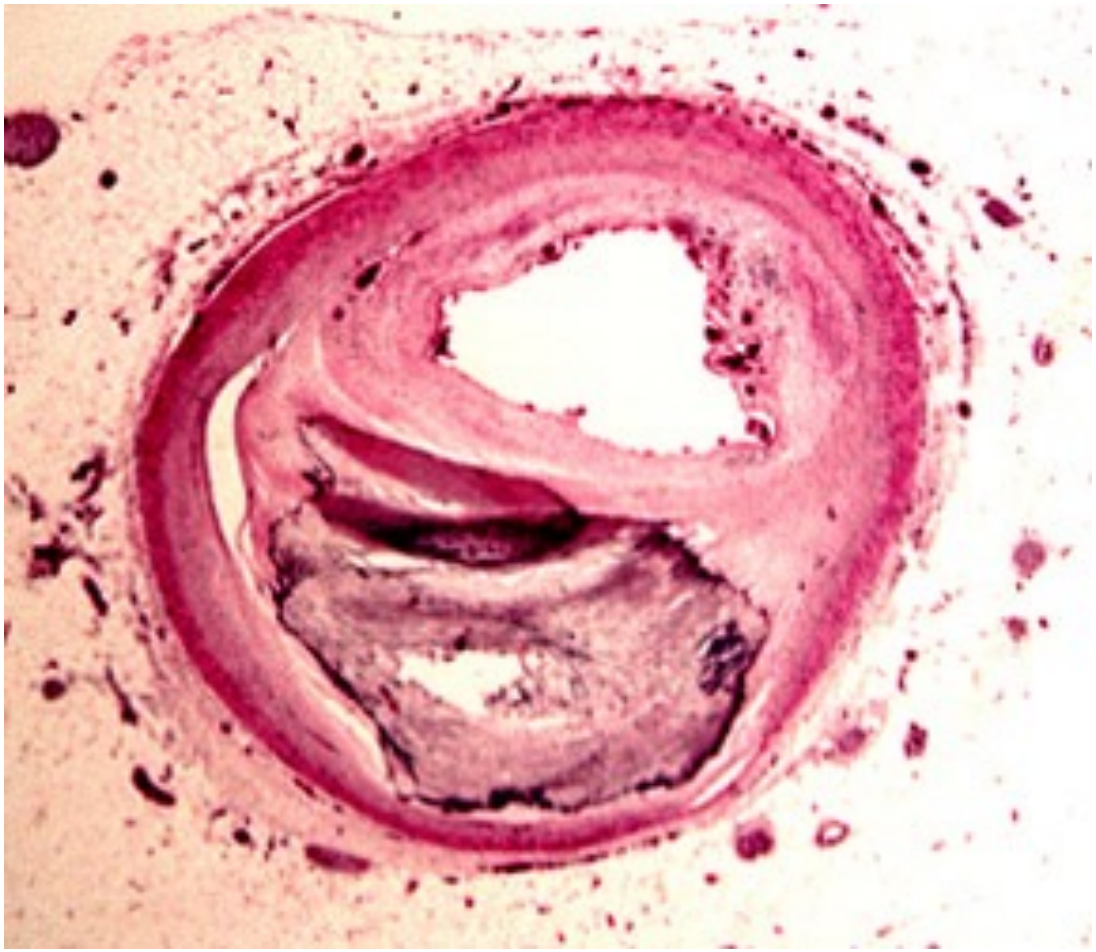
Ischemic heart disease

- Usually long-standing narrowing of coronary arteries by atherosclerotic plaque before presentation.
- Four presentations:
  - Angina pectoris
    - Stable
    - Unstable
  - Acute myocardial infarction
  - Sudden cardiac death
  - Congestive heart failure

Ischemic heart disease

- Symptoms appear when artery is >75% occluded
  - <75%, vessels can still dilate in response to hypoxia and meet demand
- Fixed obstruction – “stable angina”
  - Crushing CP, radiates to arm/jaw, <30 min.
  - Brought on by exertion, relieved by rest
  - Harbinger of worse disease/bad outcome

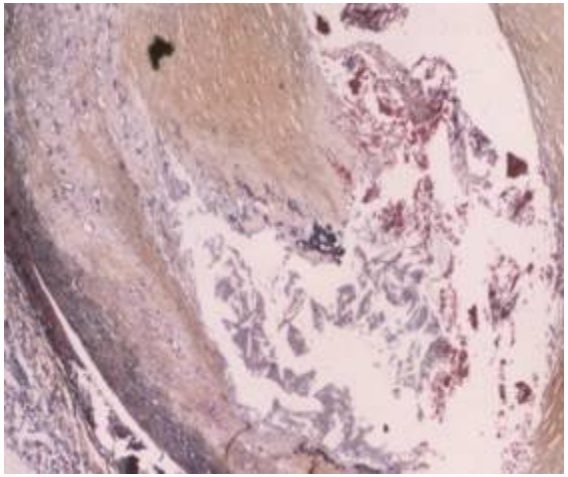
Ischemic heart disease



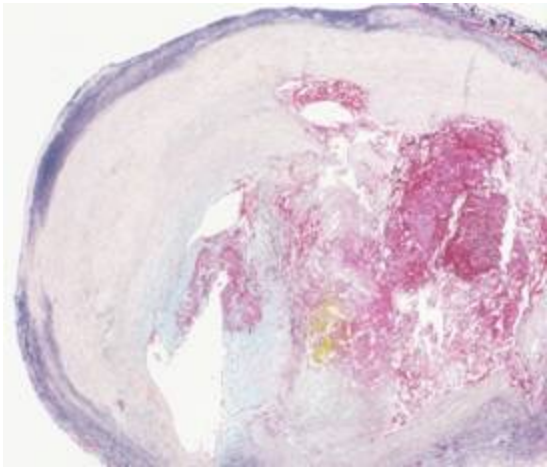
Acute coronary syndromes

- Usually a result of change in a stable atherosclerotic plaque leading to sudden increase in amount of occlusion
- Medical emergencies-
  - Unstable (crescendo) angina– longer duration, brought on by less, not relived by rest
  - Myocardial infarction– necrosis of cardiac myocytes due to localized ischemia

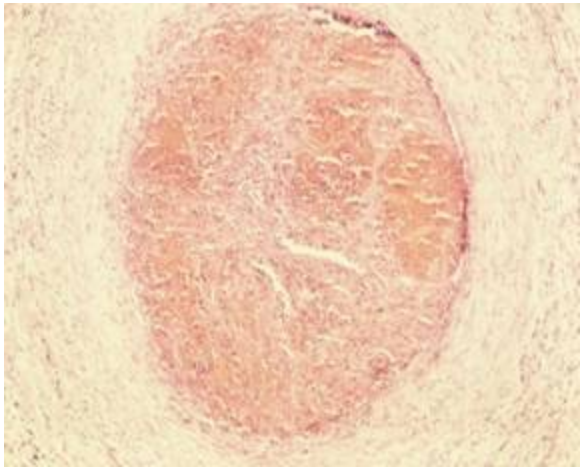
Plaque changes



Rupture or fissuring



Plaque Hemorrhage



Thrombus formation occluding the lumen of the artery

Acute Myocardial Infarction (AMI)

- Myocardial infarction– death of cardiac myocytes due to localized ischemia
- Usually cause by coronary artery thrombosis related to plaque rupture
- Irreversible damage occurs to myocytes within 20-30 minutes
- When myocytes die, they release their cellular contents into blood ("cardiac enzymes")
  - Creatine kinase (CK-MB)
  - Troponin I/T

AMI– Time is muscle!

•Cellular events occur in a predictable fashion

Feature	Time
Onset of ATP depletion	Seconds
Loss of Contractility	<2 minutes
ATP reduced	
to 50% of normal	10 minutes
to 10% of normal	40 minutes
Irreversible injury	**20-40 minutes**
Microvascular injury	>1 hr

AMI

- Location of MI depends on artery occluded
  - Left anterior descending coronary artery (40-50%)- anterior and apical left ventricle; anterior two thirds of the interventricular septum
  - Right coronary artery (30-40%)- posterior wall of the left ventricle; posterior one third of the interventricular septum
  - Left circumflex coronary artery (14-20%)-lateral wall of left ventricle
- Size of infarct depends on:
  - Where vessel occluded– proximal worse
  - Amount of collateral circulation

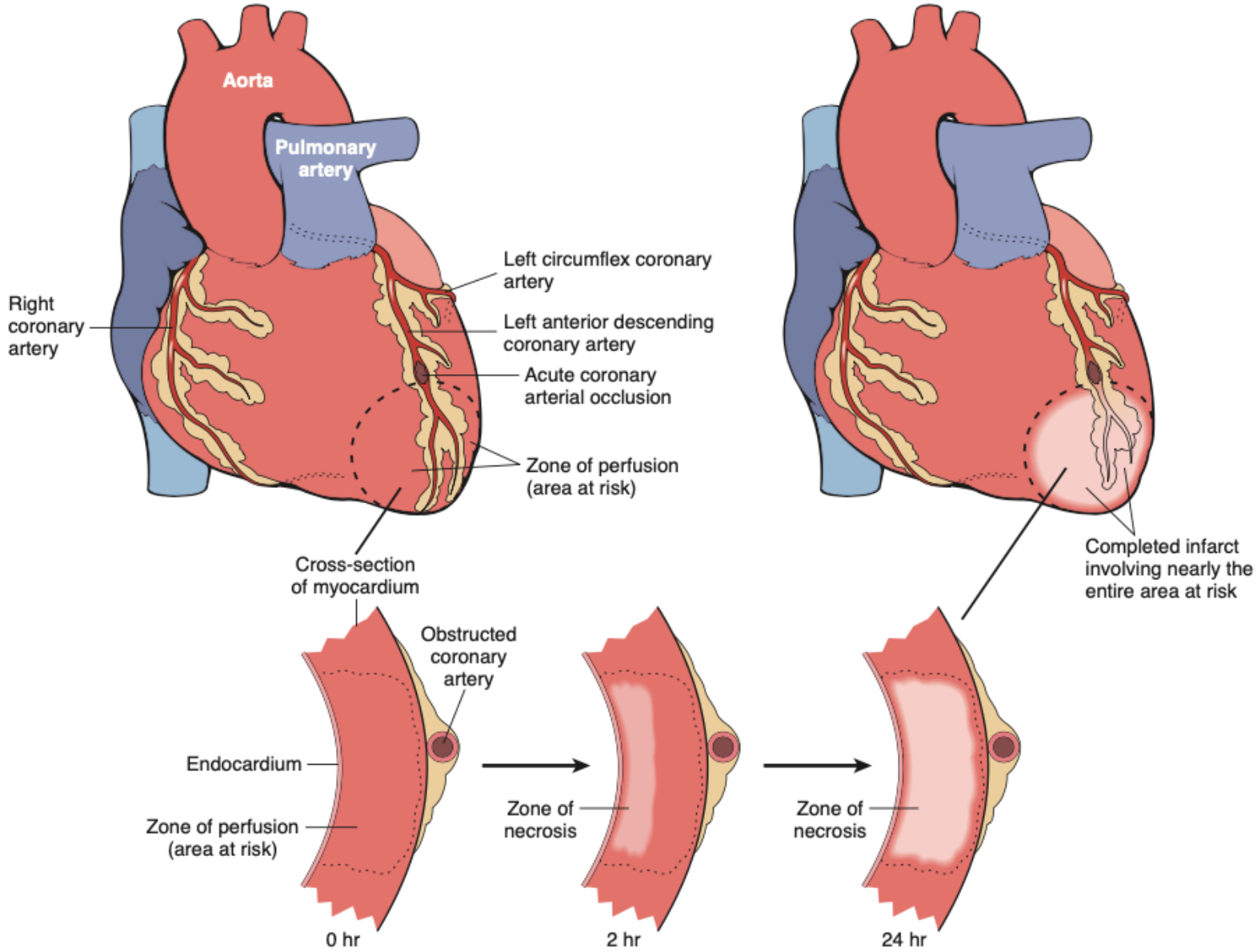


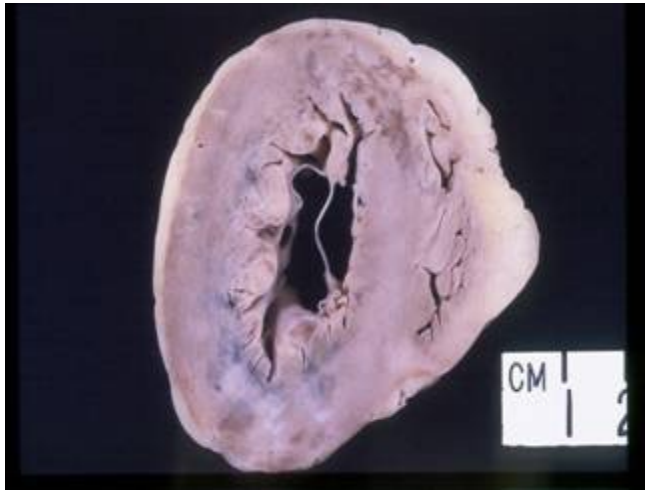
Figure 12-11 Progression of myocardial necrosis after coronary artery occlusion. Necrosis begins in a small zone of the myocardium beneath the endocardial surface in the center of the ischemic zone. The area that depends on the occluded vessel for perfusion is the "at risk" myocardium (*shaded*). Note that a very narrow zone of myocardium immediately beneath the endocardium is spared from necrosis because it can be oxygenated by diffusion from the ventricle.

Evolution of Morphologic Changes in Myocardial Infarction

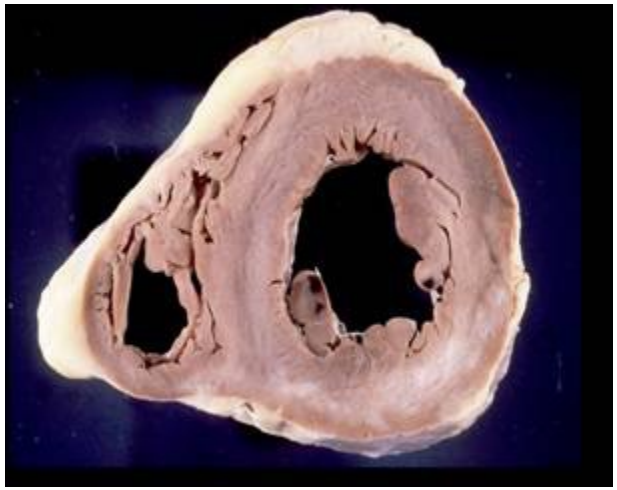
Table 12-5 Evolution of Morphologic Changes in Myocardial Infarction

Time	Gross Features	Light Microscope	Electron Microscope
Reversible Injury			
0-½ hr	None	None	Relaxation of myofibrils; glycogen loss; mitochondrial swelling
Irreversible Injury			
½-4 hr	None	Usually none; variable waviness of fibers at border	Sarcolemmal disruption; mitochondrial amorphous densities
4-12 hr	Dark mottling (occasional)	Early coagulation necrosis; edema; hemorrhage	
12-24 hr	Dark mottling	Ongoing coagulation necrosis; pyknosis of nuclei; myocyte hypereosinophilia; marginal contraction band necrosis; early neutrophilic infiltrate	
1-3 days	Mottling with yellow-tan infarct center	Coagulation necrosis, with loss of nuclei and striations; brisk interstitial infiltrate of neutrophils	
3-7 days	Hyperemic border; central yellow-tan softening	Beginning disintegration of dead myofibers, with dying neutrophils; early phagocytosis of dead cells by macrophages at infarct border	
7-10 days	Maximally yellow-tan and soft, with depressed red-tan margins	Well-developed phagocytosis of dead cells; granulation tissue at margins	
10-14 days	Red-gray depressed infarct borders	Well-established granulation tissue with new blood vessels and collagen deposition	
2-8 wk	Gray-white scar, progressive from border toward core of infarct	Increased collagen deposition, with decreased cellularity	
>2 mo	Scarring complete	Dense collagenous scar	

Gross changes in AMI



dark mottling



Gray-white scar, progressive from border toward core of infarct

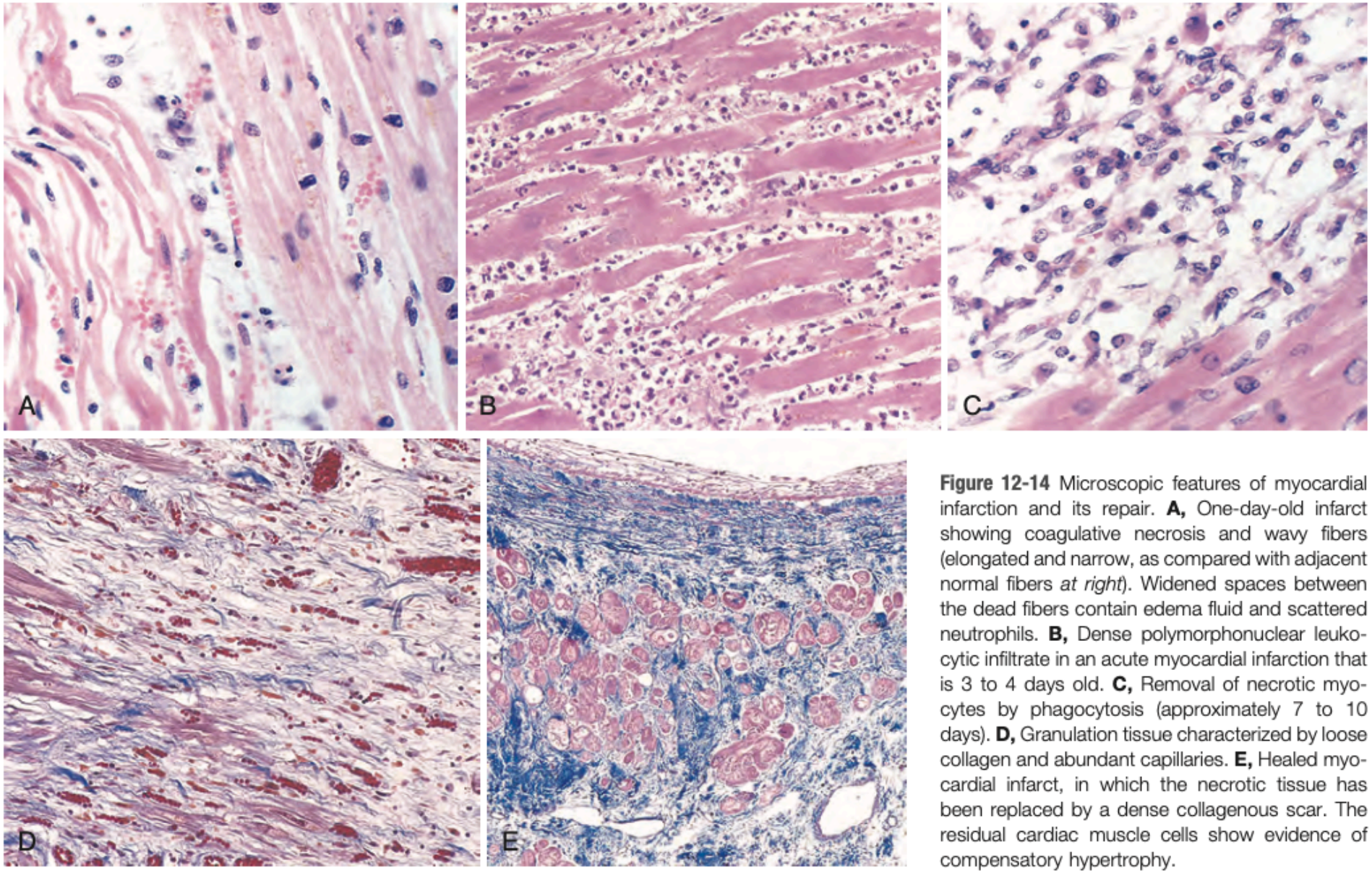


Figure 12-14 Microscopic features of myocardial infarction and its repair. **A,** One-day-old infarct showing coagulative necrosis and wavy fibers (elongated and narrow, as compared with adjacent normal fibers *at right*). Widened spaces between the dead fibers contain edema fluid and scattered neutrophils. **B,** Dense polymorphonuclear leukocytic infiltrate in an acute myocardial infarction that is 3 to 4 days old. **C,** Removal of necrotic myocytes by phagocytosis (approximately 7 to 10 days). **D,** Granulation tissue characterized by loose collagen and abundant capillaries. **E,** Healed myocardial infarct, in which the necrotic tissue has been replaced by a dense collagenous scar. The residual cardiac muscle cells show evidence of compensatory hypertrophy.

Complications of Myocardial Infarction

- **80-90% of patients suffer some complication**
- **25% suffer "sudden cardiac death" (see later)**
  - **Arrhythmias (most common in 24-48 hours)– 75-95% of patients**
    - sinus bradycardia
    - Ventricular tachycardia/fibrillation
    - asystole
  - **Myocardial rupture-- 4-8% of patients**
    - mechanical weakening of necrotic/inflamed myocardium
    - Most common at 7-10 days after infarct
    - rupture of the ventricular free wall (most common) or ventricular septum
    - papillary muscle rupture (least common)

Complications of Myocardial Infarction

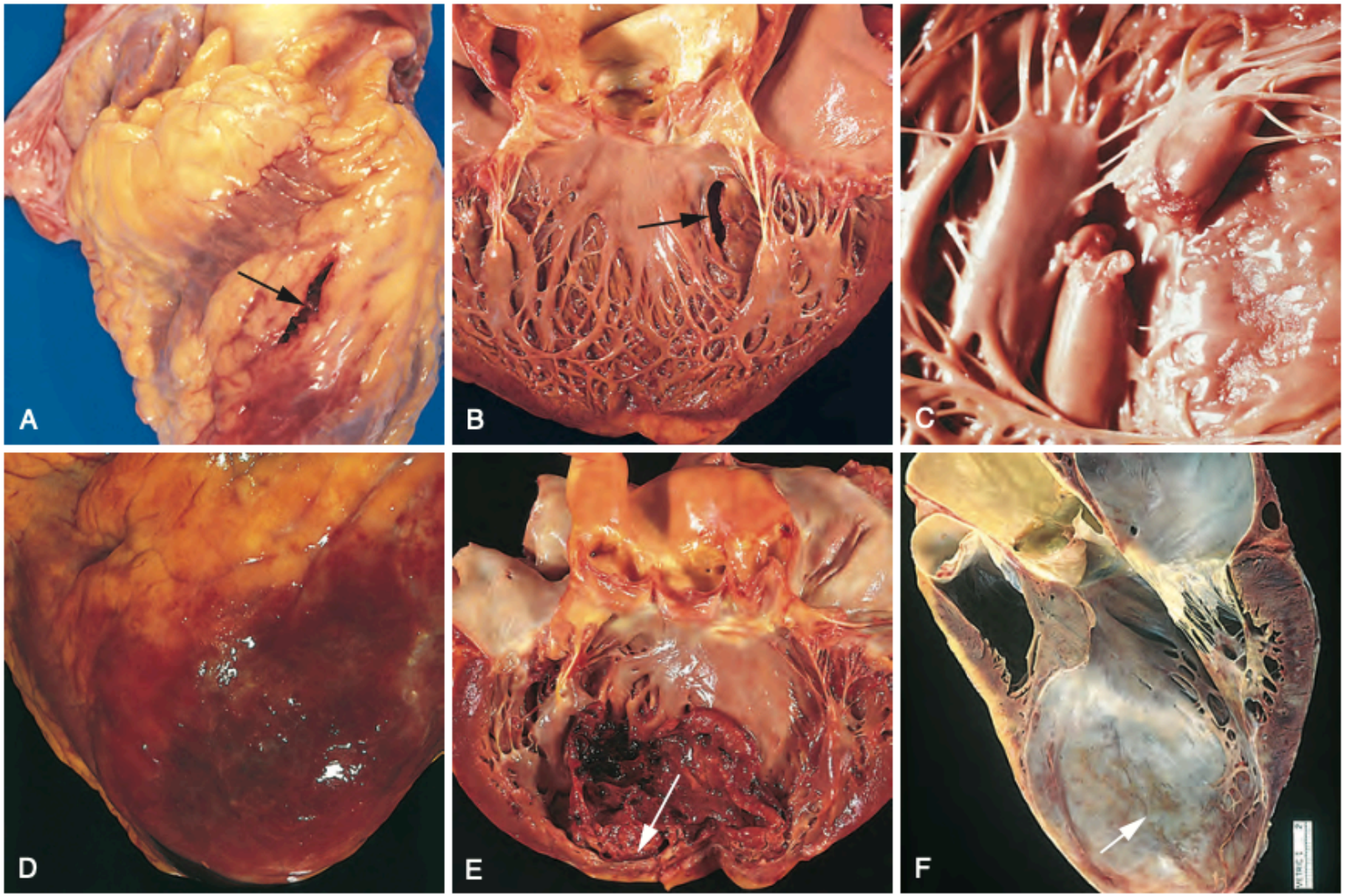


Figure 12-18 Complications of myocardial infarction. **A,** Anterior myocardial rupture in an acute infarct *(arrow)*. **B,** Rupture of the ventricular septum *(arrow)*. **C,** Complete rupture of a necrotic papillary muscle. **D,** Fibrinous pericarditis, showing a dark, roughened epicardial surface overlying an acute infarct. **E,** Early expansion of anteroapical infarct with wall thinning *(arrow)* and mural thrombus. **F,** Large apical left ventricular aneurysm. The left ventricle is on the right in this apical four-chamber view of the heart. (**A-E,** Reproduced with permission from Schoen FJ: Interventional and Surgical Cardiovascular Pathology: Clinical Correlations and Basic Principles. Philadelphia, WB Saunders, 1989; **F,** Courtesy William D. Edwards, MD, Mayo Clinic, Rochester, Minn.)

Complications of Myocardial Infarction

- **Pericarditis**
  - A fibrinous or fibrohemorrhagic pericarditis ~2-3 days post AMI
- **Mural thrombus**
  - Due to inability to pump efficiently, stasis of blood may occur.
  - The damaged endocardial surface is a thrombogenic surface which may foster mural thrombi and possible thromboemboli
- **Ventricular aneurysm**
  - Usually a result of a large transmural anteroseptal infarct that heals into a thin piece of tissue
- Papillary muscle dysfunction
  - Resulting in post infarct regurgitation

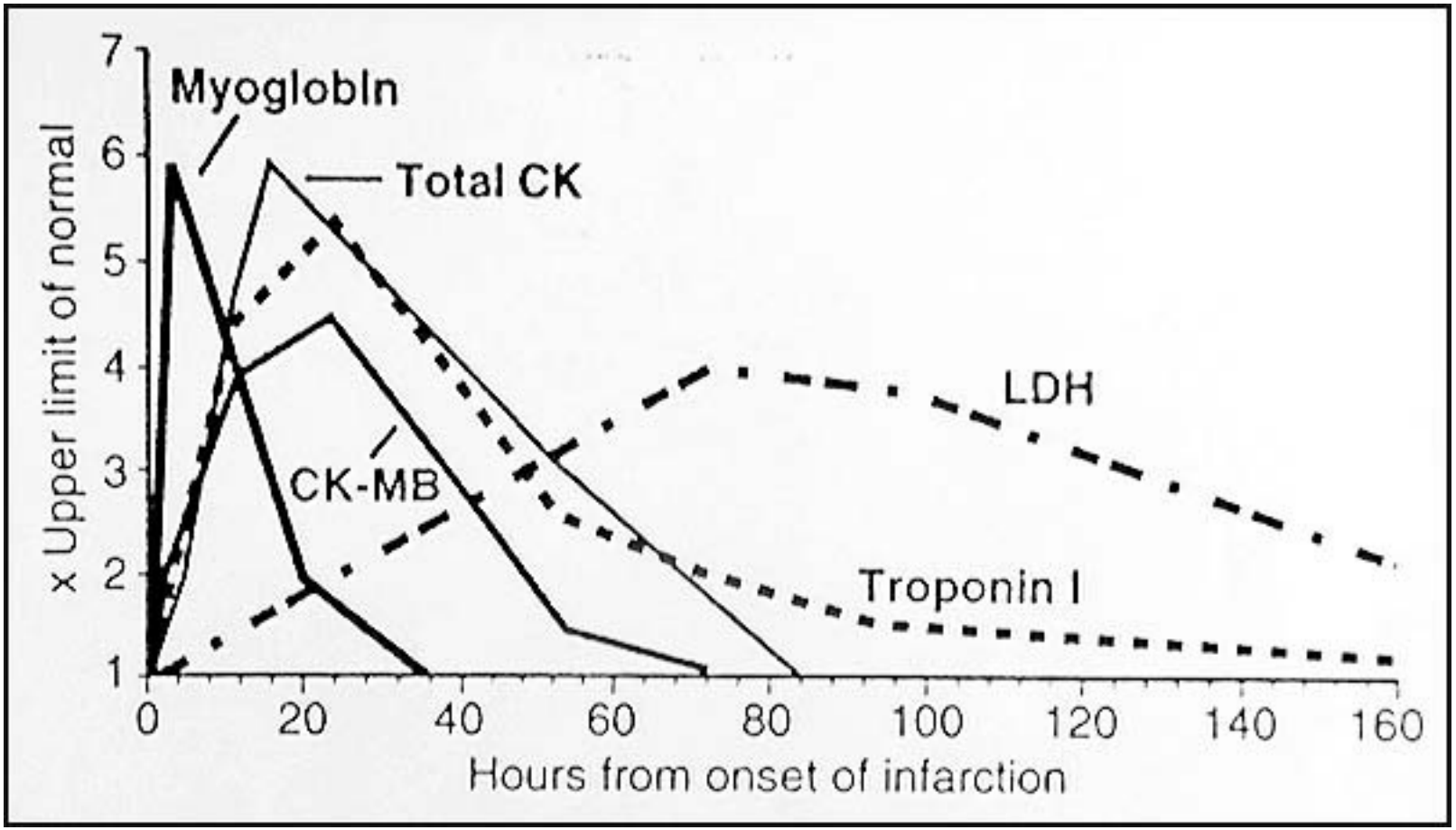
Clinical features

- Angina >30 minutes (20-30% are “silent”)
- Dyspnea
- Tachycardia
- Diaphoresis
- Acute-onset congestive heart failure
- Cardiogenic shock
  - Usually when 40% of LV affected
- Arrhythmias

Clinical features

- EKG changes:
  - Q waves (old AMI)
  - ST-segment elevation (acute MI)
  - T wave inversion
- Cardiac enzyme elevations
  - Change in a defined sequence/timeframe
  - Measured serially every 8 hours x 3
  - Usually positive within 4-6 hours
  - Troponin I is most specific

Cardiac enzymes



Chronic Ischemic Heart Disease

- Progressive myocardial damage caused by moderate to severe atherosclerosis (years)
- Can be punctuated by AMI(s)
- Leads to progressive heart failure– common cause of transplantation
- Features:
  - Dilation of all cardiac chambers
  - Myocardial fibrosis
  - Hypertrophy

Sudden cardiac death

- Death within 24 hours of symptom onset
- Often no preceding symptoms
- Often no proximate cause– patient “went down in the community”
- Attributed to sudden onset of arrhythmia that does not allow for sufficient cardiac output to support life.
- Rule out other causes of sudden death:
  - Pulmonary embolism
  - Ruptured cerebral aneurysm
  - Ruptured aortic aneurysm

Sudden cardiac death

- AMI ("heart attack") is not synonymous with SCD
- **Any structural heart lesion can predispose to arrhythmia**
  - Scars, interstitial fibrosis, inflammation, ventricular dilation, areas of myocardial infarction
- Lesions related to coronary artery disease or HTN are the most common etiologies

Geoff's rules of cardiac pathology

- The harder the heart works (more pressure), the more blood supply it needs
- When subjected to increased volume or pressure for extended periods of time, cardiac muscle enlarges like your biceps
- In adulthood the heart may grow in size, but its blood supply does not
- A ventricle can only hypertrophy so much before it dilates and becomes dysfunctional
- Any structural disease to the heart makes it electrically unstable and prone to arrhythmias

Hypertensive heart disease

- Normotension: BP <120/80
- Hypertension: BP >140/90
- Effects seen in brain, heart, kidneys
- Effects in the heart related to increased AFTERLOAD
  - Heart must generate more pressure to eject blood into aorta to counteract systemic pressure
- Cardiac myocytes undergo HYPERTROPHY to deal with this increased amount of work
  - “concentric” hypertrophy

Hypertensive heart disease

0_2

$C0_2$

waste

art.

(Heart)

"preload"

"afterload"

vein

Systemic circ.

Preload<
afterload

Hypertensive heart disease

0_2

$C0_2$

waste

(Heart)

"preload"

"afterload"

vein

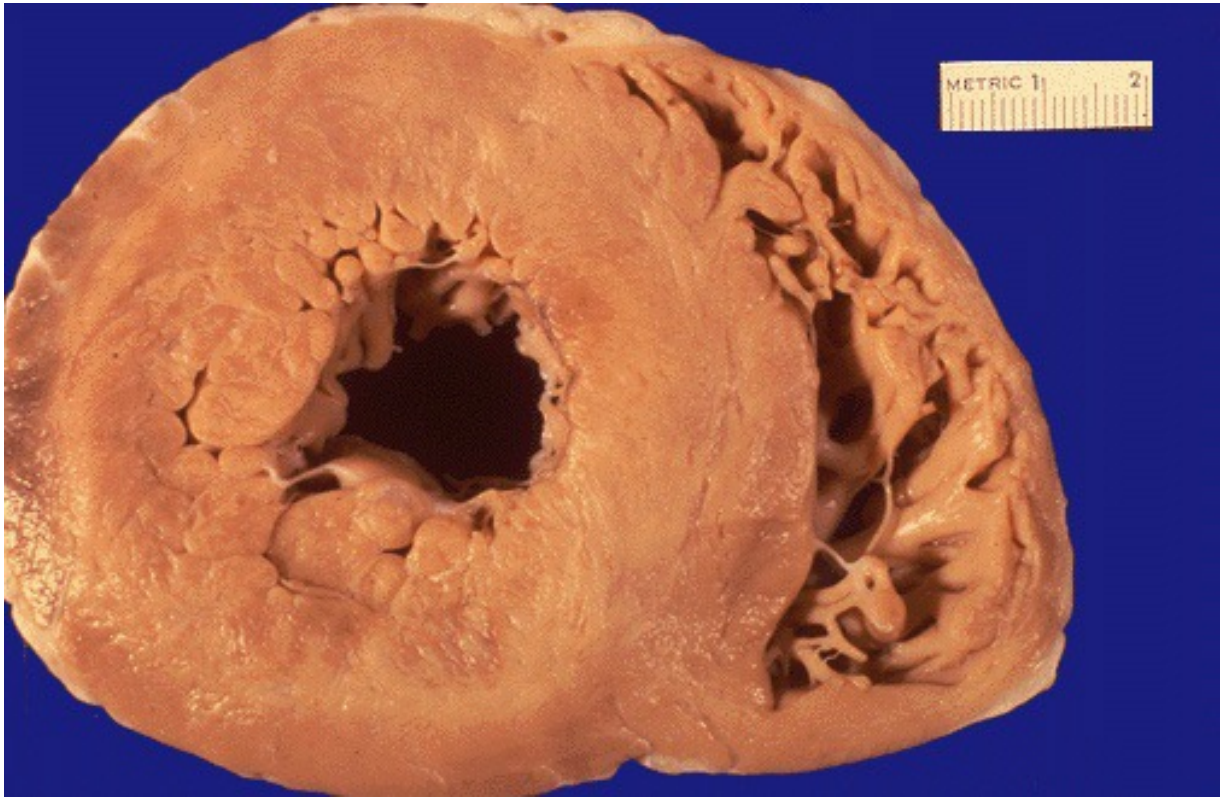
Systemic circ.

Preload< afterload

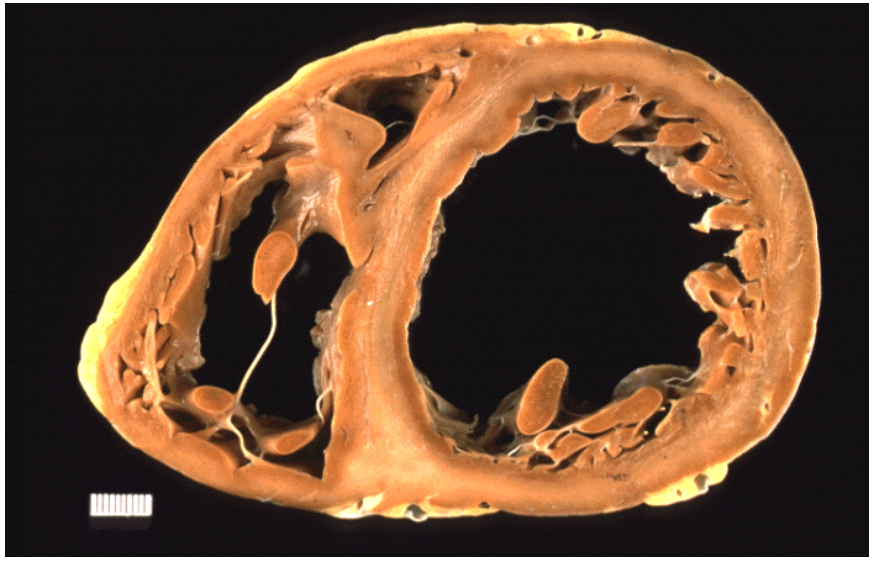
Effects of LVH

- Increased demand for oxygen/fuel
  - Myocardium outgrows blood supply, eventually leading to interstitial scar tissue formation
  - Effect worsened if overlying CAD
  - Structural heart disease = increased risk for arrhythmia and SCD
- Thickened ventricle not able to relax
  - Extra heart sound (S4)
- If not corrected, eventually muscle cannot hypertrophy more and dilation occurs with CHF developing

Left ventricular hypertrophy



Hypertensive heart disease



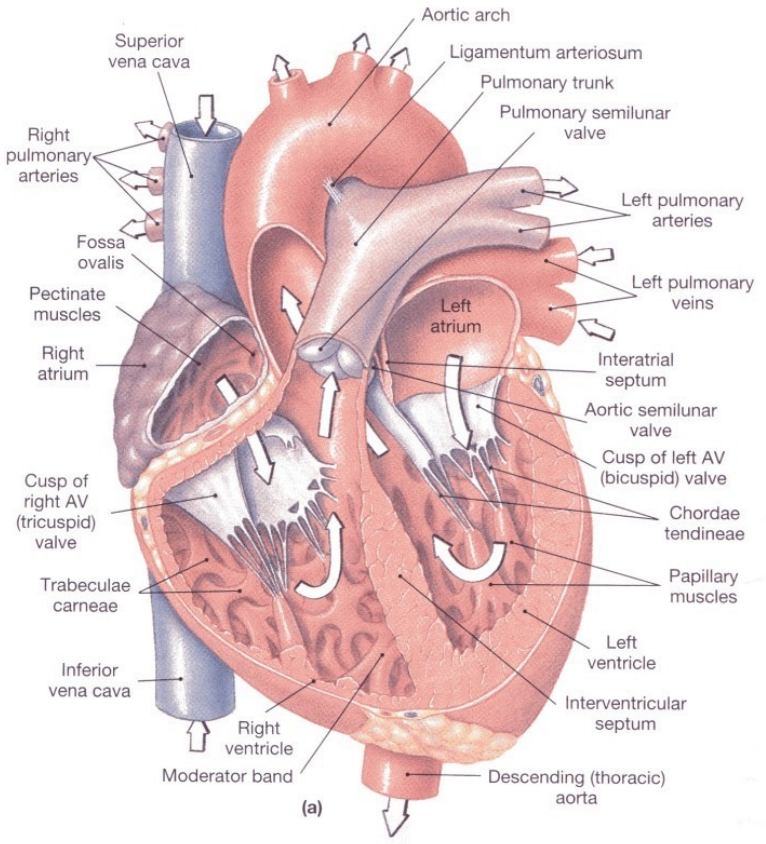
Valvular Heart Disease

- Calcific Valvular Degeneration
  - *Calcific Aortic Stenosis*
  - *Calcific Stenosis of Congenitally Bicuspid Aortic Valve*
  - *Mitral Annular Calcification*
- Mitral Valve Prolapse (Myxomatous
  - Degeneration of the Mitral Valve)
- Rheumatic Fever and Rheumatic Heart Disease
- Infective Endocarditis
- Noninfected Vegetations
  - *Nonbacterial Thrombotic Endocarditis*
  - *Endocarditis of Systemic Lupus Erythematosus (Libman-Sacks Disease)*
- Carcinoid Heart Disease
- Complications of Prosthetic Valves

Valvular diseases

- Valves exist between heart chambers to ensure one-way blood flow
- Heart valves can suffer from congenital or acquired lesions
- Two major types:
  - Stenosis– tight valve (more pressure needed)
  - Regurgitation/insufficiency– leaky valve (backwards flow)
- Two major effects:
  - Hemodynamic stress placed on chambers because of abnormal flow
    - Causes upstream ventricle to hypertrophy or dilate
  - Abnormal valves are more susceptible to infection (endocarditis)

Valvular diseases

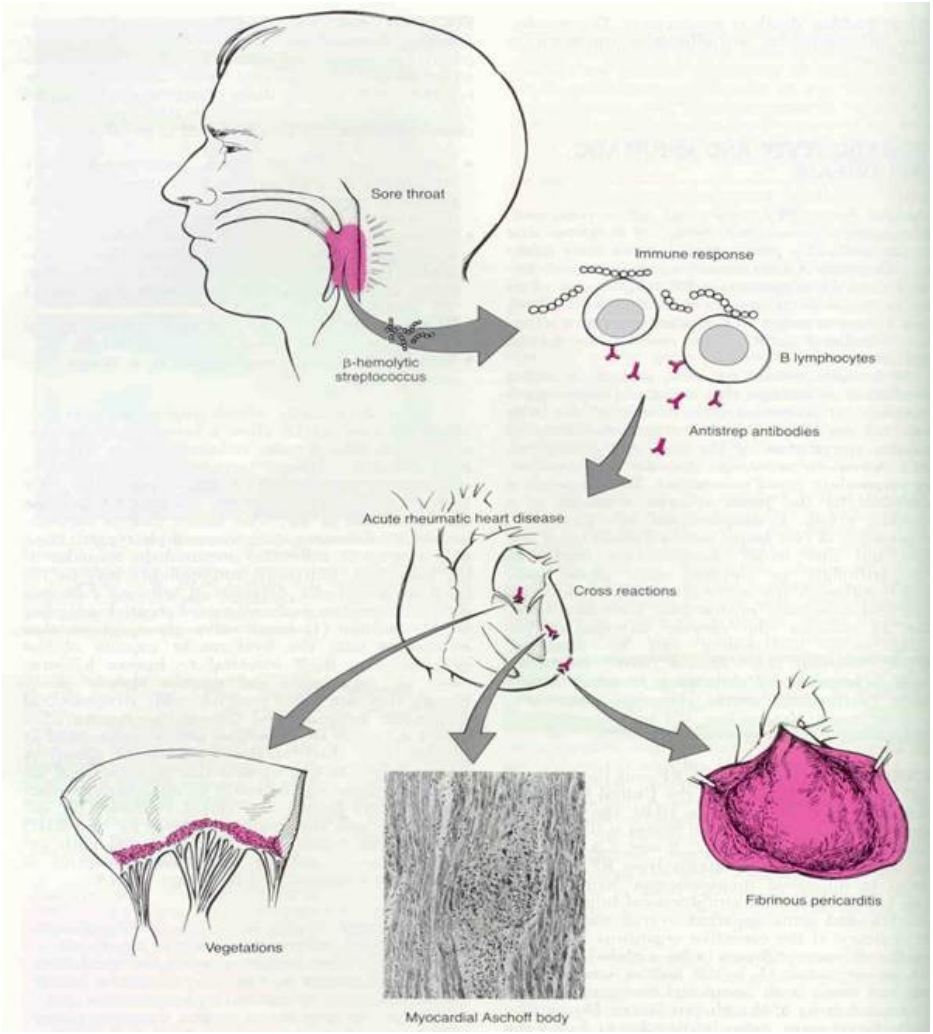


- Present as **murmur**
- As a rule, left sided valvular lesions are more common and clinically significant
  - Aortic stenosis
  - Aortic regurgitation
  - Mitral stenosis
  - Mitral regurgitation
- Infective endocarditis more common on left sided valves

Causes of valvular disease

- Mitral stenosis
  - **Rheumatic heart disease**
- Mitral regurgitation
  - **LV dilation**
  - **Papillary muscle dysfunction (s/p AMI)**
  - **Rupture of chordae**
  - **Mitral valve prolapse**
  - Infective endocarditis
- Aortic stenosis
  - **Senile calcific stenosis**
  - **Calcification of bicuspid valve**
  - Rheumatic heart disease
- Aortic regurgitation
  - **Aortic dilation**
    - **HTN**
    - **Syphilis**
    - **Marfan's**
    - **CTD**
  - Rheumatic heart disease
  - Infective endocarditis

Rheumatic heart disease

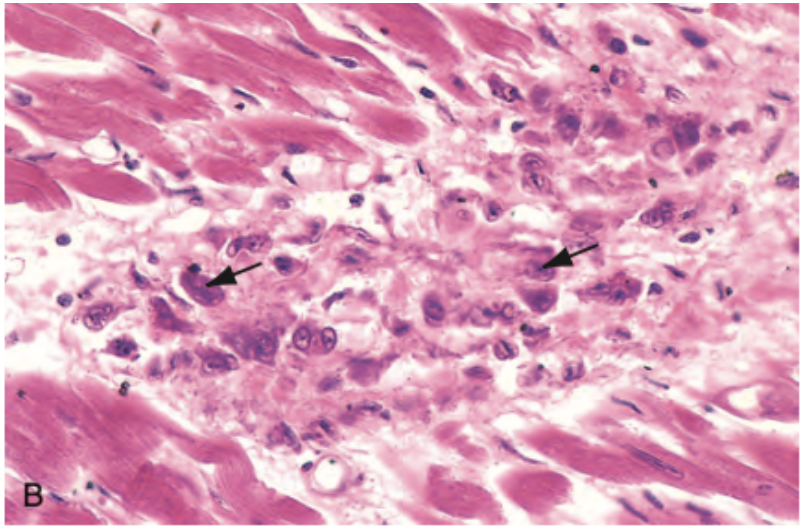


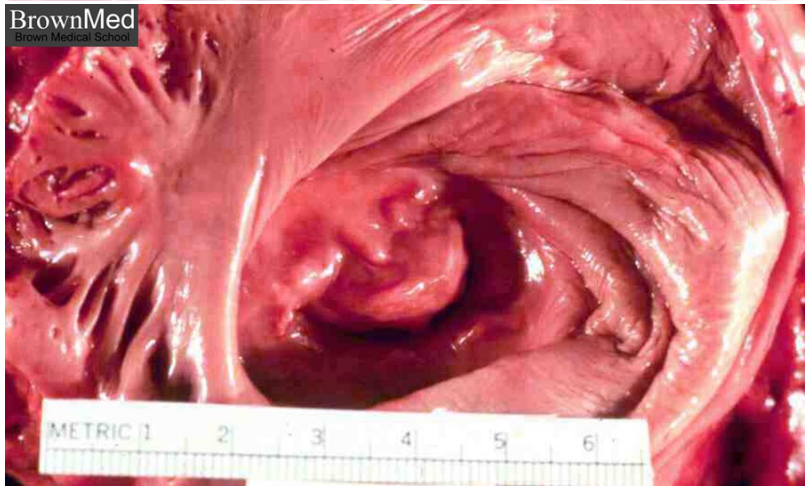
- Sequela of rheumatic fever, a syndrome following group A Streptococcal pharyngitis
- Cross reaction to tissue antigens or streptococcal-induced autoimmune reaction
- Two presentations:
  - Acute rheumatic fever
  - Mitral valvulitis
- Decreased incidence because of antibiotic use

Rheumatic heart disease

- Acute rheumatic fever
  - Inflammation of numerous tissues (joints, skin, and heart)
  - "Pancarditis"– all three layers of the heart (epicardium/ myocardium/endocardium) can be affected
    - Aschoff bodies within connective tissue
  - Fibrinous pericarditis common
  - Endocardium often hardest hit
    - Valves are extensions of endocardium, hence are prime targets
  - MITRAL VALVE IS MOST COMMONLY INVOLVED
    - Aortic valve involved 25% of the time

Rheumatic carditis





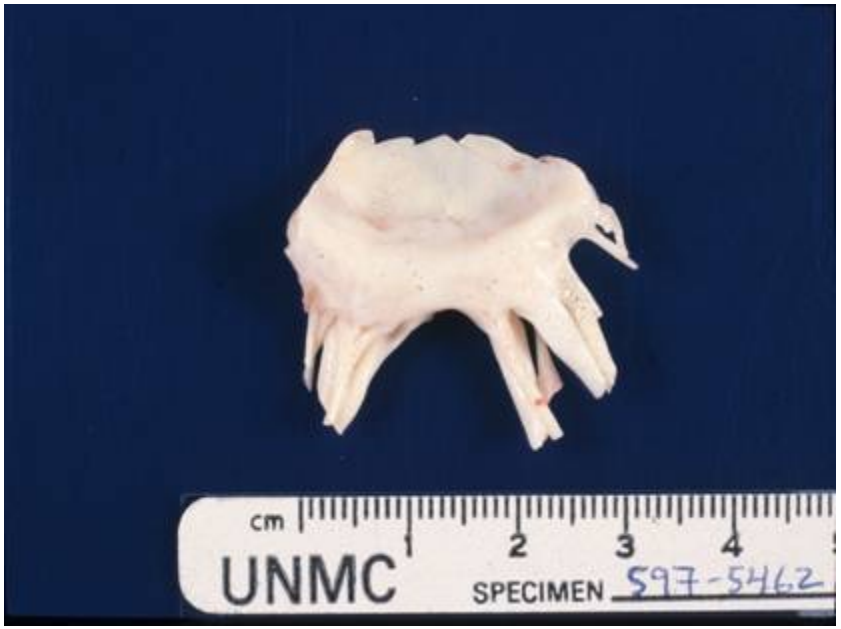
- Aschoff body --focus of fibrinoid necrosis surrounded by lymphocytes and macrophages

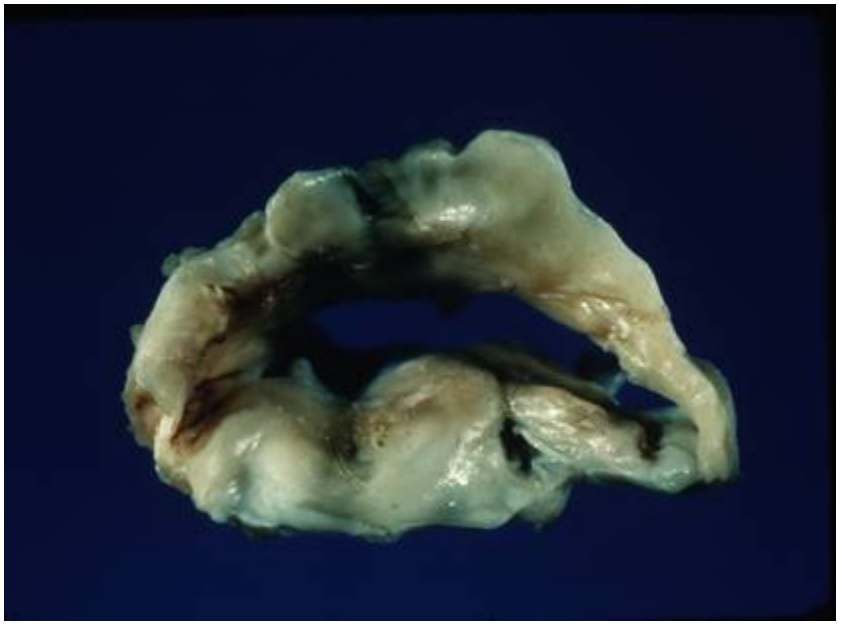
- Verrucous endocarditis– warty growths on free edges of valve leaflets

Chronic rheumatic valvular disease

- Inflammation leads to scarring of the valve
  - Thickened leaflets
  - Fusion of the commissures
  - Thickened chordae
  - “Fish mouth” opening
- MOST FREQUENT CAUSE OF MITRAL STENOSIS
  - Can occasionally scar open– cause regurgitation.

Mitral stenosis



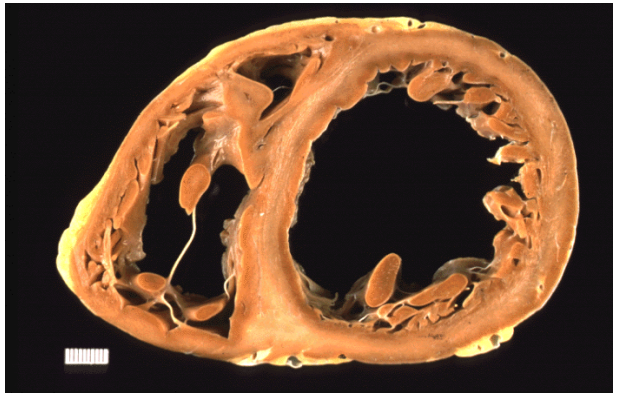


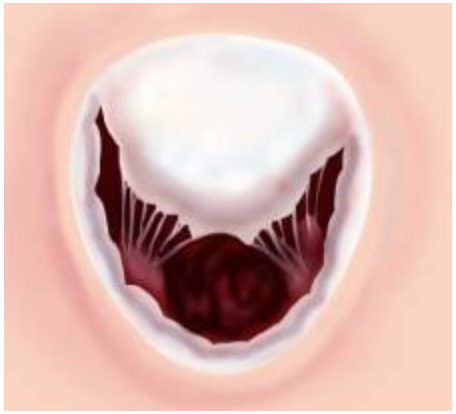
Effects of mitral stenosis

- Impedence of flow leads to back-up of blood and left atrial dilation
- Enlarged atrium is electrically unstable and prone to arrhythmias

Mitral regurgitation

- Much more common than mitral stenosis
- Most often caused by enlargement of the supporting ring of the valve (“annulus”) so the leaflets can no longer meet
- Caused by LV dilation.

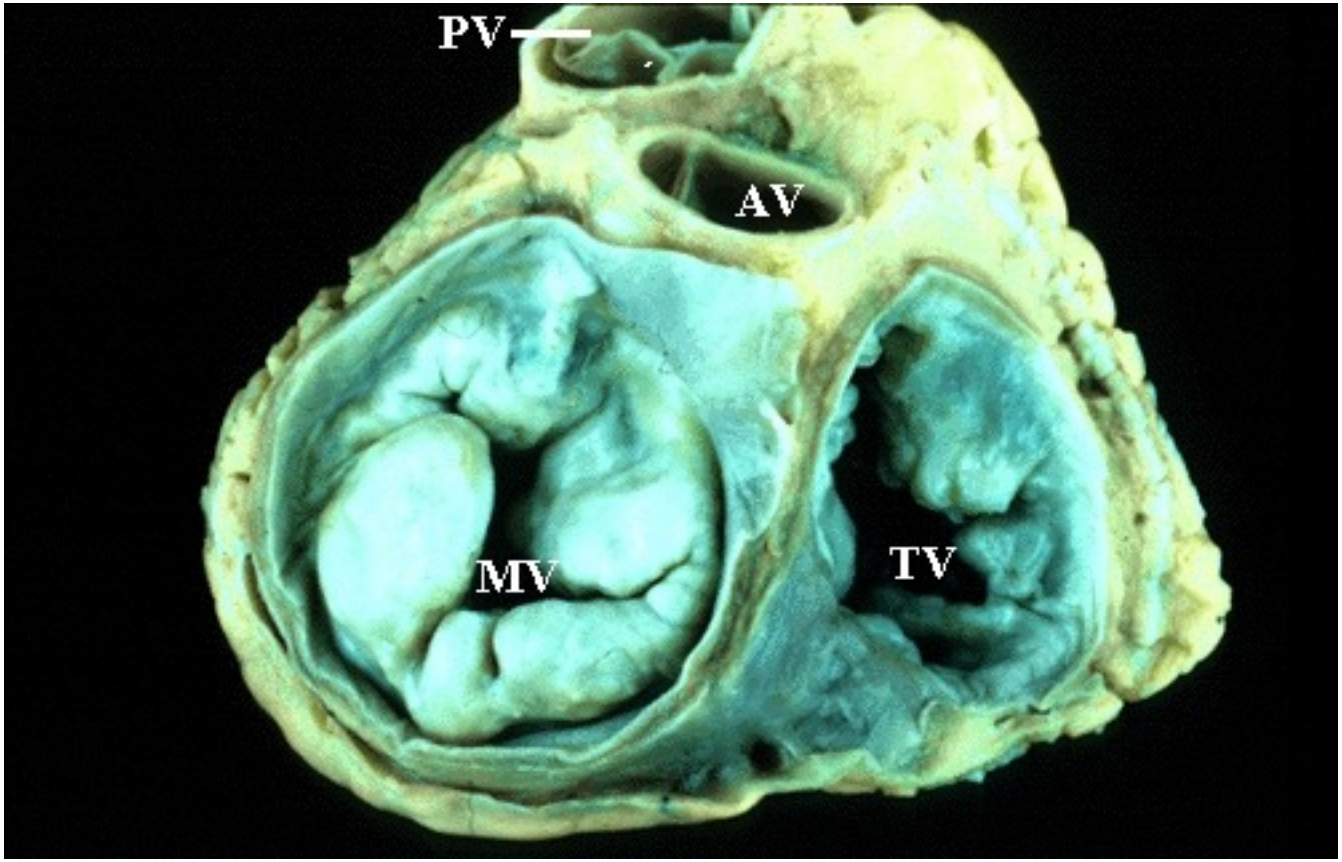




Mitral valve prolapse

- Another important cause of MR
- Occurs in 5% of population
- Caused by increased glycosaminoglycans in the mitral valve making it “floppy”
- Results in ballooning of the valve into the left atrium with leakage of blood
- Presents with fatigue, palpitations, chest pain
- PE: “mid-systolic click”

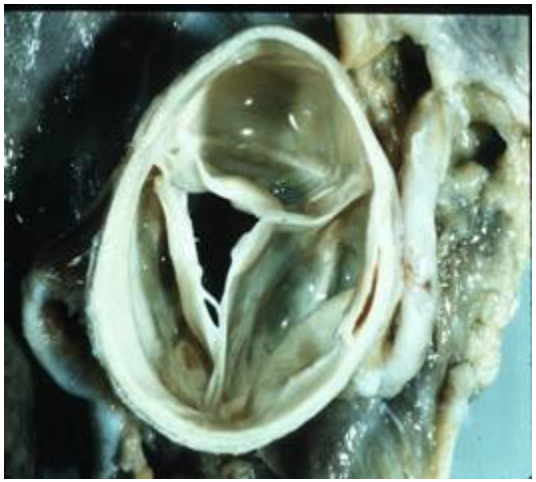
Mitral valve prolapse

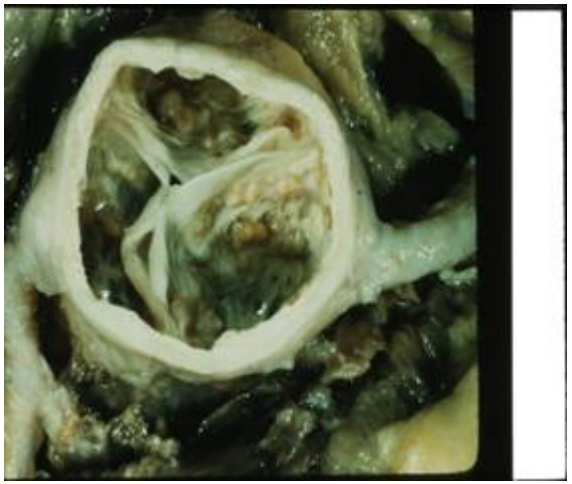


Aortic stenosis

- Aortic valve subject to incredible pressure variations with every heartbeat and susceptible to calcification due to damage.
  - Worse if valve is structurally abnormal (i.e.-bicuspid)
- Aortic stenosis the most common valvular abnormality
- Two main entities:
  - Senile calcification
    - normal valve, 60-70 y.o.
  - Calcification of bicuspid valve
    - Affects 1-2% of population, 50-60 y.o.

Aortic Valve Disease





Heaped up calcifications, commissures not affected

Biscuspid valve

Effects of aortic stenosis

- Increased pressure needed to get blood through aortic valve
  - LVH with all of its attending complications
- Often asymptomatic
  - Common presentations
    - Angina
    - Syncope
    - CHF
- Onset of symptoms mean treatment is necessary

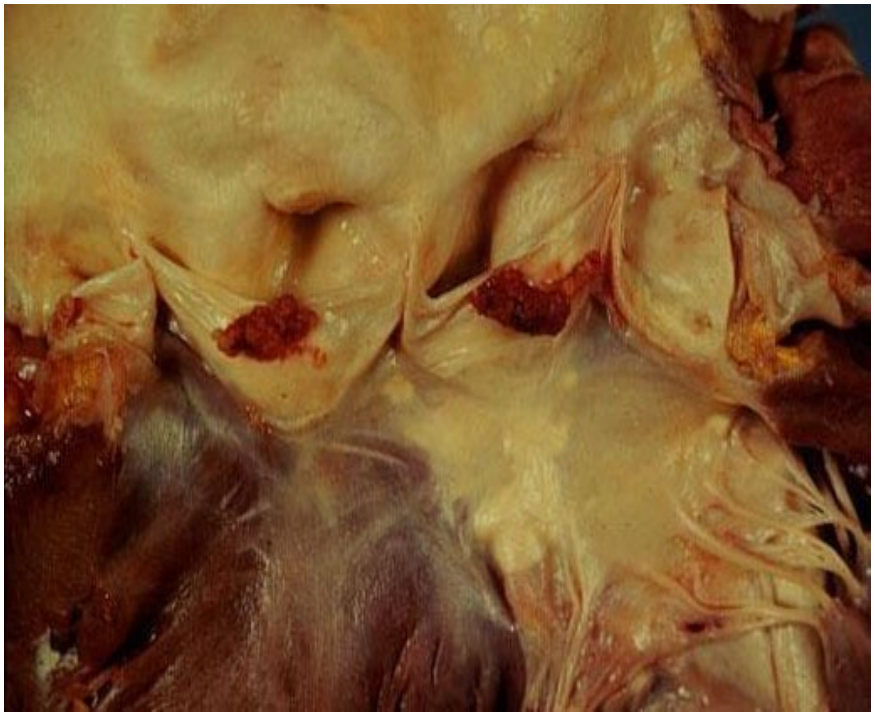
Effects of aortic regurgitation

- Backward flow increases pressure in LV → hypertrophy
- Eventually, hypertrophy → dilation → CHF
- Common causes–
  - chronic HTN with dilation of aortic root
  - Marfans
  - syphilis

Endocarditis

- Pathology involving the inner layer of the heart
- Classified as to etiology and clinical presentation
  - Nonbacterial thrombotic endocarditis (marantic)
  - Bacterial endocarditis
    - Acute
    - subacute

Nonbacterial thrombotic endocarditis



- Patients with hypercoagulable states (esp. malignancies)
- Small masses of fibrin and platelets on valve surfaces at lines of closure
- Devoid of inflammation, fibrosis, and microorganisms
- Underlying valves are normal
- Aortic valve most common

Infective endocarditis

- Infection of the cardiac valves causing an adherent mass of fibrin inflammatory cells and bacteria– “vegetation”
- Result from episodes of bacteremia
  - Patients with endovascular catheters and IVDA at highest risk
- Left sided valves most commonly affected except in IVDA
- Divided on the basis of clinical progression and severity:
  - Acute– rapidly progressive
  - Subacute– often indolent

Acute bacterial endocarditis

- 10-20% of cases, rapidly fatal
- Caused by highly virulent organisms (S. aureus), often skin flora in IVDA
- Affect normal valves
- Form bulky vegetations that erode into valve ("ring abscess") and can destroy chordae
- Pieces embolize elsewhere (brain, heart, spleen, kidney)

Subacute bacterial endocarditis

- Caused by less virulent organisms (S. viridans-50-60%, “HACEK” organisms)
  - Often oral commensals
- Usually occurs on previously abnormal valves:
  - Chronic valvular disease
  - Prosthetic valves
  - Congenital heart abnormalities
- Slow, less severe
  - LGF, weight loss, new onset heart murmur
- Vegetations less destructive (no ring abscesses), inflammation with granulation tissue common

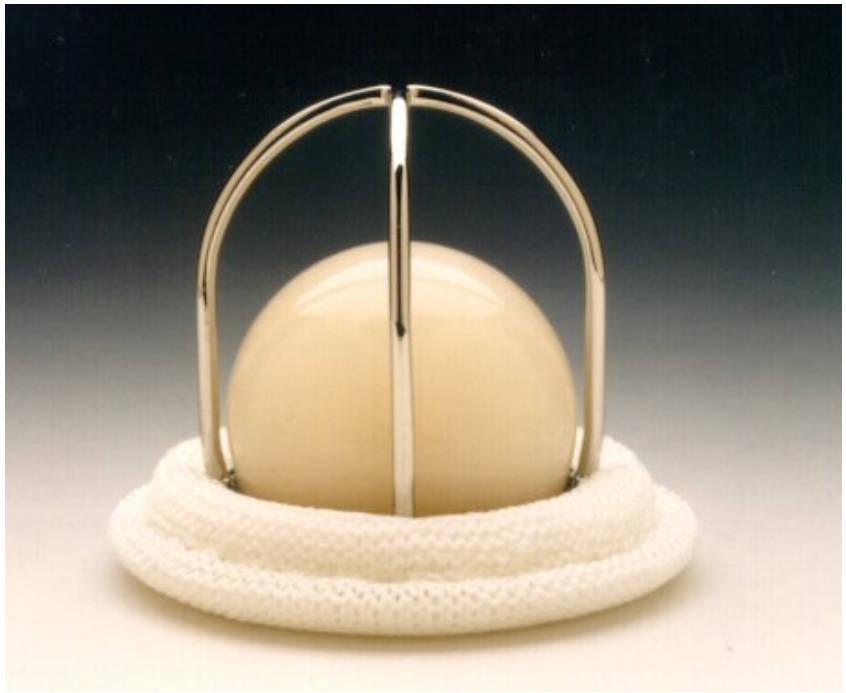
Acute vs. subacute BE

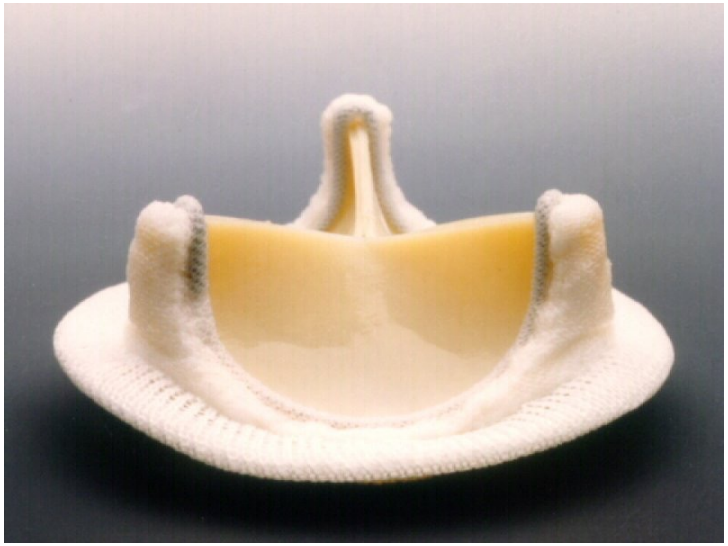
Acute Bacterial Endocarditis	**Subacute Bacterial Endocarditis**
Normal valve	Abnormal valve
S. Aureus (skin flora)	S. viridans / HACEK (oral/GI flora)
Rapidly progressive, fatal	Indolent
IVDA, catheters	Valve/heart abnormalities, prosthetic valves
destructive	Less destructive

Prosthetic valve issues

- Valve replacement common and patients living for extended periods
- Two types:
  - Bioprosthetic- prone to calcification, perforation, tearing, no anticoagulation
  - Mechanical- heartier, requires life long anticoagulation
- Increased risk for endocarditis
- Valvular failure
  - Leakage around valve
  - occlusion or dysfunction by tissue overgrowth

Prosthetic valves





Cardiomyopathies

- Dilated Cardiomyopathy
- Arrhythmogenic Right Ventricular Cardiomyopathy
- Hypertrophic Cardiomyopathy
- Restrictive Cardiomyopathy
- Myocarditis
- Other Causes of Myocardial Disease

Pericardial Disease

- Pericardial Effusion and Hemopericardium
- Pericarditis
    - *Acute Pericarditis*

Heart Disease Associated with Rheumatologic Disorders

Tumors of the Heart

- Primary Cardiac Tumors
- Cardiac Effects of Noncardiac Neoplasms

Cardiac Transplantation

Primary myocardial diseases

- Diseases INTRINSIC TO THE MYOCARDIUM
  - Excludes conditions caused by CAD, HTN, valvular disease
- Myocarditis
- Cardiomyopathies
  - Dilated
  - Hypertrophic
  - Restrictive
  - Arrhythmogenic Right Ventricular Cardiomyopathy

Myocarditis

- Inflammation of the heart muscle without other explanation
  - Infection (viruses and parasites)
    - Coxsackie A and B
    - CMV
    - HIV
    - *Trypanosoma cruzi*
    - *C. diphtheriae (*caused by toxin*)*
    - Lyme disease
  - Connective tissue disease
  - Allograft rejection

Table 12-13 Major Causes of Myocarditis

Infections
Viruses (e.g., coxsackievirus, ECHO, influenza, HIV, cytomegalovirus)
Chlamydiae (e.g., *Chlamydophyla psittaci*)
Rickettsiae (e.g., *Rickettsia typhi*, typhus fever)
Bacteria (e.g., *Corynebacterium diphtheriae, Neisseria meningococcus, Borrelia* (Lyme disease)
Fungi (e.g., *Candida*)
Protozoa (e.g., *Trypanosoma cruzi* [Chagas disease], toxoplasmosis)
Helminths (e.g., trichinosis)
Immune-Mediated Reactions
Postviral
Poststreptococcal (rheumatic fever)
Systemic lupus erythematosus
Drug hypersensitivity (e.g., methyldopa, sulfonamides)
Transplant rejection
Unknown
Sarcoidosis
Giant cell myocarditis

HIV, Human immunodeficiency virus.

Myocarditis

- Presentation ranges **from asymptomatic to signs and symptoms of inflammation (fever, malaise, etc.) to unexplained or sudden congestive heart failure**
- Often a preceding "**flu-like**" illness or viral syndrome
- **Treatment usually supportive**, condition frequently self-limited

Myocarditis

- Often an enlarged, flabby heart
- Myocardium infiltrated with **inflammatory cells** causing **myocyte destruction**
  - Viral: lymphocytes
  - Bacterial: neutrophils
  - Parasitic/drugs: eosinophils
- Later can lead to fibrosis

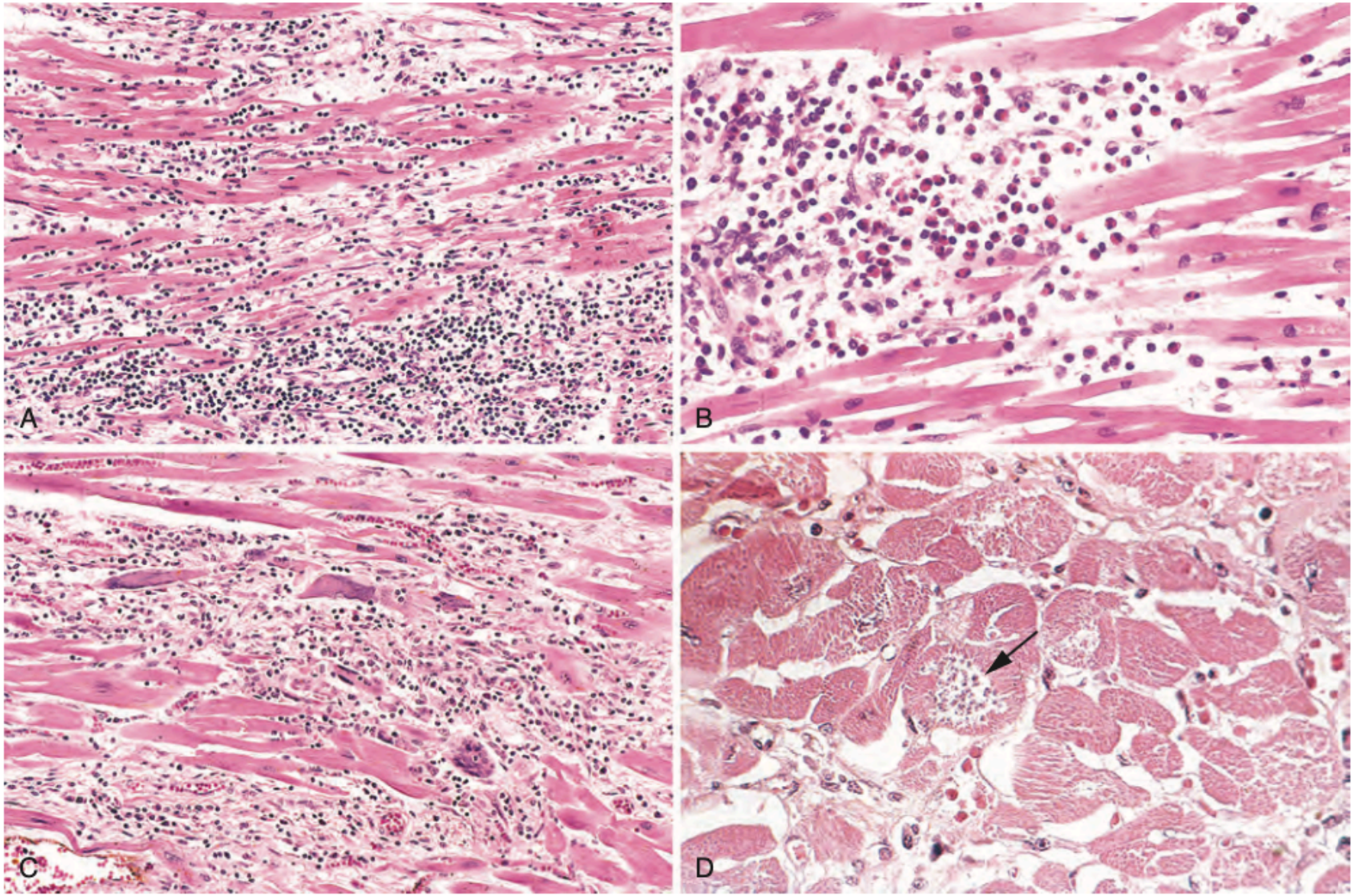
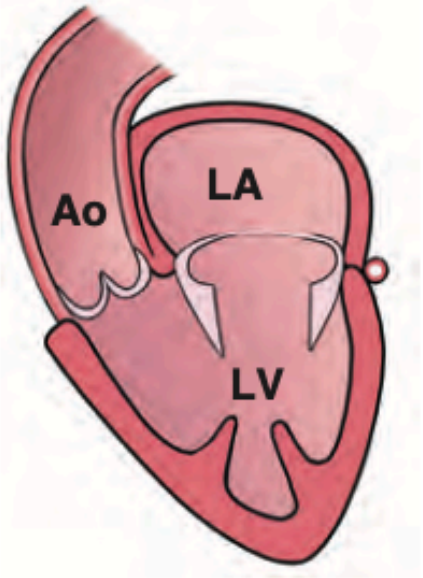


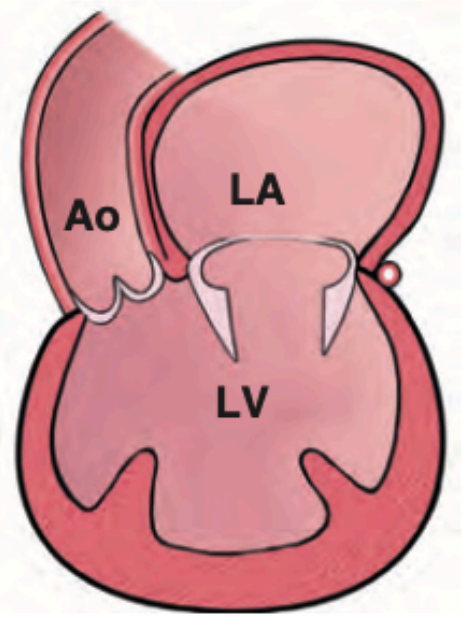
Figure 12-35 Myocarditis. **A,** Lymphocytic myocarditis, associated with myocyte injury. **B,** Hypersensitivity myocarditis, characterized by interstitial inflammatory infiltrate composed largely of eosinophils and mononuclear inflammatory cells, predominantly localized to perivascular and expanded interstitial spaces. **C,** Giant-cell myocarditis, with mononuclear inflammatory infiltrate containing lymphocytes and macrophages, extensive loss of muscle, and multinucleated giant cells (fused macrophages). **D,** The myocarditis of Chagas disease. A myofiber distended with trypanosomes *(arrow)* is present along with individual myofiber necrosis, and modest amounts of inflammation.

Cardiomyopathies

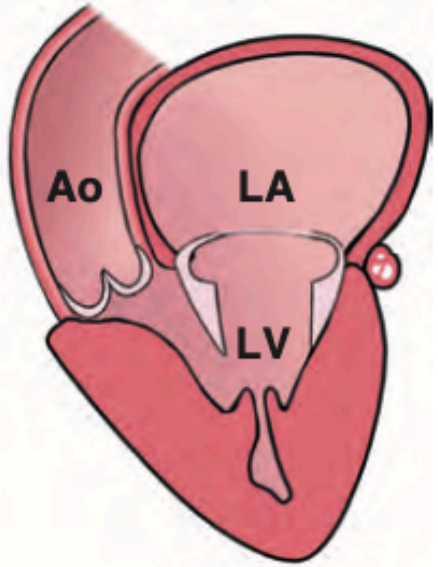
- **Primary abnormality of the myocardium**
  - Excludes any condition that secondarily involves the heart (infection, metabolic, inflammatory…)
- Often no definitive cause (“idiopathic”) or associated with insults
- Clinically divided into three types:
  - Dilated (including arrhythmogenic right ventricular cardiomyopathy)
  - Hypertrophic
  - Restrictive



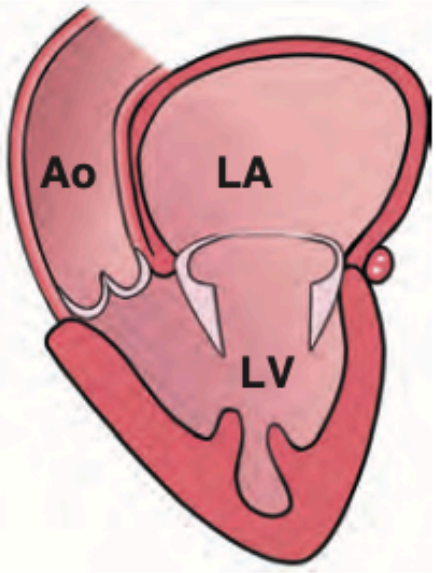
Normal



Dilated
cardiomyopathy



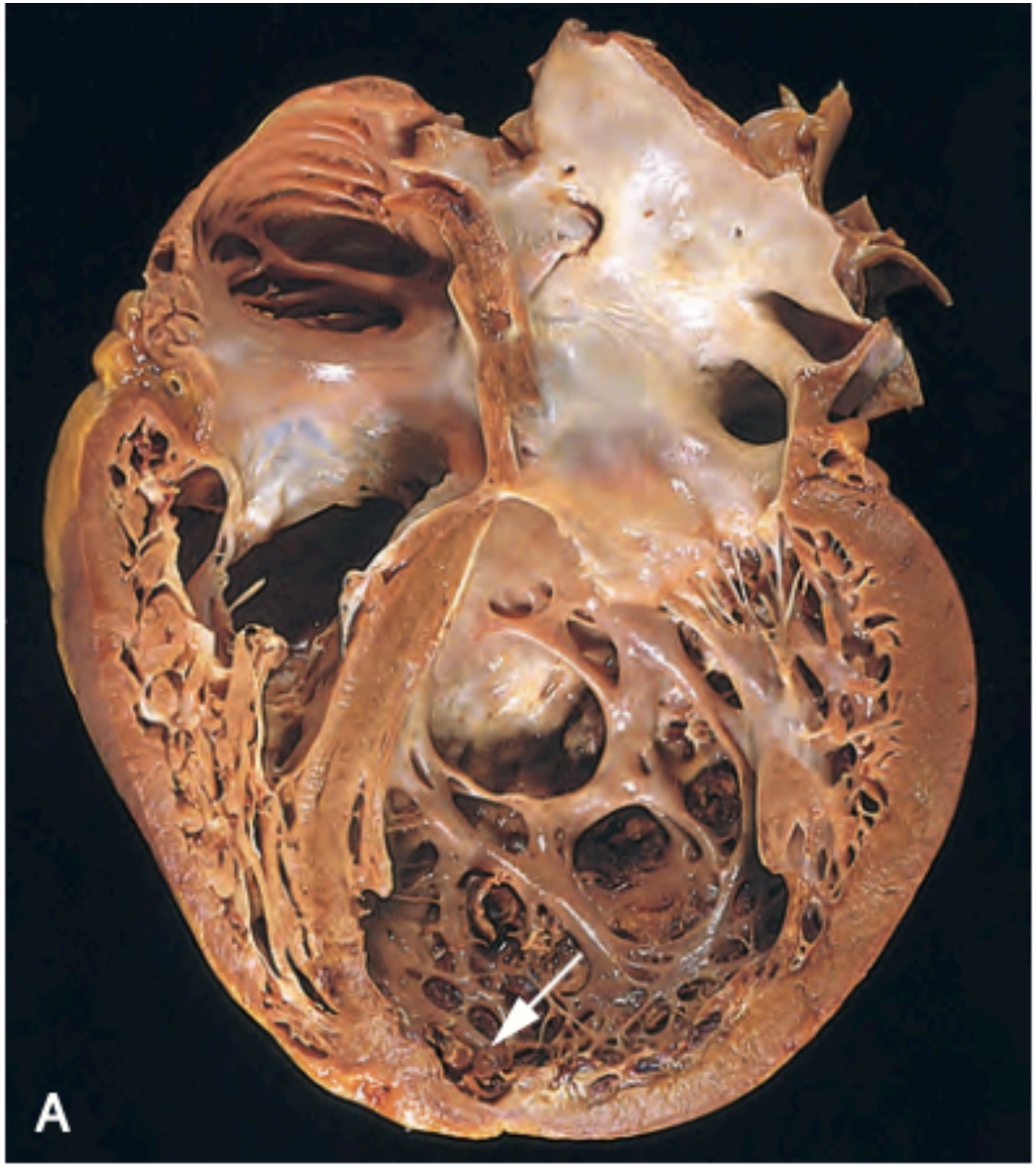
Hypertrophic
cardiomyopathy

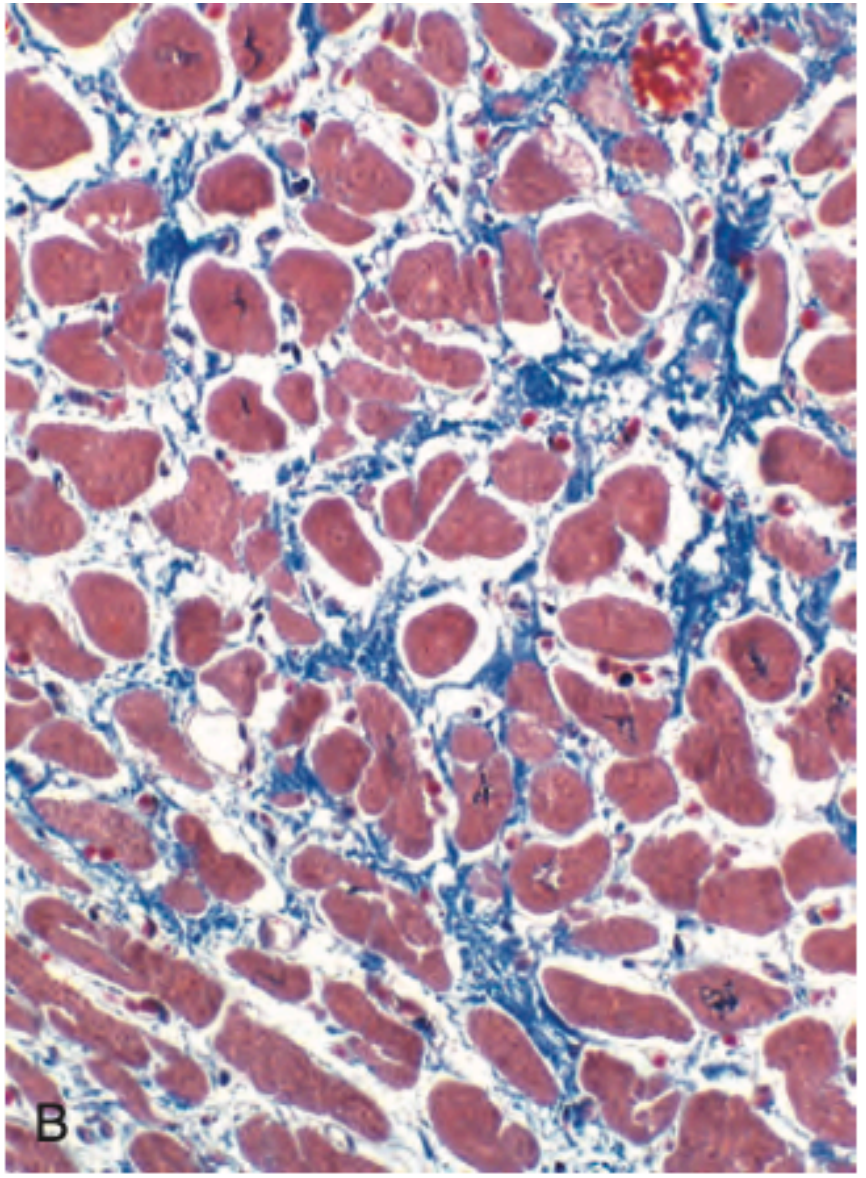


Restrictive
cardiomyopathy

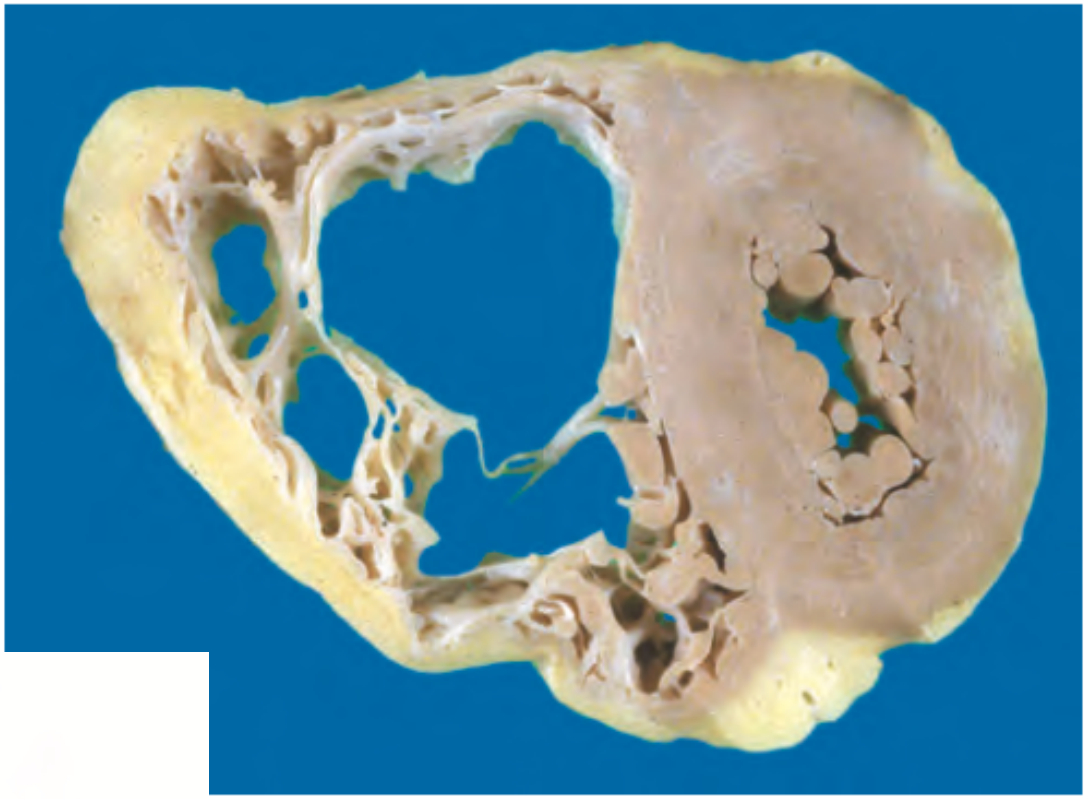
Dilated cardiomyopathy (DCM)

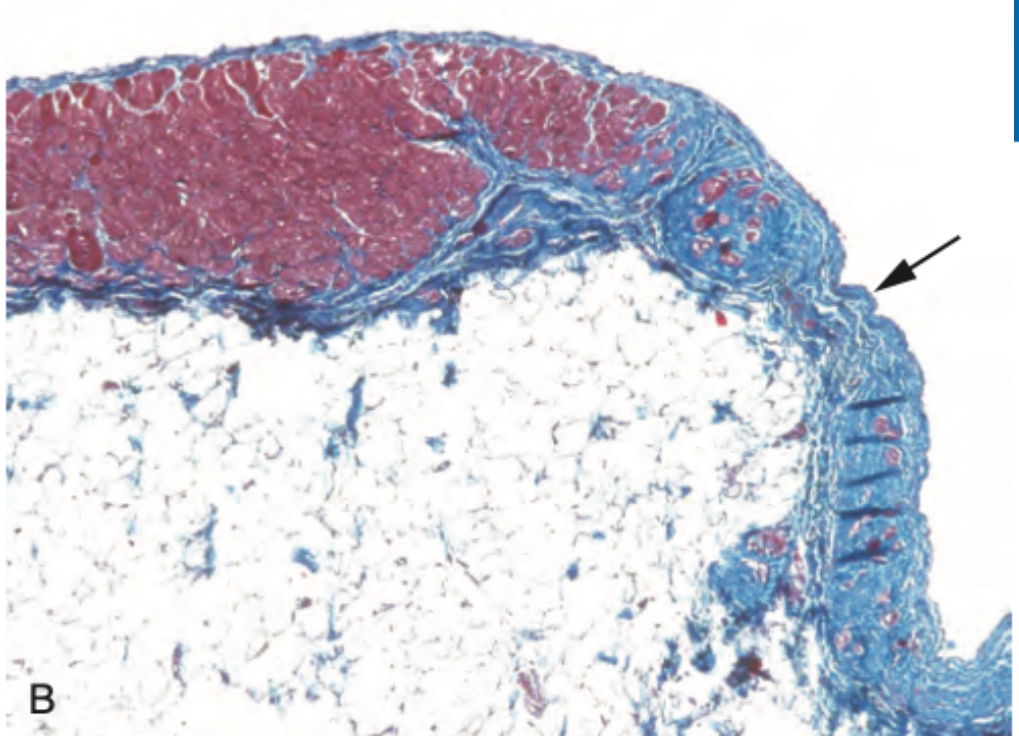
- most common pattern (90%)
- contractile (systolic) dysfunction
- Characterized by progressive cardiac
  - hypertrophy → dilation → failure
- Associated with:
  - EtOH
  - Toxin (doxorubicin, cobalt, etc.)
  - ? Late stage of myocarditis
  - peripartum
- Majority of the cases are “idiopathic”
- Present with progressive CHF, emboli, or arrhythmias


A


B

- ARVC

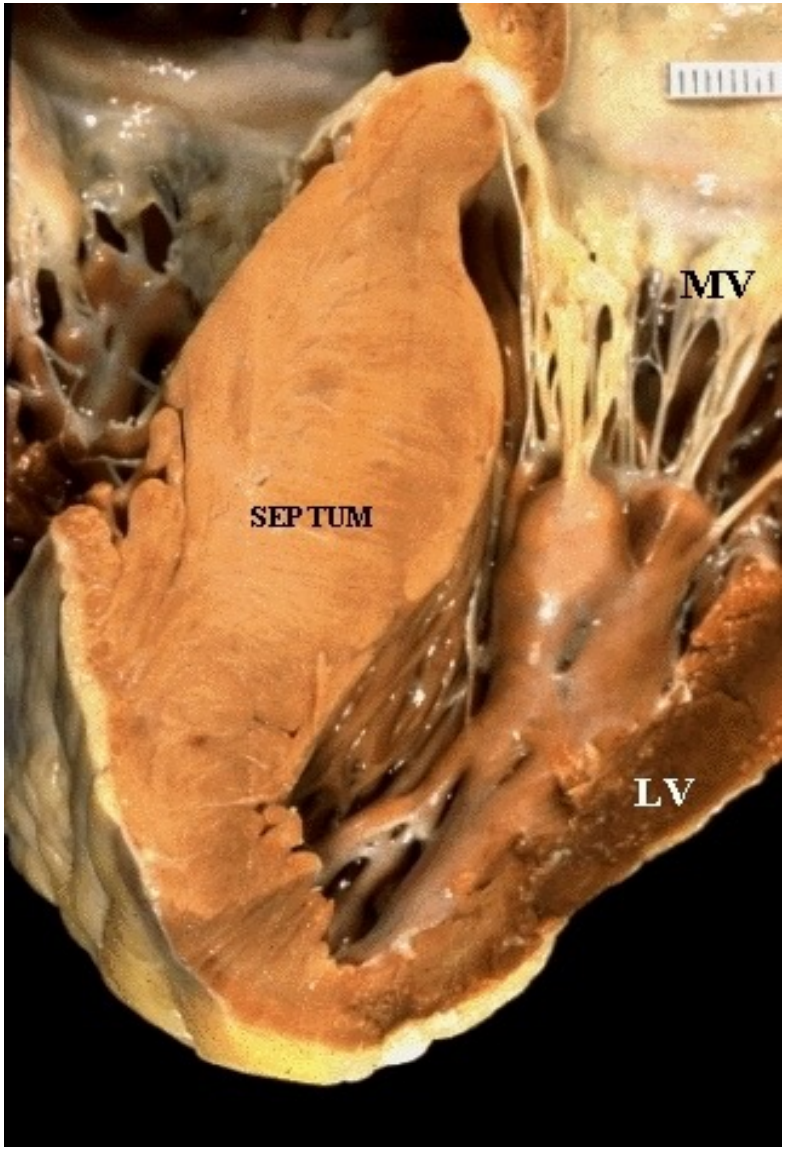




Hypertrophic obstructive cardiomyopathy (HOCM)

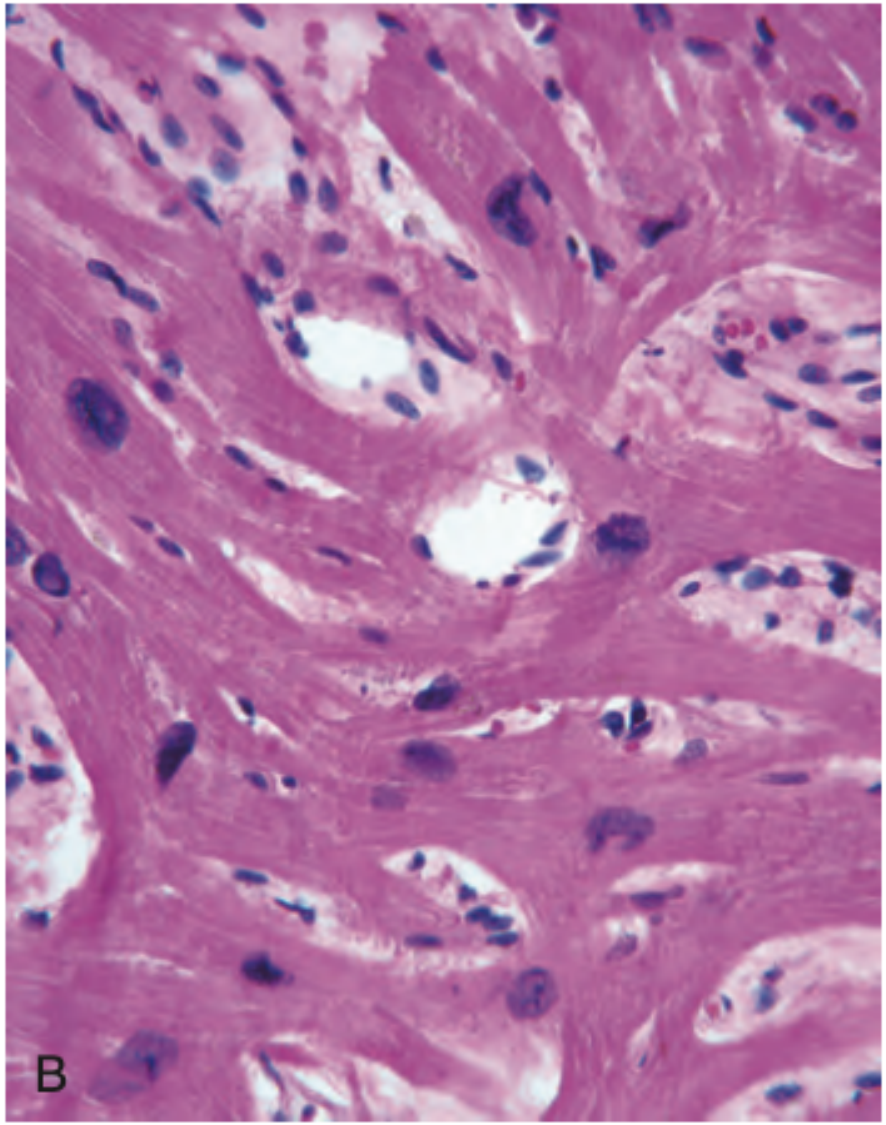
- **Asymmetric hypertrophy of the interventricular septum** with obstruction of aortic outflow
- Often systolic function is preserved
- Most cases result from a mutation in beta myosin heavy chain (autosomal dominant)
  - mutations in any one of several genes that code sarcomeric proteins

HOCM

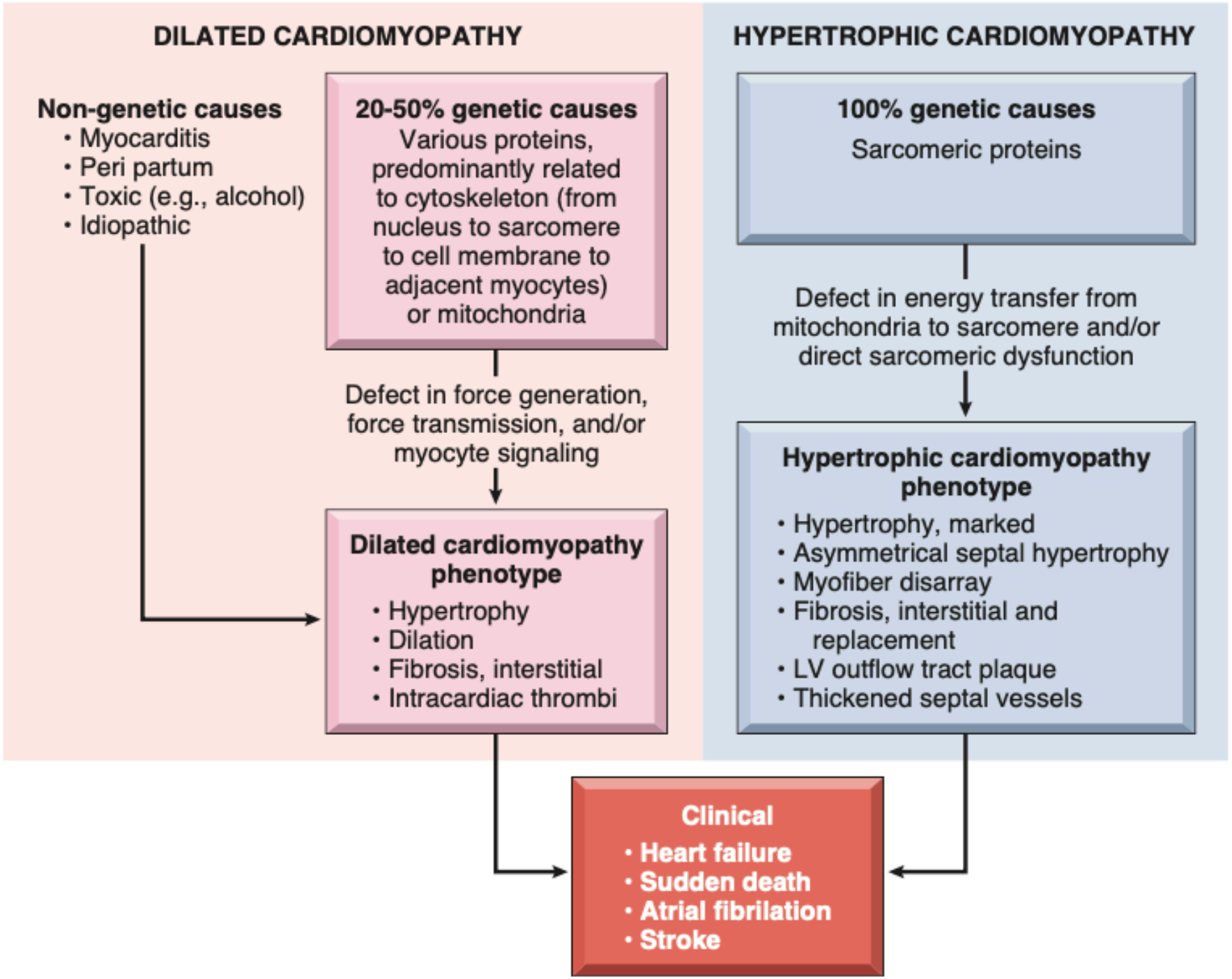


- IVS usually much thicker than LVFW (“asymmetric”)
- Bulging IVS obstructs outflow of LV
  - Thickening of anterior leaflet of the mitral valve
- Thick ventricle doesn’t relax well– left atrial enlargement

HOCM



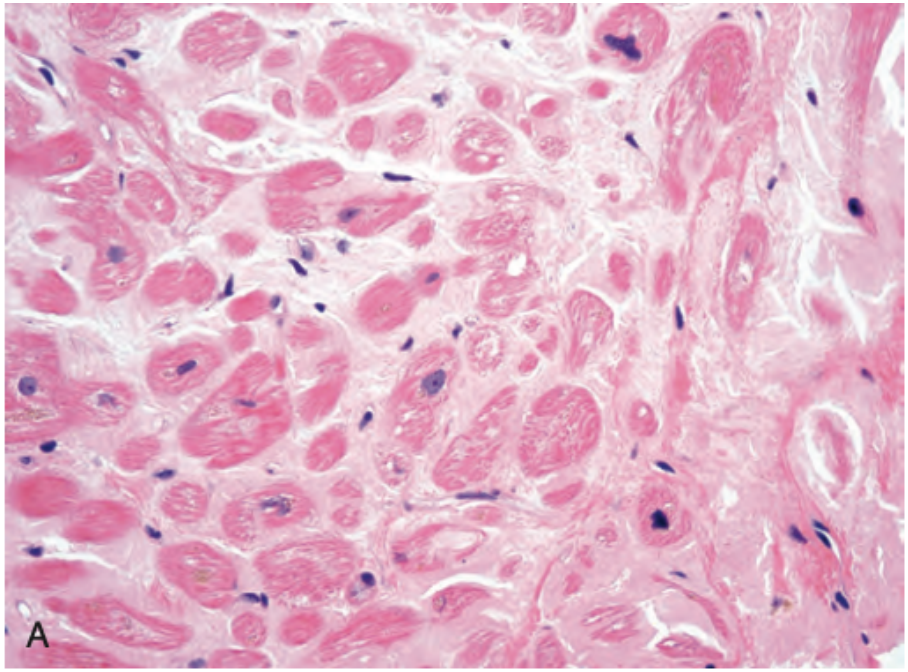
- Microscopic– myofiber **disarray**
- Presents with symptoms and murmur similar to AS
- Cause of sudden cardiac death in young people

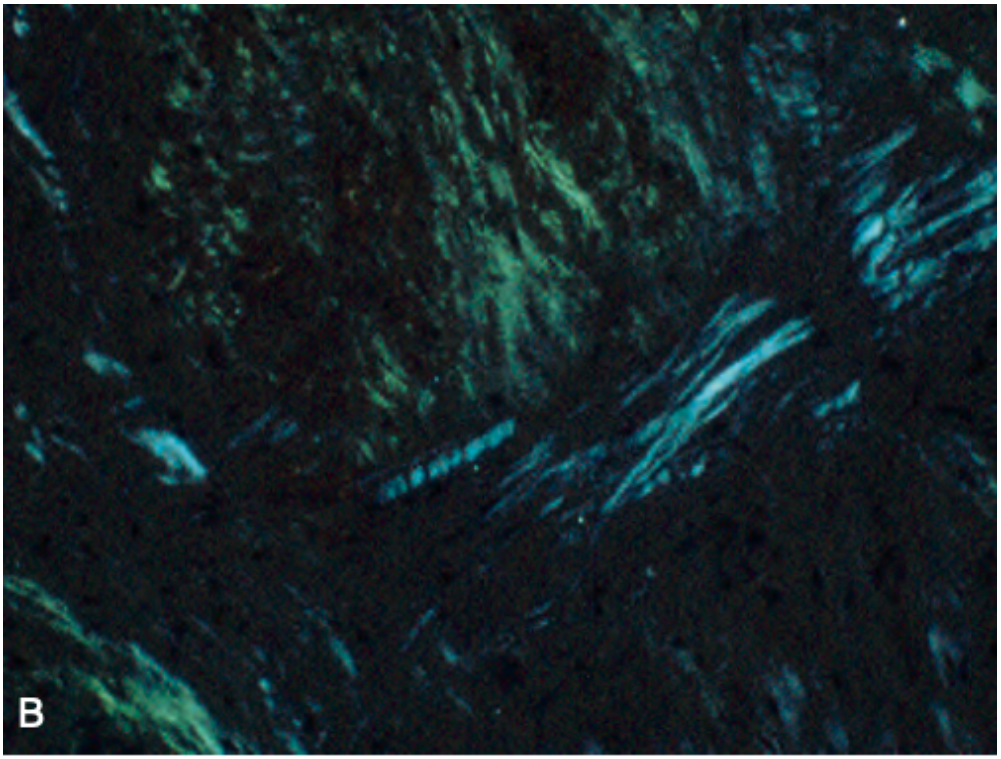

DILATED CARDIOMYOPATHY
HYPERTROPHIC CARDIOMYOPATHY
Non-genetic causes
• Myocarditis
• Peri partum
• Toxic (e.g., alcohol)
• Idiopathic
20-50% genetic causes
Various proteins, predominantly related to cytoskeleton (from nucleus to sarcomere to cell membrane to adjacent myocytes) or mitochondria
100% genetic causes
Sarcomeric proteins
Defect in energy transfer from mitochondria to sarcomere and/or direct sarcomeric dysfunction
Defect in force generation, force transmission, and/or myocyte signaling
Dilated cardiomyopathy phenotype
• Hypertrophy
• Dilation
• Fibrosis, interstitial
• Intracardiac thrombi
Hypertrophic cardiomyopathy phenotype
• Hypertrophy, marked
• Asymmetrical septal hypertrophy
• Myofiber disarray
• Fibrosis, interstitial and replacement
• LV outflow tract plaque
• Thickened septal vessels
Clinical
• Heart failure
• Sudden death
• Atrial fibrilation
• Stroke

Restrictive cardiomyopathy

- Myocardial process that makes the wall stiff (decreased compliance) → **poor filling**
- Less common than the other two
- Often the result of **infiltration of the interstitium with non-native material**
- In U.S., the most common causes are:
  - Amyloidosis
  - Hemochromatosis
  - Fibrosis due to radiation
  - In tropical areas– Loeffler's syndrome (eosinophilic endomyocardial fibrosis)

Cardiac amyloidosis





Congenital heart disease

- 8:1,000 births
- **Most common cause of heart disease in children**
- Diverse group of entities
  - Range from **asymptomatic murmurs** to **severe CHF** immediately after birth
- Genetic/environmental factors implicated
- Only 10% can be linked to definite etiology

Congenital heart disease basics

- **Most are malformations**– defects in heart formation
- The larger or more serious the defect, the worse the symptoms
- Although found in isolation, **often multiple abnormalities are present**
- Right sided flow– low pressure, low oxygen
- Left sided flow– high pressure, high oxygen
  - Mixture of the two results in changes in the oxygen content of blood and causes symptoms

Congenital Heart Disease

- Left-to-Right Shunts
  - *Atrial Septal Defect*
  - *Ventricular Septal Defect*
  - *Patent Ductus Arteriosus*
- Right-to-Left Shunts
  - *Tetralogy of Fallot*
  - *Transposition of the Great Arteries*
  - *Tricuspid Atresia*
- Obstructive Lesions
  - *Coarctation of the Aorta*
  - *Pulmonary Stenosis and Atresia*
  - *Aortic Stenosis and Atresia*

Congenital heart disease basics

- Classified by the abnormal diversion in blood flow that the defect causes
  - Left to right– **(acyanotic)**, blood from left side of heart mixes with right
  - Right to left– **(cyanotic)**, blood from the right side mixes with the left
- The pulmonary circulation does not handle high amounts of pressure for very long– causes remodeling of vessels and **pulmonary hypertension**
  - In time, acyanotic defects become cyanotic
  - “Eisenmeinger’s syndrome”

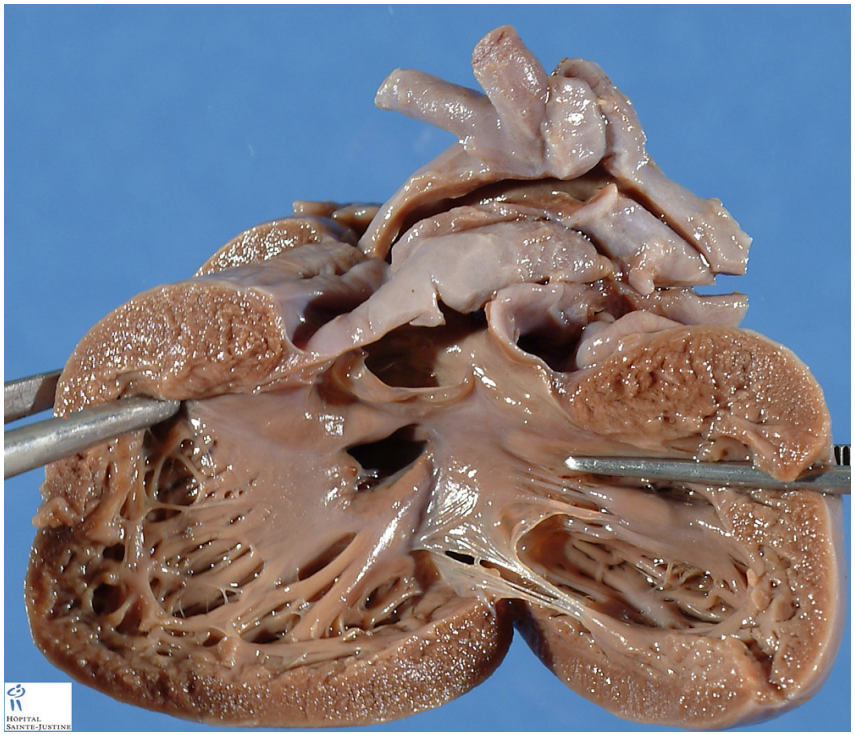
Frequency of cardiac malformations

Malformation	Frequency	
VSD	33	62%!
PDA	10	
Pulmonary stenosis	10	
TOF	9	
Aortic stenosis	8	
Coarctation of aorta	5	
Transposition	5	
ASD	5	

Left to right shunts

- Most common type
  - Atrial septal defect (ASD)
  - Ventricular septal defect (VSD)
  - Patent ductus arteriosus (PDA)
- Hole between high pressure/high oxygen left sided circulation and right sided circulation
  - Acyanotic
  - Can become cyanotic after time due to the development of pulmonary hypertension (Eisenmeinger's syndrome)

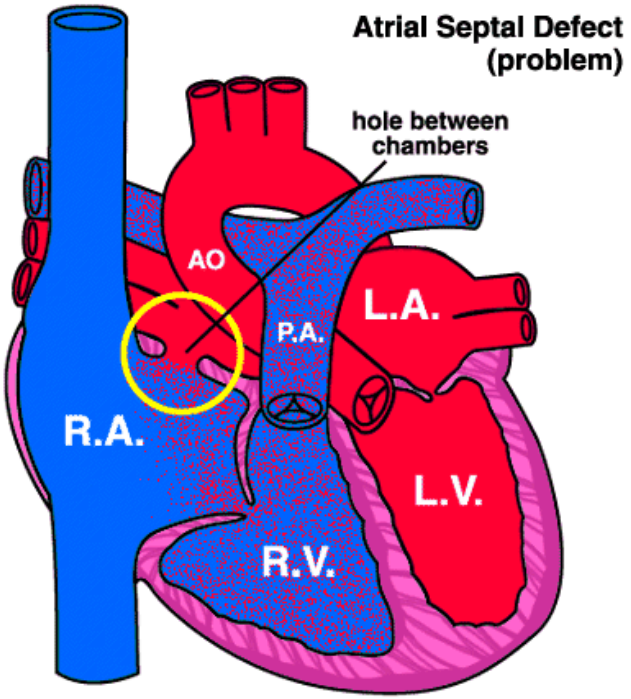
VSD



- THE MOST COMMON HEART DEFECT
- Commonly associated with **Down syndrome**
- Left to right shunt → acyanotic
- Size of the defect varies:
  - Small (pinhole) are most common– asymptomatic heart murmur
  - Large defects- Eisenmeinger's syndrome and RHF
- Membranous defects more common than muscular

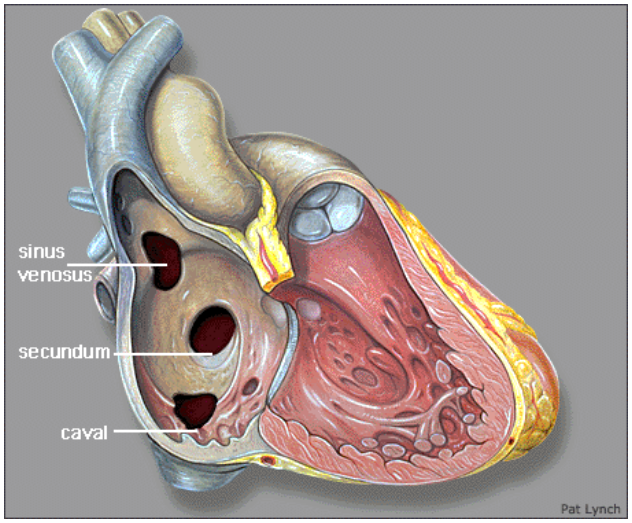
ASD

- During heart development, an **ostium is left between the right and left atrium to allow blood to bypass the lungs**
- Most of the time, when the infant breathes and right sided pressures drop, this hole closes permanently
- When this fails to happen, abnormal communication persists and blood can move from the left atrium to the right atrium

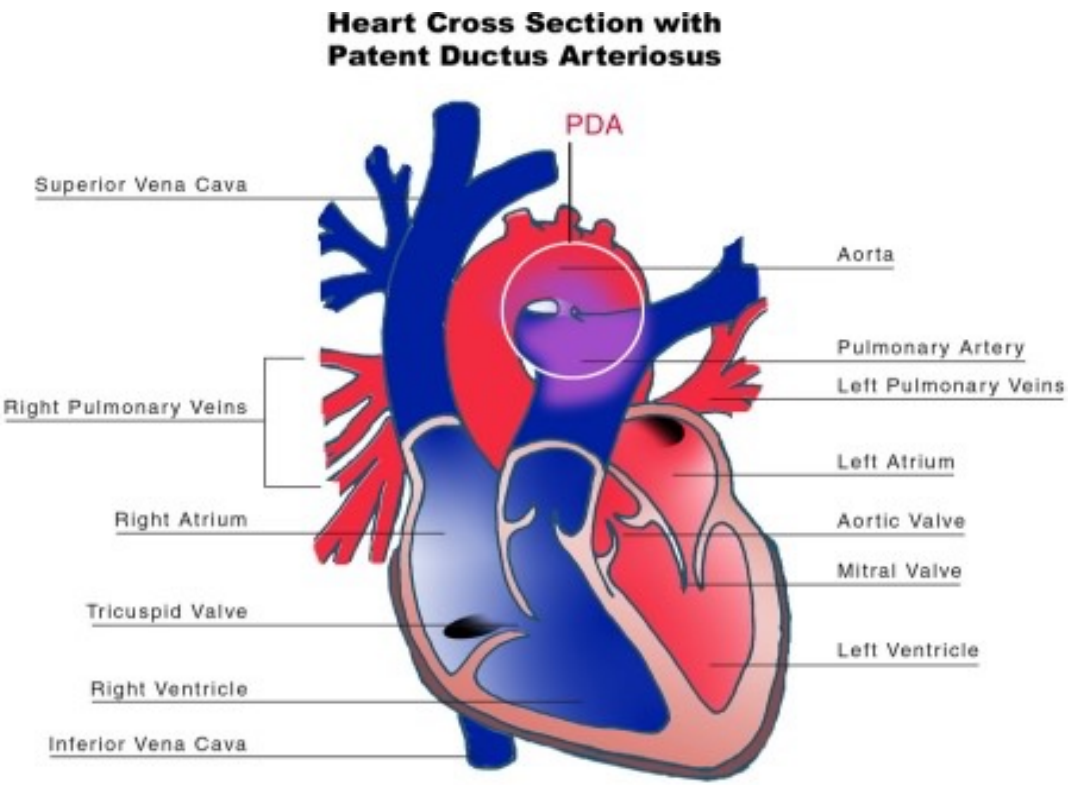


ASD

- Defects in different phases of development of the atrial septum lead to holes in different places
  - Ostium secundum is most common
- As Eisenmeinger's syndrome develops, RVH, dilation, and failure occur



PDA

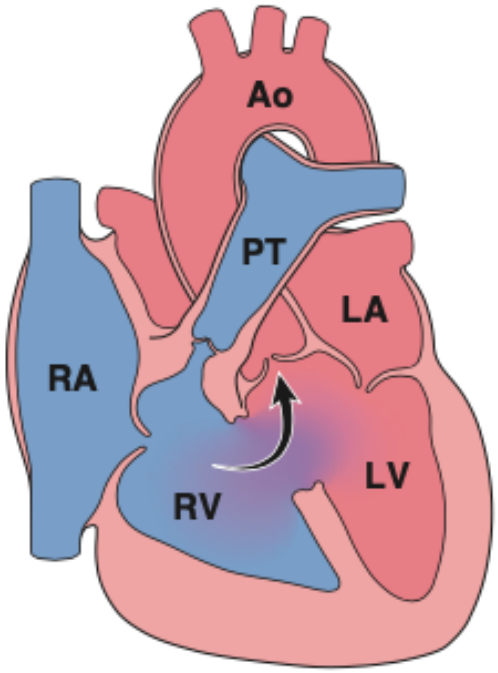


- **To bypass the lungs, a connection exists between the pulmonary artery and aorta ("ductus arteriosus")**
- Closes off 1-2 d after birth ("**ligamentum arteriosum**")
- PDA = failure of closure
  - Increased risk if baby is hypoxic
- Classic "machinery" murmur
- Risk of Eisenmeinger's syndrome

Right to left shunts

- Defect causes mixing of deoxygenated blood with oxygenated blood of the arterial system– “Cyanotic”
  - Tetralogy of Fallot (TOF)
  - Transposition of great vessels (TGV)

TOF



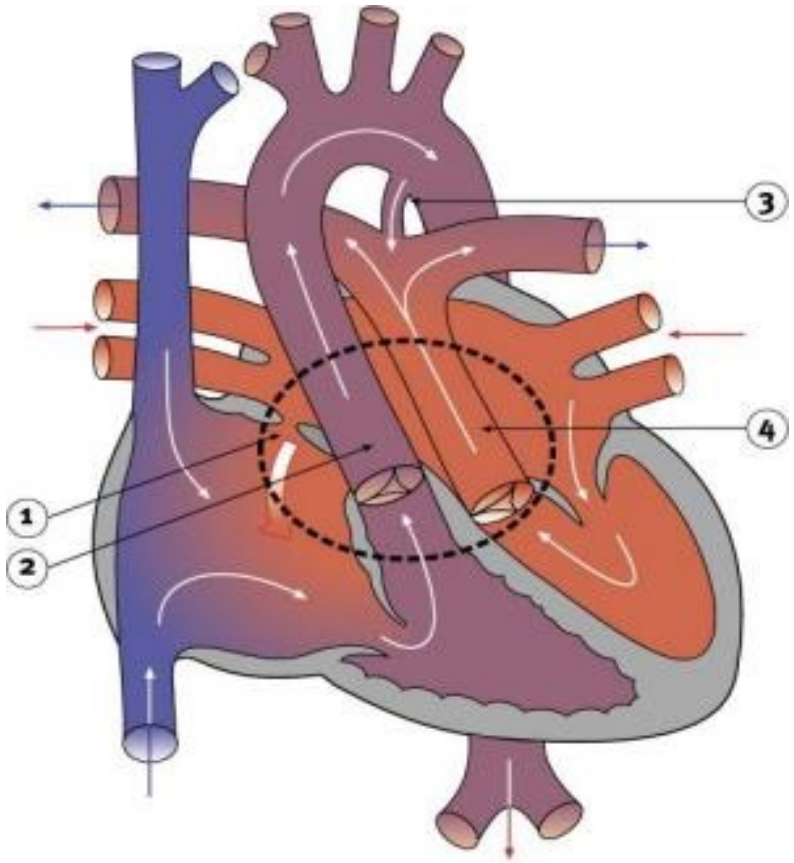
A Classic tetralogy of Fallot

- **Most common cause of cyanotic heart disease**
- Four components
- “Boot-shaped heart” on CXR
- Severity dependent on amount of pulmonary stenosis
- Lungs protected from Eisenmeinger’s syndrome
- “Tet” spells

4 Cardinal features:

- (1) VSD
- (2) obstruction of the right ventricular outflow tract (subpulmonary stenosis)
- (3) an aorta that overrides the VSD,
- (4) right ventricular hypertrophy

TGV



- Aorta and pulmonary trunk arise from wrong ventricle
- Babies only survive after birth if they have a ASD, VSD, or PDA
  - Often emergently created if not present

Pericardial diseases

- Pericarditis– inflammation of the pericardium
  - Infection (viral most common)
  - Autoimmune (lupus)
  - Post myocardial infarction
  - Renal failure
- Three outcomes:
  - Resolution
  - Effusion
  - Constrictive pericarditis/fibrosis with chronic cases

Pericardial diseases

- **1. Pericardial effusion**
  - Fluid accumulation in pericardial space
  - Fluid can be:
    - **Serous** (CHF, renal failure)
    - **Serosanginous** (trauma, tumor)
    - **Chylous** (lymphatic obstruction)
    - **Hemopericardium** (pure blood– trauma or ruptured aneurysm)
- Cause difficulties if place too much external pressure on heart to prevent filling **(TAMPONADE)**

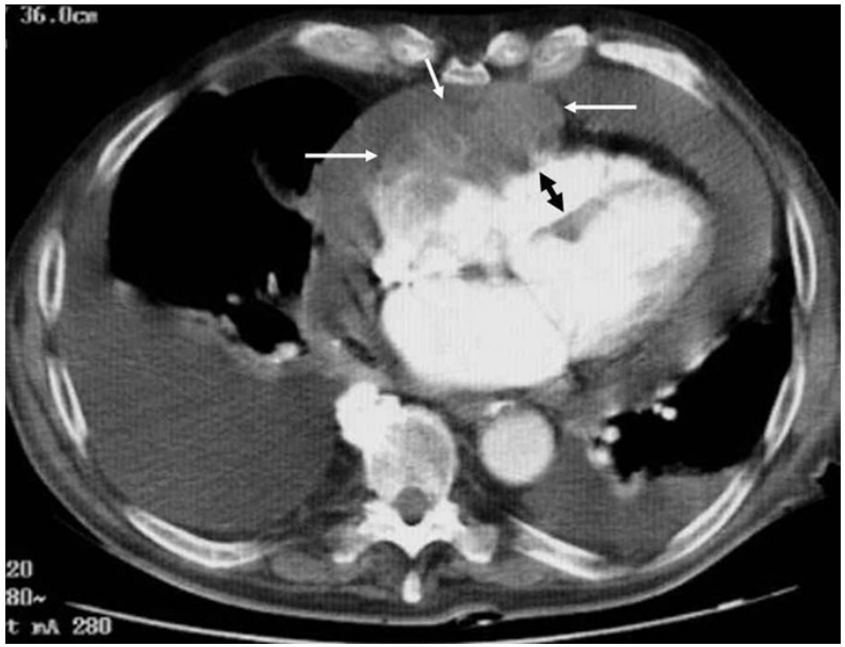
Pericarditis

Table 12-14 Causes of Pericarditis

Infectious Agents
Viruses
Pyogenic bacteria
Tuberculosis
Fungi
Other parasites
Presumably Immunologically Mediated
Rheumatic fever
Systemic lupus erythematosus
Scleroderma
Postcardiotomy
Postmyocardial infarction (Dressler) syndrome
Drug hypersensitivity reaction
Miscellaneous
Myocardial infarction
Uremia
Following cardiac surgery
Neoplasia
Trauma
Radiation

- ACUTE PERICARDITIS
    - Serous pericarditis
    - Fibrinous pericarditis
    - Hemorrhegic pericarditis
    - Caseous pericarditis
- CHRONIC/HEALED PERICARDITIS

Cardiac tumors



- Metastases from other sites far more common than primary cardiac neoplasms (10% of disseminated cancers met to heart)
  - Lung, breast, melanoma, leukemia, lymphoma
- Frequently found in pericardium with resultant effusion

Cardiac tumors

- Primary tumors rare
  - myxoma-
    - Adults
    - Arise in left atrium
    - Bland stellate cells
    - Cause problems with obstruction or emboli
  - Rhabdomyomas
    - Neoplasm of cardiac muscle
    - Associated with tuberous sclerosis

Cardiac tumors

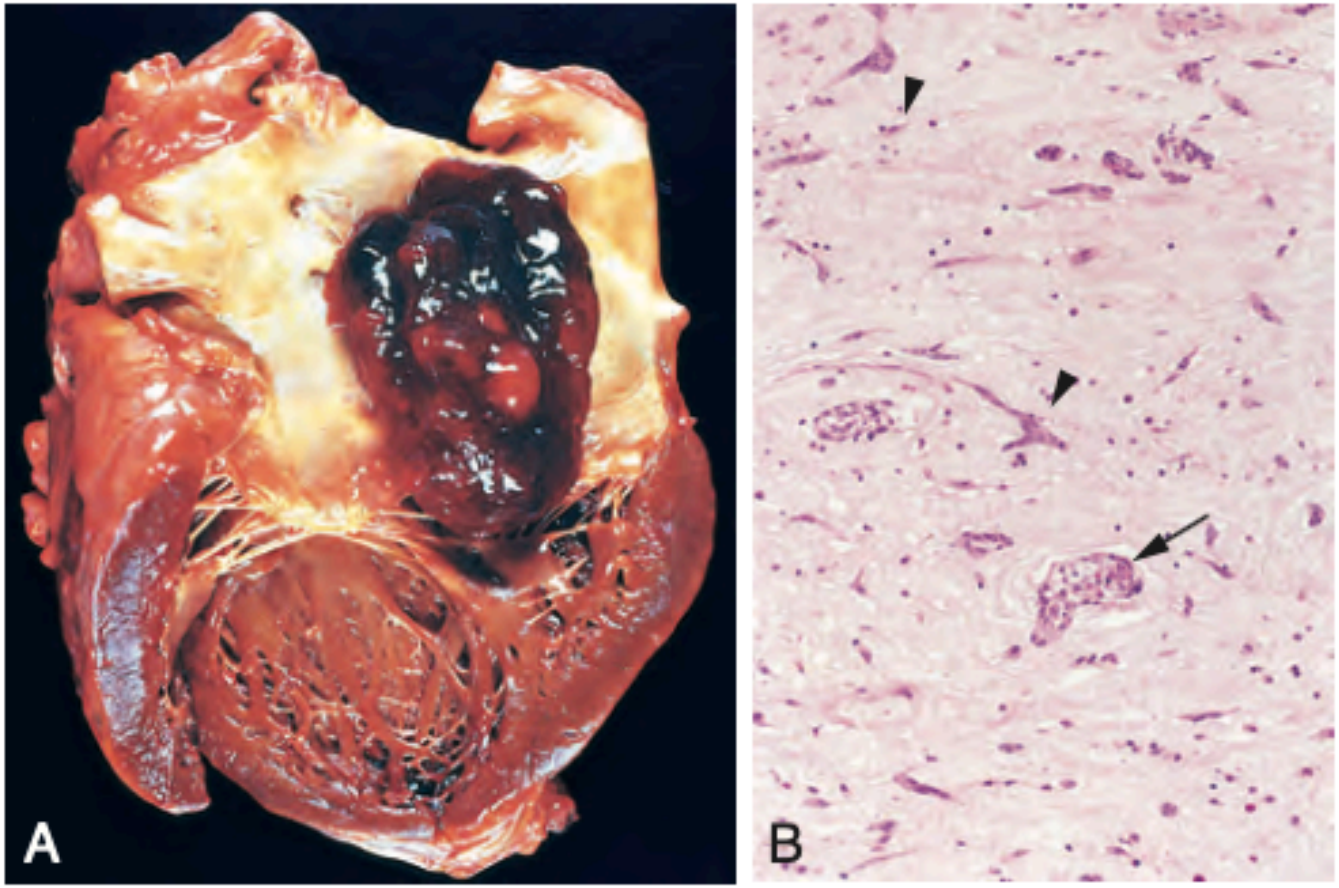


Figure 12-38 Atrial myxoma. **A,** A large pedunculated lesion arises from the region of the fossa ovalis and extends into the mitral valve orifice. **B,** Abundant amorphous extracellular matrix contains scattered multinucleate myxoma cells (*arrowheads*) in various groupings, including abnormal vessel-like formations *(arrow).*

END