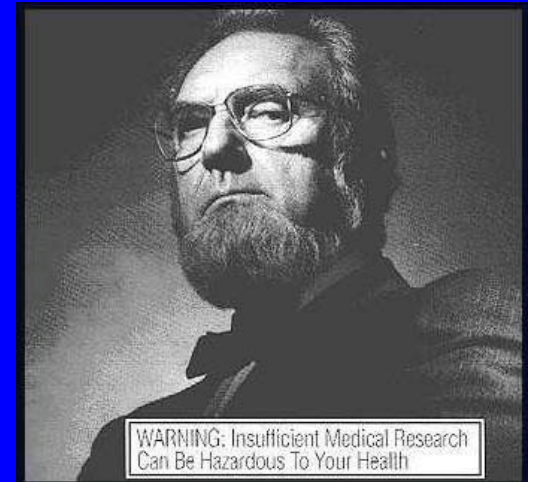


# Biomedical Engineering for Global Health

## Lecture Seventeen



# Outline

- The burden of heart disease
- The cardiovascular system
- How do heart attacks happen?
- How do we treat atherosclerosis?
  - Open heart surgery
  - Angioplasty
  - Stents
- What is heart failure?
- How do we treat heart failure?
  - Heart transplant
  - Left ventricular assist devices
  - Artificial heart

# Burden of Heart Disease

US and Worldwide

# Global Burden-Cardiovascular Disease

- In 1999:

- CVD contributed to a third of global deaths

- In 2003:

- 16.7 million deaths due to CVD

- By 2010:

- CVD is estimated to be the leading cause of death in developing countries

# 2002 Worldwide Mortality

## Mortality – adults aged 15–59

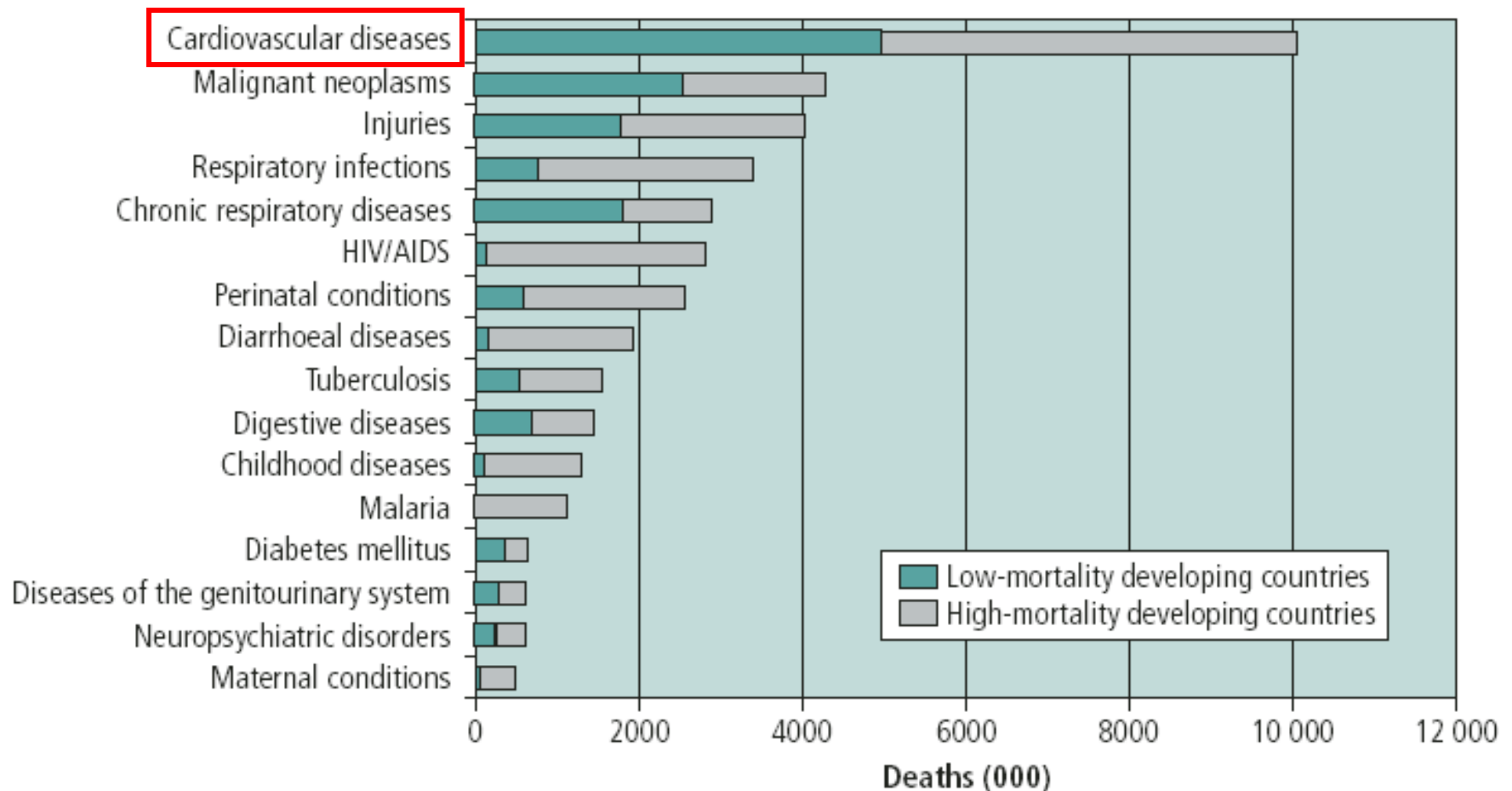
Rank	Cause	Deaths (000)
1	HIV/AIDS	2279
2	Ischaemic heart disease	1332
3	Tuberculosis	1036
4	Road traffic injuries	814
5	Cerebrovascular disease	783
6	Self-inflicted injuries	672
7	Violence	473
8	Cirrhosis of the liver	382
9	Lower respiratory infections	352
10	Chronic obstructive pulmonary disease	343

## Mortality – adults aged 60+

Rank	Cause	Deaths (000)
1	Ischaemic heart disease	5825
2	Cerebrovascular disease	4689
3	Chronic obstructive pulmonary disease	2399
4	Lower respiratory infections	1396
5	Trachea, bronchus, lung cancers	928
6	Diabetes mellitus	754
7	Hypertensive heart disease	735
8	Stomach cancer	605
9	Tuberculosis	495
10	Colon and rectum cancers	477

# Mortality in Developing Countries

Figure 6.1 Deaths attributable to 16 leading causes in developing countries, 2001



# Burden of CVD: United States

## ■ CVD:

- About 61 million Americans (almost ¼ of population) have CVD
- Accounts for more than 40% of all deaths
- 950,000 Americans die of cardiovascular disease each year
- Two main forms of CVD:
  - Ischemic heart disease
  - Stroke

## ■ Ischemic Heart disease:

- Leading cause of death in US
- Coronary heart disease is a leading cause of premature, permanent disability among working adults

## ■ Stroke

- Third leading cause of death in the US

## ■ Cost of CVD disease:

- \$351 billion
  - \$209 billion for health care expenditures
  - \$142 billion for lost productivity from death and disability

# US: Burden of Heart Attack

- Consequences of ischemic heart disease
  - Caused by a narrowing of the coronary arteries that supply blood to the heart
  - Often results in a heart attack
- Each year:
  - 1.1 million Americans suffer a heart attack
  - 460,000 of those heart attacks are fatal
  - Half of those deaths occur within 1 hour of symptom onset, before person reaches hospital



# Early Detection of CVD

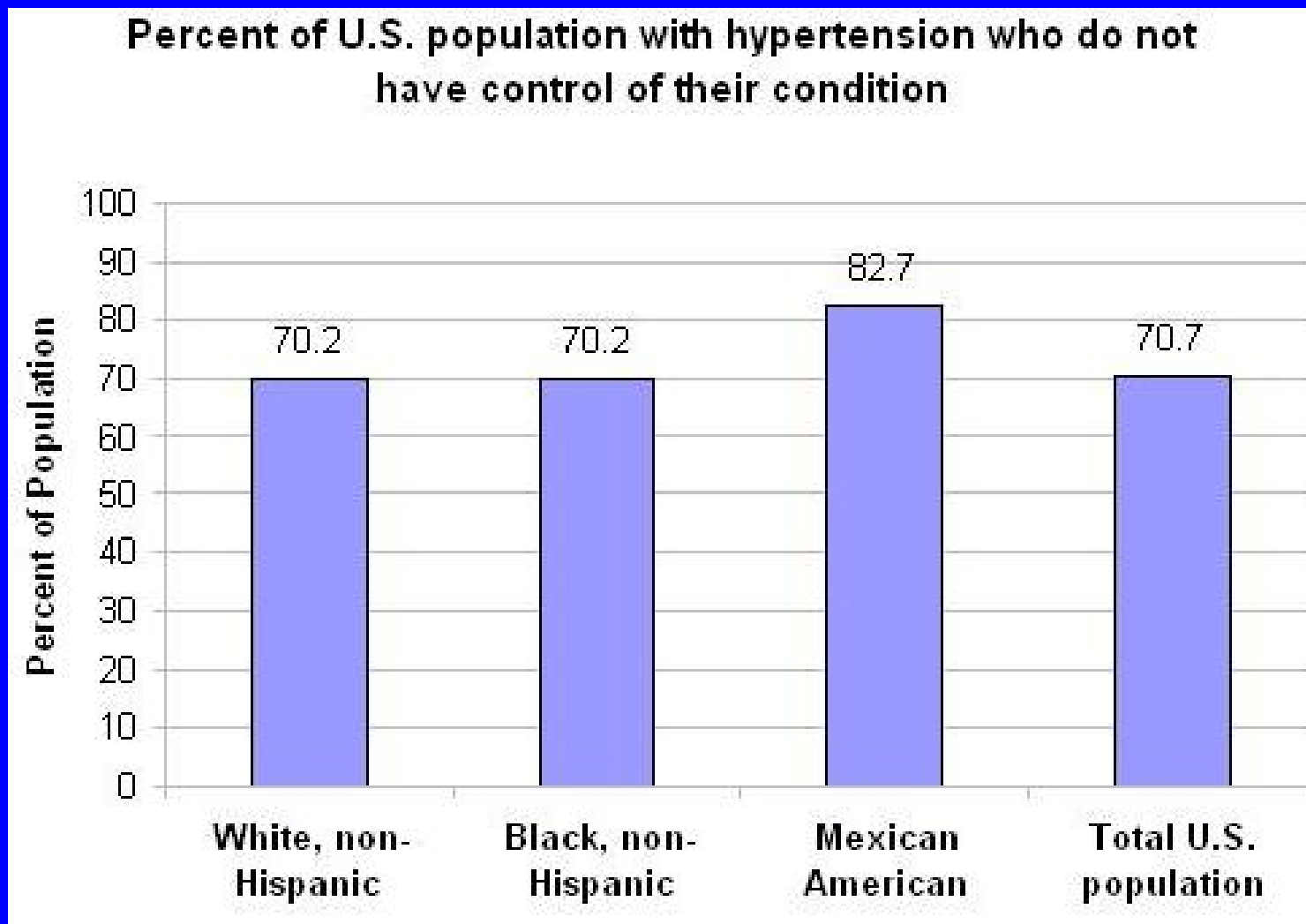
## ■ Risk Factors:

- Tobacco use
- Low levels of physical activity
- Inappropriate diet
- High blood pressure – Over 70% not under control
- High cholesterol – Over 80% not under control

## ■ Screening for CVD:

- Measure BP annually
  - 12-13 point reduction in blood pressure can reduce heart attacks by 21%
- Check cholesterol every 5 years
  - 10% drop in cholesterol can reduce heart attacks by 30%

# Of Those With High BP:



# Blood Pressure

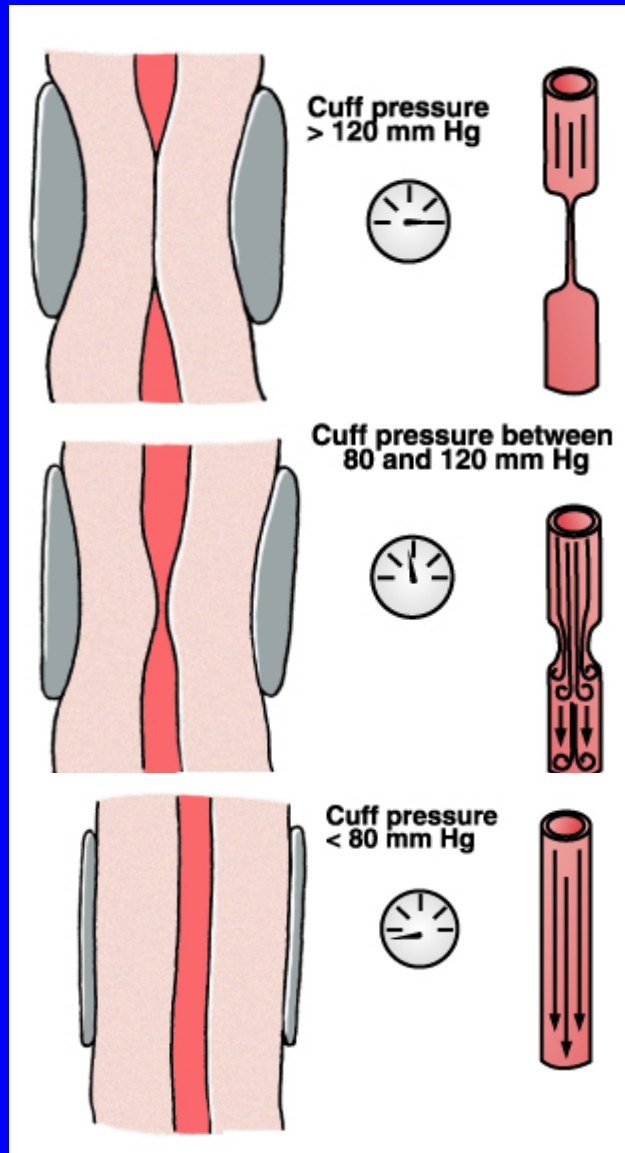
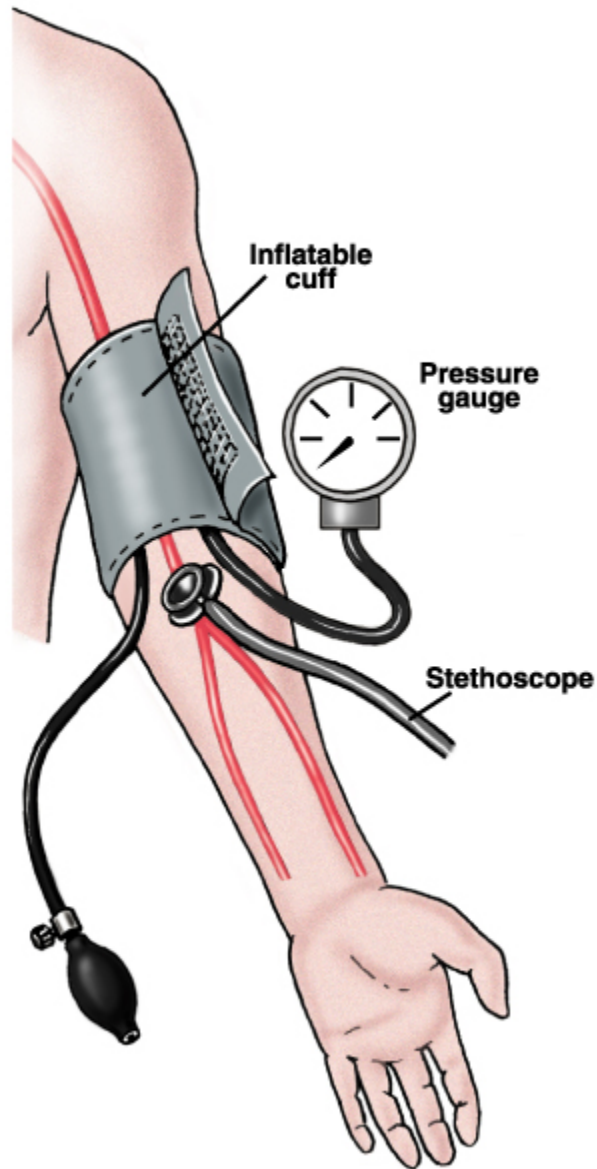
- **My blood pressure = 103/68**
  - The higher (systolic) number represents the pressure while the heart is beating
  - The lower (diastolic) number represents the pressure when the heart is resting between beats
- **Normal blood pressure:**
  - Varies from minute to minute
  - Varies with changes in posture
  - Should be < 120/80 mm Hg for an adult
- **Pre-hypertension:**
  - Blood pressure that stays between 120-139/80-89
- **Hypertension:**
  - Blood pressure above 140/90 mm Hg

# How Do We Measure BP?

## ■ Sphygmomanometer

- Increase cuff pressure until it is higher than systolic pressure
  - Blood flow into arm stops
- Gradually release pressure
  - When cuff pressure = systolic pressure:
    - Blood begins to flow again
    - Hear Korotkoff sound associated with turbulent flow through artery
  - When cuff pressure = diastolic pressure:
    - Artery is no longer compressed
    - No longer hear Korotkoff sound

# How Do We Measure Blood Pressure?



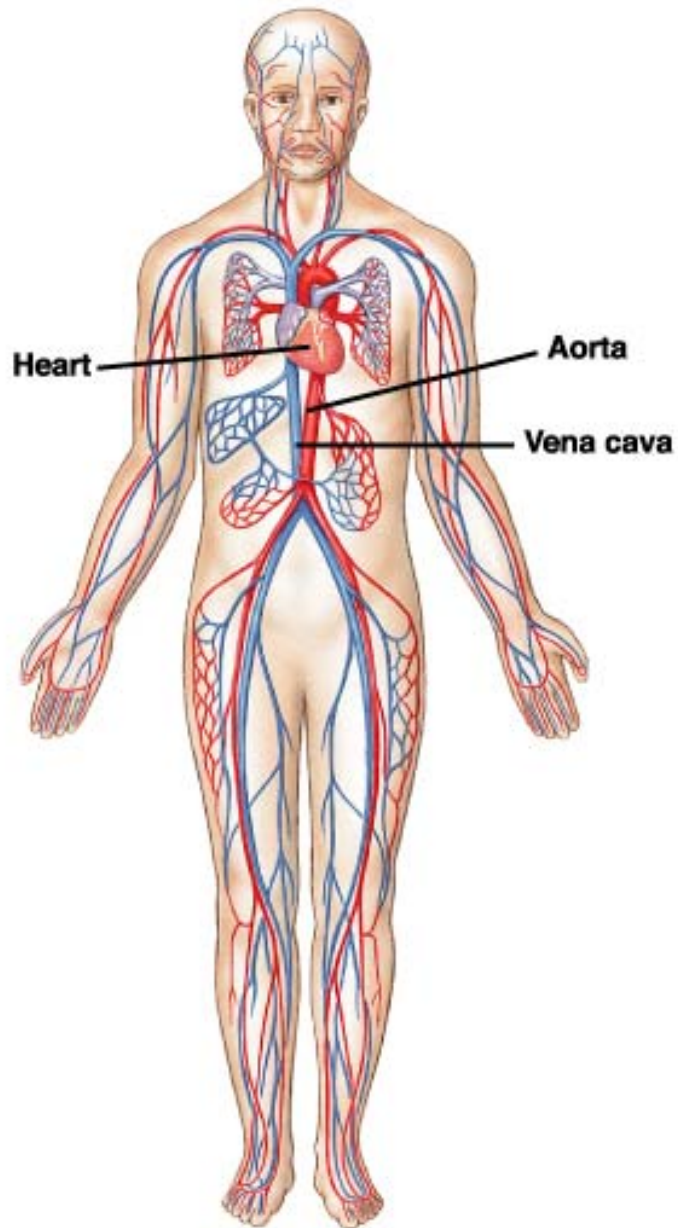
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# Serum Cholesterol Levels

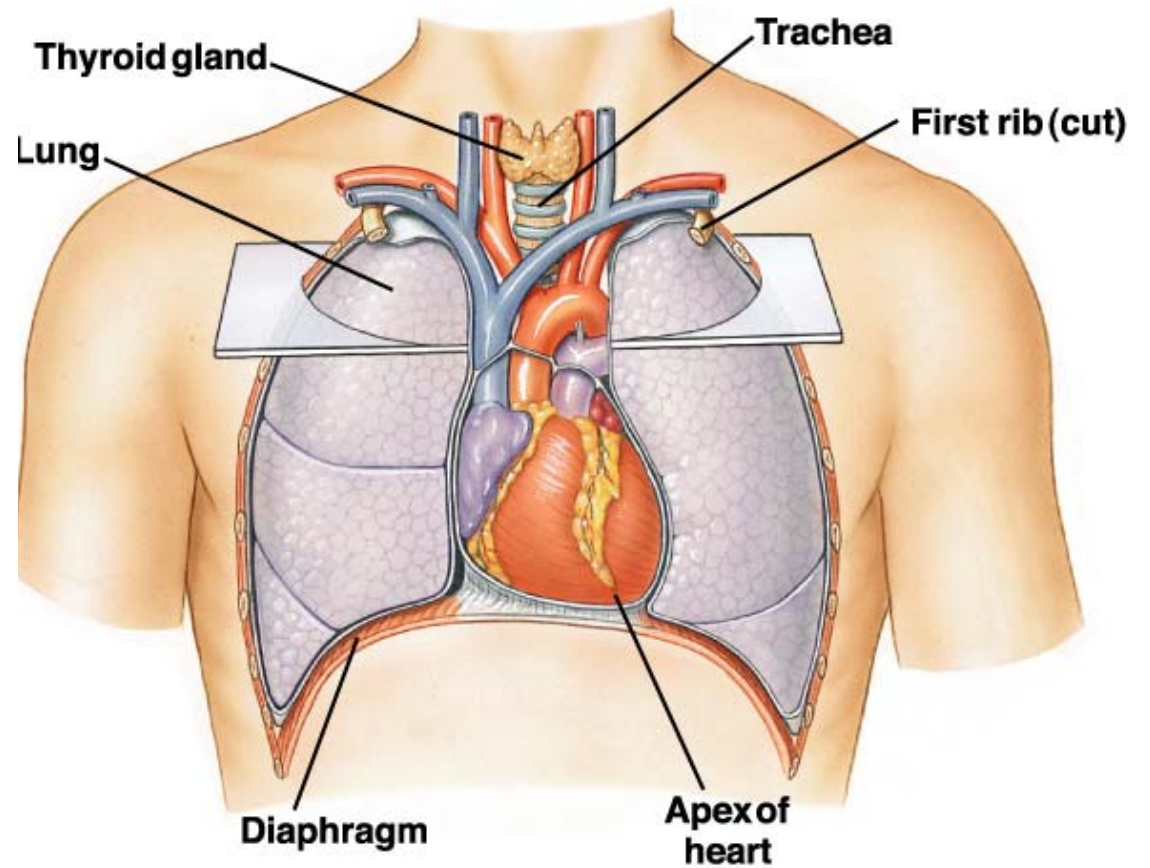
	Total Cholesterol	LDL	HDL
Optimal		under 100	above 60
Desirable	under 200	under 130	
Borderline	200-239	130-159	
Abnormal	over 240	over 160	below 35

LDL causes cholesterol to build up inside blood vessels.  
HDL actually removes cholesterol from the walls of blood vessels and brings it back to the liver to be safely excreted.

# The Cardiovascular System



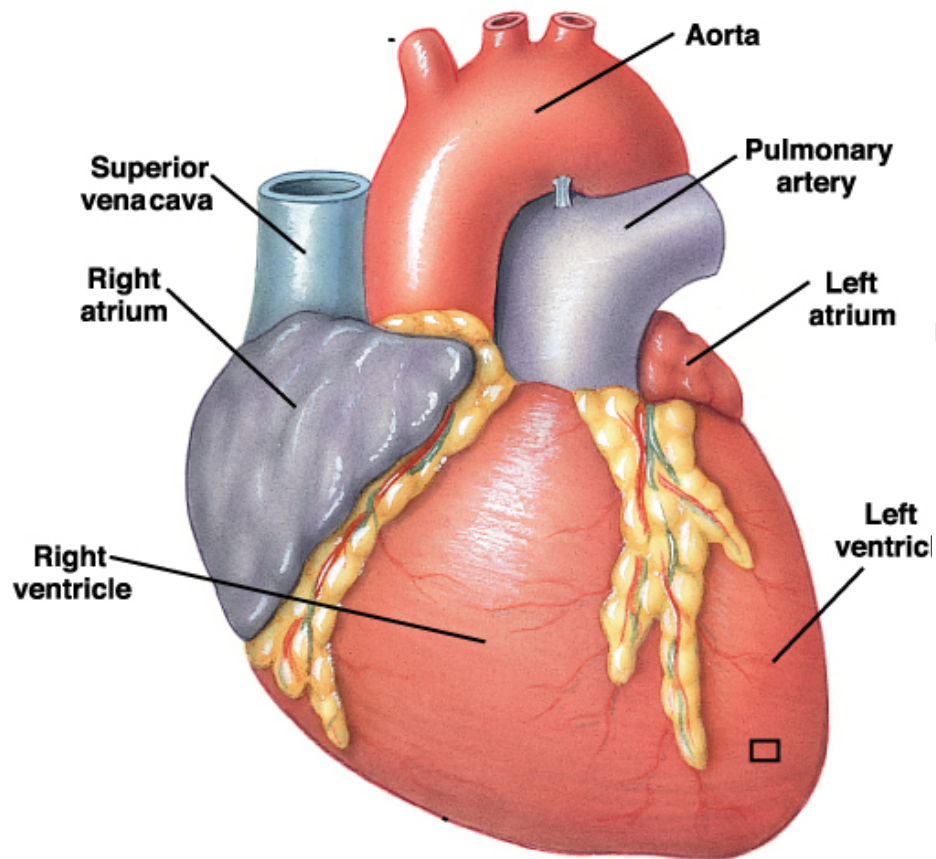
**Vessels that carry well-oxygenated blood are red; those with less well-oxygenated blood are blue.**



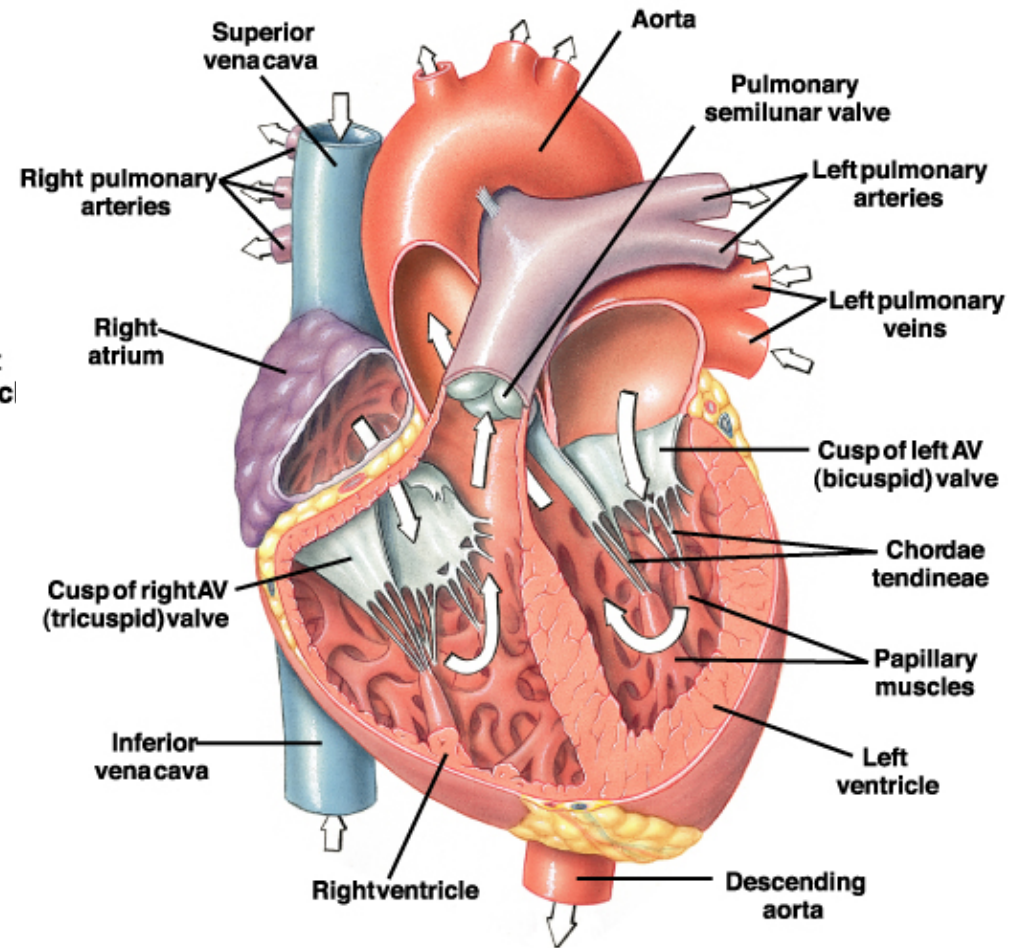
**The heart is on the ventral side of the thoracic cavity, sandwiched between the lungs.**

Fig 14.7 a-d – The Cardiovascular System





The ventricles occupy the bulk of the heart. The arteries and veins all attach to the base of the heart.



One-way flow through the heart is ensured by two sets of valves.

<http://www.innerbody.com/anim/heart.html>  
<http://www.pbs.org/wgbh/nova/eheart/human.html>

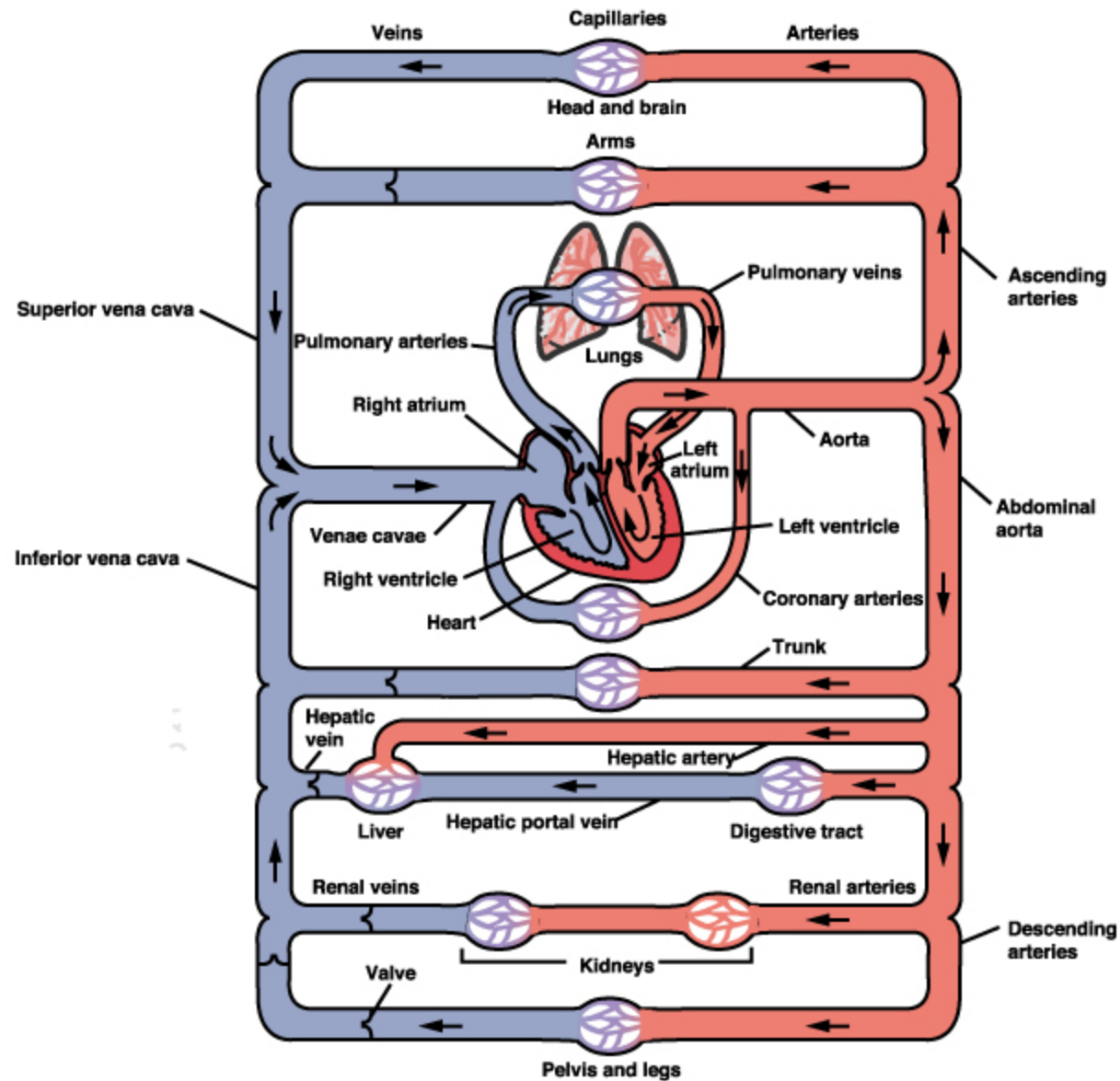


Fig 14.1 – General anatomy of the circulatory system

# Quantifying Heart Performance

- **Heart Rate (HR)**
  - Number of heart beats per minute
  - Normal value is 60-90 bpm at rest
- **Stroke Volume (SV)**
  - Amount of blood pumped by ventricle with each heart beat
  - Normal value is 60-80 ml
- **Cardiac output (CO)**
  - Total volume of blood pumped by ventricle per minute
  - $CO = HR \times SV$
  - Normal value is 4-8 L/min
- **Blood volume**
  - Total volume of blood in circulatory system
  - Normal value is ~5 L
  - Total volume of blood is pumped through our heart each minute!!

# Quantifying Heart Performance

## ■ Ejection Fraction (EF)

- Fraction of blood pumped out of ventricle relative to total volume (at end diastole)
- $EF = SV/EDV$
- Normal value  $> 60\%$
- Measured using echocardiography

## ■ Normal echocardiogram

- <http://www.ardingerphoto.com/pcaweb site/cardiology/movies/sssmovies/normallao2cycle.html>
- Dilated cardiomyopathy
- <http://www.ardingerphoto.com/pcaweb site/cardiology/movies/sssmovies/dilcardiomyopsss.html>

# Heart Attacks

Pathophysiology

Diagnosis

Treatment

# Heart Attacks

## Pathophysiology

# Case Study

- Three months following his first visit to your office, Mr. Solomon presents to the ER in the early morning, with chest pain of one hour duration.
- Mr. Solomon describes the pain as being severe and "like someone was sitting on his chest." The pain, located "in the lower part of my breast bone," awakened him from his sleep. Although he tried to relieve the pain by changing positions in bed, sitting up and drinking water, it remained unchanged.
- He did not sleep well because "I had an upset stomach an acid-burning feeling." He attributed these symptoms to over eating and drinking at a Christmas party.
- He has no pain or discomfort in his arms but says he has an "acheness" in his left jaw which he attributes to "bad teeth."
- Physical examination reveals the patient to be anxious, pale, diaphoretic and in obvious discomfort. He is unshaven and accompanied by his wife. He tries to relieve his pain by belching. He coughs occasionally. Mr. Solomon says "the flu has been going around the office, and I've had a little cough and fever all week."
- [http://www.meddean.luc.edu/lumen/meded/mech/cases/case2/Case\\_f.htm](http://www.meddean.luc.edu/lumen/meded/mech/cases/case2/Case_f.htm)

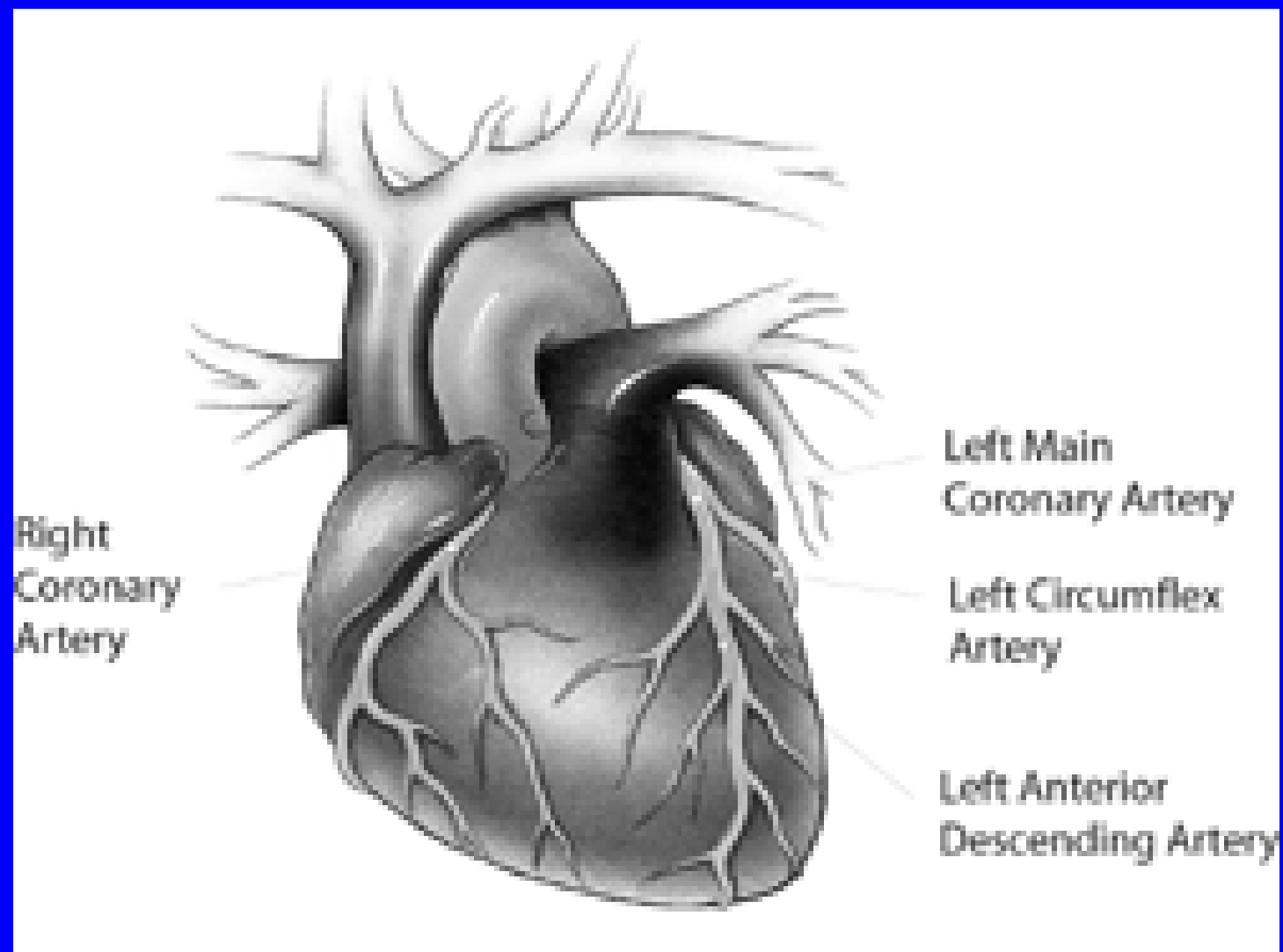
# Early Warning Signs of Heart Attack

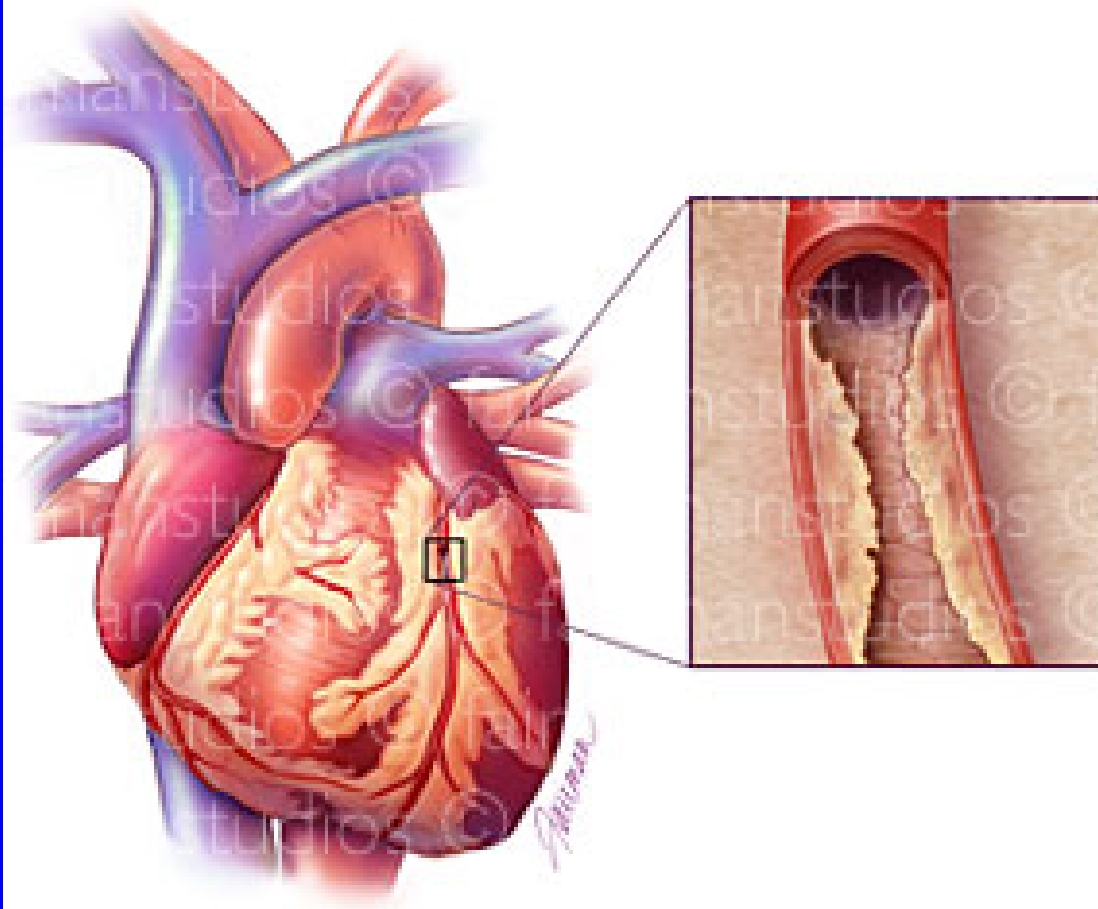
- Many heart attacks start slowly; symptoms may come and go
- Chest discomfort
  - Most heart attacks involve discomfort in the center of the chest that lasts for more than a few minutes, or goes away and comes back. The discomfort can feel like uncomfortable pressure, squeezing, fullness, or pain
- Discomfort in other areas of the upper body
  - Can include pain or discomfort in one or both arms, the back, neck, jaw, or stomach
- Shortness of breath
  - Often comes along with chest discomfort. But it also can occur before chest discomfort
- Other symptoms
  - May include breaking out in a cold sweat, nausea, or light-headedness



# Heart Attack Signs

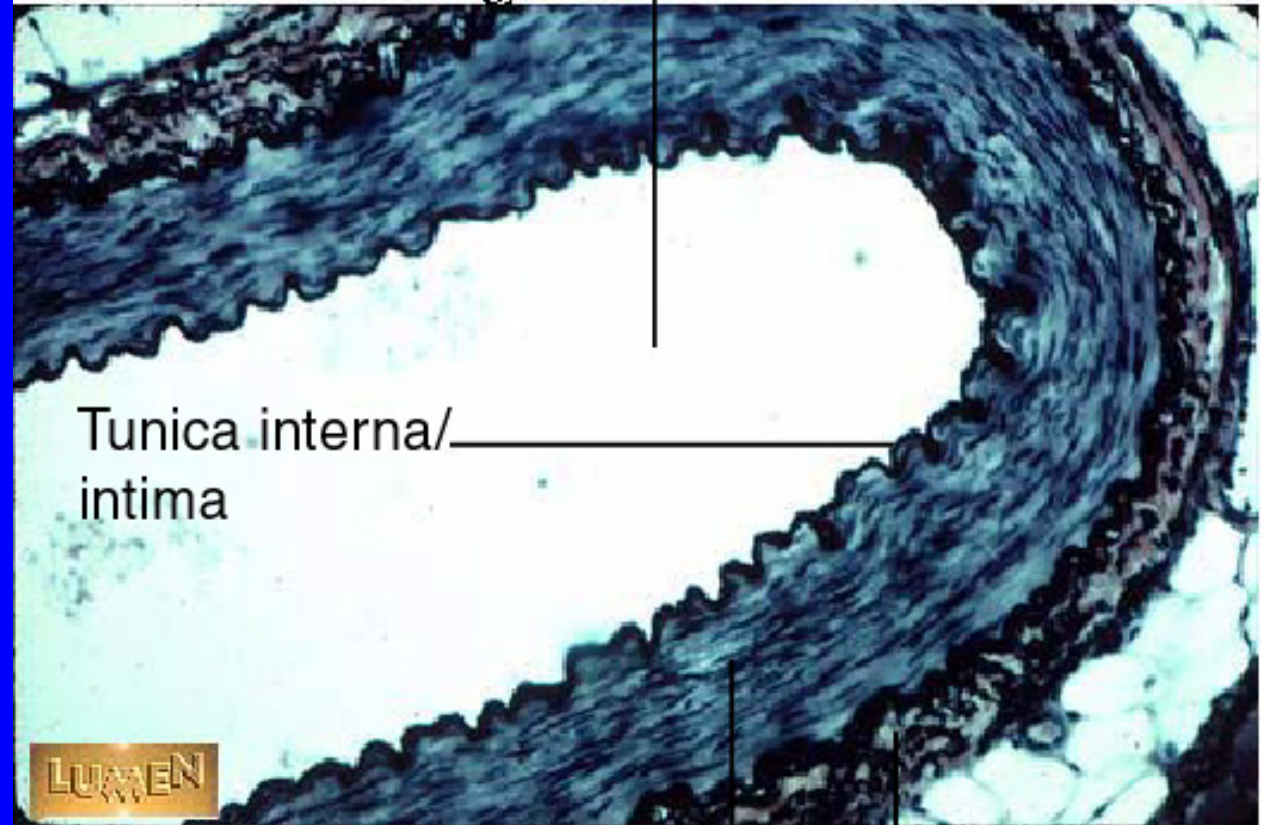
- <http://www.nhlbi.nih.gov/actintime/video.htm>







Histology Lab Part 8: Slide 12



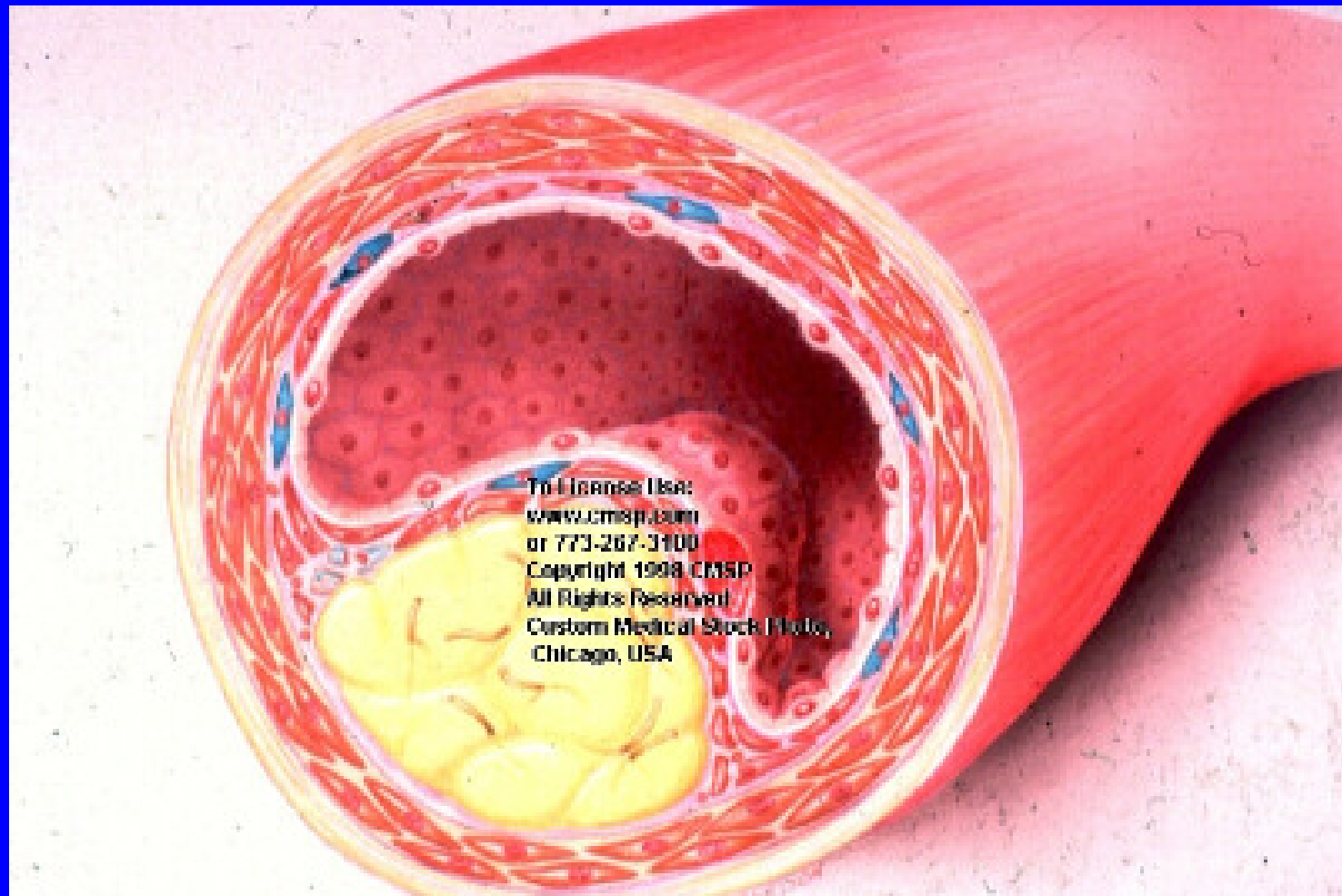
ARTERY

Tunica media

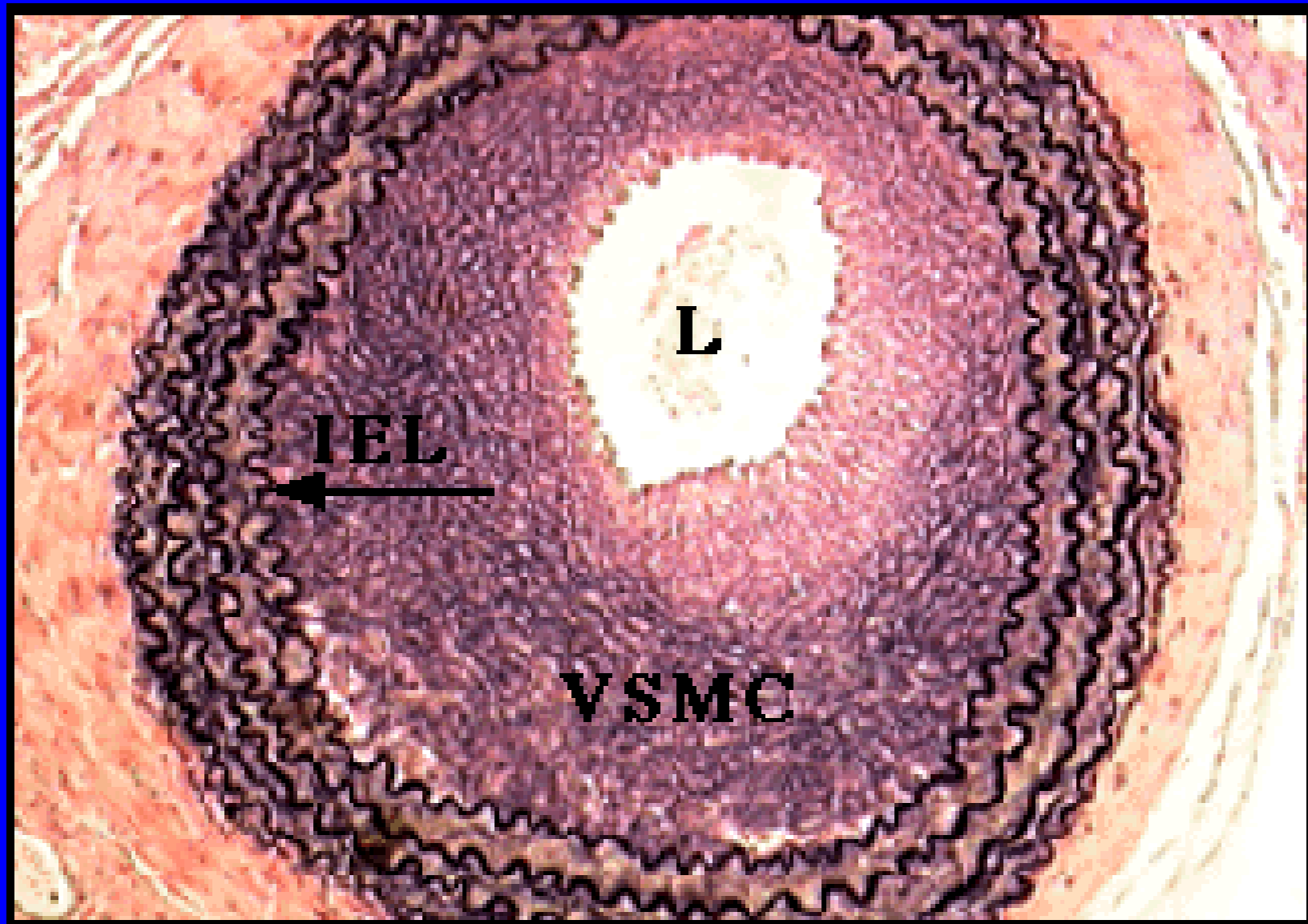
Tunica adventitia

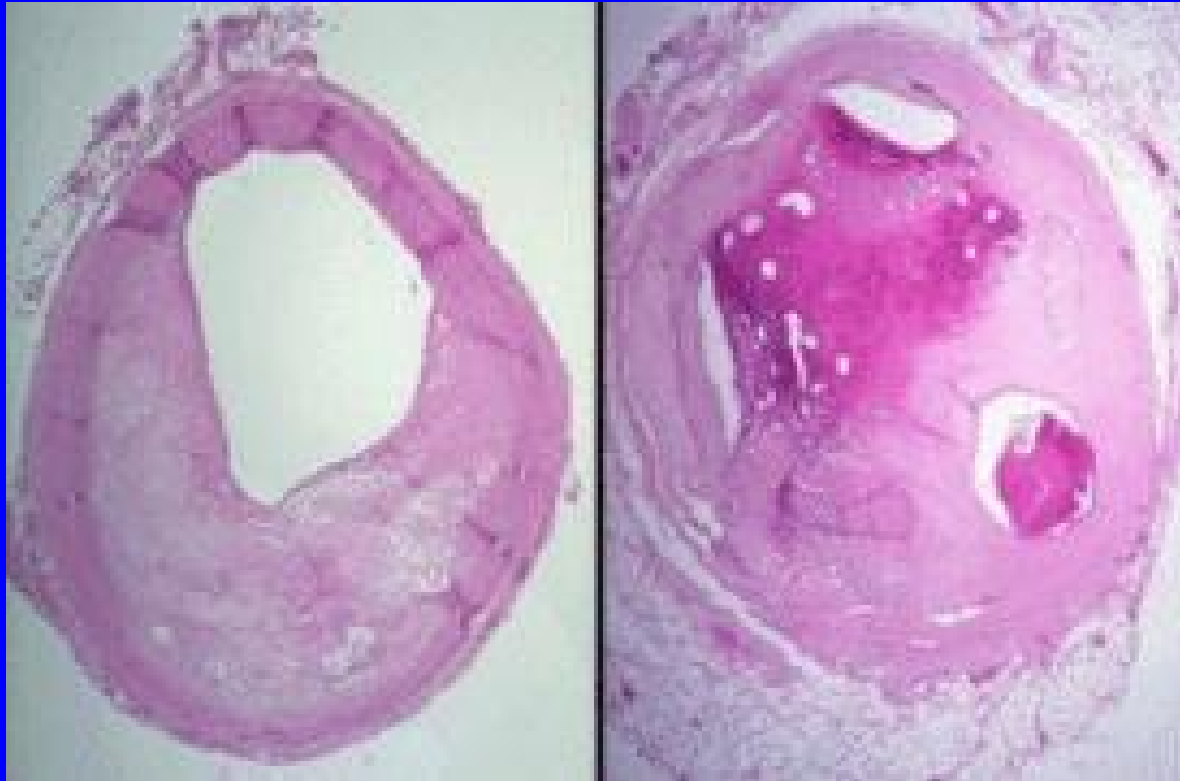


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cardio/images/1d.a.jpg](http://www.pathology.vcu.edu/education/cardio/images/1d.a.jpg)



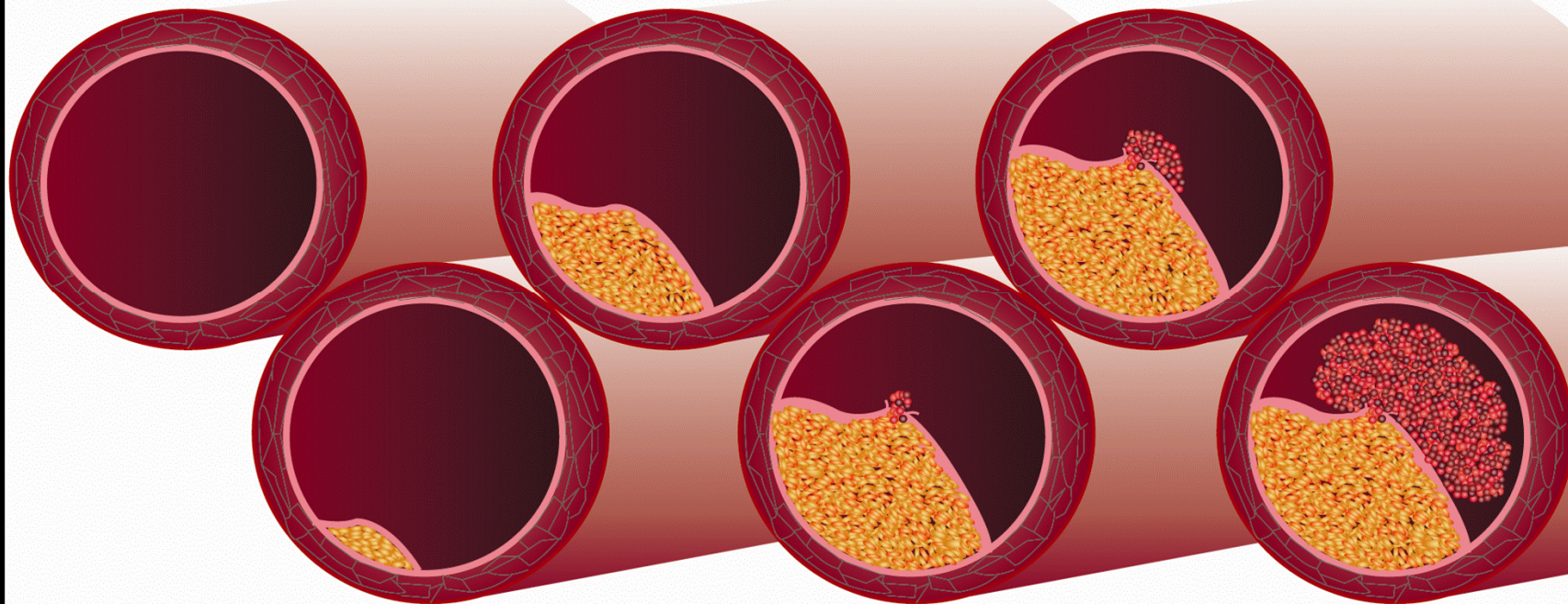
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<http://medlib.med.utah.edu/WebPath/jpeg5/CV119.jpg>





# Heart Attack Video

- <http://www.heart1.com/attack/guidant.cfm>

# Heart Attacks

Treatment of Acute Occlusion:  
tPA

# Tissue Plasminogen Activator

- Tissue plasminogen activator (tPA):
  - A thrombolytic agent (can dissolve blood clots)
  - Approved for use in certain patients having heart attack or stroke
- Clinical Studies:
  - tPA and other clot-dissolving agents can reduce the amount of damage to the heart muscle and save lives
  - To be effective, they must be given within a few hours after symptoms begin
  - Administered through an intravenous (IV) line in the arm by hospital personnel
  - Patients treated within 90 minutes after onset of chest pain are one-seventh as likely to die compared to patients who receive therapy after 90 minutes

# Thrombolytics

- Risks of thrombolytics:
  - Intra-cranial hemorrhage
    - Increased risk in those > age 70
  - Patients may require further intervention
- Costs of thrombolytics:
  - tPA = \$2300
  - Streptokinase = \$320

# Effectiveness of Thrombolytics

## ■ Clinical Trial:

- In 15 countries and 1081 hospitals
- 41,021 patients with evolving myocardial infarction
- Randomly assigned to 4 different strategies:
  - Streptokinase and subcutaneous heparin
  - Streptokinase and IV heparin
  - Accelerated tissue plasminogen activator (t-PA) and IV heparin
  - Combo of streptokinase plus t-PA with IV heparin
- Primary end point was 30-day mortality

## ■ Result:

- Streptokinase & subcut. heparin: 7.2% (stroke 0.49%)
- Streptokinase & IV heparin: 7.4% (stroke 0.54%)
- Accelerated t-PA & IV heparin: 6.3% (stroke 0.72%)
- Combo of both with IV heparin: 7.0% (stroke 0.94%)

# Cost-Effectiveness of Thrombolytics

Therapy	Patient Group	\$ per yr life saved
tPA	Post MI high risk	\$3,600
tPA	Acute MI, large infarct, treatment started >2 hours post	\$24,200
Counseling	Smoking cessation	\$1300-\$3900
CABG	Two vessel disease, severe angina	\$9,200-\$42,500

[http://www.sciencedirect.com/science?\\_ob=ArticleURL&\\_aset=B-WA-A-A-A-MsSAYZA-UUA-AUYWDCBYZYAUUYUBBVZZYBWAUBWEUBAU&\\_rdoc=1&\\_fmt=full&\\_udi=B6T1048NJXK25&\\_coverDate=5%2F22%2F2003&\\_cdi=4876&\\_orig=search&\\_st=13&\\_sort=d&view=c&\\_acct=C000004378&\\_version=1&\\_urlVersion=0&\\_userid=108429&md5=5f493caa5f65762c23c0d90eaea8b92d](http://www.sciencedirect.com/science?_ob=ArticleURL&_aset=B-WA-A-A-A-MsSAYZA-UUA-AUYWDCBYZYAUUYUBBVZZYBWAUBWEUBAU&_rdoc=1&_fmt=full&_udi=B6T1048NJXK25&_coverDate=5%2F22%2F2003&_cdi=4876&_orig=search&_st=13&_sort=d&view=c&_acct=C000004378&_version=1&_urlVersion=0&_userid=108429&md5=5f493caa5f65762c23c0d90eaea8b92d)

# Heart Attacks

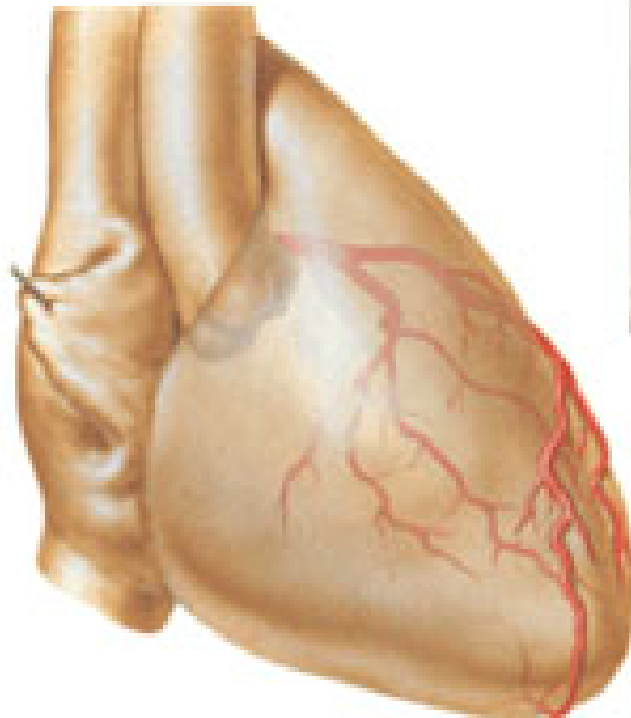
Diagnosis of Atherosclerosis



# Detection of Atherosclerosis



## Left Coronary Artery Arteriographic View 2



*Handwritten signature*  
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