BI 358 Lecture 10

I. **Announcements**  Dr. Padgett next Tuesday! Drafts due?

II. **Lymphatic System**  Alternative circulation Torstar, DC…

III. **Cardiovascular Physiology**  Torstar, G&H, Katz, LS,…
   A.  ♥ structure & function  LS, Torstar, G&H fig 9-8 +…
   B.  Blood flow through ♥ & periphery  G&H fig 9-1, LS…
   C.  Coronary circulation & the cardiac cycle  
       G&H fig 21-3, Katz, G&H fig 21-5, 21-6, 21-4, 21-7, 21-8 +…

IV. **CVDs**  Definitions, US Disease Statistics:  CDC 2012 + AHA

V. **Atherosclerosis + Mechanisms**  Torstar Books, G&H, +…
   A.  Linking proposed historical mechanisms  
       Endothelial Injury Hypothesis (Ross & Glomset)  
       Lipid Infiltration Hypothesis (Steinberg & Witzum) + new!
   B.  Cholesterol metabolism:  Dr. Kottke’s bathtub analogy
   C.  1° modifiable risks:  cigarette smoking, hypertension, 
       hypercholesterolemia/hyperlipidemia, lack of exercise
   D.  Treatment triad,  PTCA, CABG, prevention, practical tips!

VI. **Additional Resource Slides**  Development, electrical highway,…
Remember to submit comments about Dr. Kraig’s lecture by 5 pm today!

Yes, Sherlock! Avian & human immune systems evolved from a common reptilian ancestor!!

Whoopee! For the birds??
https://www.peacehealth.org/ohvi?from=/sacred-heart-ri
Lymphatic System

1. Lymph Nodes
2. Vessels
3. Lymph

No pump!
Lymphatic System

Alternative System of Circulation or Drainage System

Lymph Vessels || Veins
Lymphatic Vessel

Torstar Books 1984
Elephantiasis: Lymphatic Blockage Due to Mosquito-Borne Parasitic Worm

L Sherwood 2007
Cardiovascular (CV) = Heart + Vessels + Blood!
NB: Figure-8 loop

Pulmonary Systemic

Capillary beds of lungs where gas exchange occurs

Pulmonary circuit

Pulmonary arteries

Vena cavae

Right ventricle

Left ventricle

Aorta and branches

Pulmonary veins

Arterioles

Capillary beds of all body tissues where gas exchange occurs

Oxygen-poor, CO₂-rich blood

Oxygen-rich, CO₂-poor blood

D Chiras 2013 fig 4-1b
Dual Pump Action & Parallel Circulation
Heart Protection & Layers

- Aorta
- Superior vena cava
- Right atrium
- Right ventricle
- Inferior vena cava

- Endocardium
- Myocardium
- Epicardium

- Pericardial cavity
- Fibrous pericardium
- Parietal pericardium

Torstar 1984 p 34
What the heck’s a *bruit*?
(brwe, brøot) [Fr.] sound ≥ 25 subclassifications!

Aneurysmal *b.* a blowing sound over an aneurysm.

*b. de canon* [Fr. sound of cannon] abnormally loud 1st heart sound heard in complete heart block.

*b. de craquement* [Fr. sound of crackling] a crackling pericardial or pleural bruit.

False *b.* artifact caused by pressure of the stethoscope or derived from circulation of the ear.

*b. de lime* [Fr. sound of a file] cardiac sound resembling filing.
Human ❤️ = 4-chambered box? 2 separate pumps?

Upper = Atria

Lower = Ventricles

RA ➔ RV

LA ➔ LV

Pulmonary

Systemic

Primer Pumps

Power Pumps

R ❤️

L ❤️
Coarctation, Crimping or Narrowing of the Aorta

Human ♠ = 4 unique valves?
2 valve sets?

**Semilunar** = *Half-moon shaped*

1. Pulmonic/Pulmonary
2. Aortic

**AV** = *Atrioventricular*

3. ① AV = Tricuspid
4. ② AV = Mitral/Bicuspid
MITRAL VALVE

Cusp

Chordae tendineae

Papillary muscles

AORTIC VALVE

Cusp

G&H 2006 fig 9-6; G&H 2011 fig 9-7; G&H 2016 fig 9-8
Heart Valve Orientation & Scaffolding

- Pulmonary ring
- Aortic ring
- Mitral ring
- Tricuspid ring
- Muscle fiber
TAVR Transcatheter Aortic Valve Replacement

Dr. Padgett is a TAVR pro & doing several right now!

https://www.mayoclinic.org/tests-procedures/transcatheter-aortic-valve-replacement/about/pac-20384698
Veins ➔ Atria ➔ Ventricles ➔ Arteries

Superior vena cava (from head)
Right atrium
Inferior vena cava (from body)
Right ventricle
Endocardium
Pericardium
Left atrium
Left ventricle
Myocardium
Aorta

https://www.nhlbi.nih.gov/health-topics/how-heart-works

cf: G&H
fig 9-1
2011 & 2016 ed

VAVA!
Coronary Circulation ≡ Crowns the Heart!
Heart Dominance May Influence Survival?

**FIG. 1.9.** Diagrammatic views of the posterior surfaces of the human heart showing left (A) and right dominant (B) patterns of coronary artery supply. In the left dominant pattern, the posterior descending artery (PDA) is supplied by the circumflex branch of the left coronary artery (CIRC). In the right dominant pattern, the posterior descending artery is supplied by the right coronary artery (RCA). Other abbreviations: LAD, left anterior descending coronary artery; LA, left atrium; RA, right atrium; LV, left ventricle; RV, right ventricle; SVC, superior vena cava; IVC, inferior vena cava.
Coronary Arteries Pierce the Heart from Epi to Endo
Anastomoses May Provide Lifesaving Collateral Circulation!!
Cardiac Cycle

Systole
Contract & Empty

Diastole
Relax & Fill
Coronary blood flow (ml/min)

Systole
Contract & Empty

Diastole
Relax & Fill

G&H 2011 & 2106 fig 21-4
AMI
CVDs
CVA
TIA
HTN
PVD
FIGURE 9-35

Extent of myocardial damage as a function of the size of the occluded vessel.
What is the Ultimate Cause of Death?

1. ↓ $\dot{Q}$, CO or Cardiac Output
2. Pulmonary damming w/edema
3. Cardiac fibrillation
4. Cardiac rupture (occasionally)
5. Thromboembolism (2011 ed. but not 2016)

G&H 2016 p 266
G&H 2011 p 250
Systolic Stretch Due to Necrotic Tissue

- Normal Muscle
- Nonfunctional Muscle
- Systolic Stretch
G&H 2016, 2011 fig 21-8

Mild ischemia
Non-functional
Dead fibers
Nonfunctional
Dead fibers
Fibrous tissue
Treatment Triad

 Drugs/Surgery

Exercise

Dietary Modification

NB: Last blasted resort!!
An LDL to HDL ratio *greater than* 5 to 1 in men or 4.5 to 1 in women

*Increased risk of heart disease*
A typical lipoprotein

- Phospholipid
- Cholesterol
- Triglyceride
- Protein
Selected Atherosclerotic Genetic Determinants – Ultra-short List!

Genes for HDL, LDL+ receptors, Apolipoproteins Apo B-100, Apo-E, Apo-M, lipoprotein a/Lpₐ, homocysteine metabolism enzymes N5,N10-methylene-tetrahydrofolate reductase, cystathionine beta-synthase, Type I antithrombin, mitochondrial haplogroup A, Protein tyrosine phosphate PTPN22 C/T single nucleotide polymorphism (SNP) @ +1858, HMG COA reductase, SNPs in TNF-alpha, IL-1beta & TGF-beta1, IL-6, IL-10, CD14, TLR-4 receptors, Human Leukocyte Antigens HLA-DRB1*01, HLA-B*07 + haplotype LTA+253a-LTA+633g-C4A3-C4B1, HDL-associated paraoxonase (PON1), lysosomal acid lipase (LAL), MEF2A protein affecting artery walls…
Bruce Kottke’s Bathtub Analogy

5 forms of cholesterol:

Chylomicrons, VLDL, LDL, IDL, HDL

\[ \beta \]

\[ \text{Atherogenic} \quad \text{Anti-Atherogenic} \]

\[ \beta - \text{VLDL} + \text{LDL} = \text{Faucet} \]

Total Cholesterol Level

Bathtub

HDL = Drain

Bruce Kottke

“I don’t think the total cholesterol test by itself is worth a damn.”
—Eliot Corday

Biological Artifact!?
Historical Hypotheses for Atherosclerosis Development

 Ross & Glomset

- Endothelial Injury
  - Platelet Adherence
    - PDGF Release
      - Cell Proliferation
        - Advanced Lesion

 Steinberg & Witztum

- High Plasma LDL
  - LDL Infiltration into Intima
    - Oxidized LDL + Macrophages
      - Foam Cells
        - Fatty Streak

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2032127/
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC295745/
How Inflammation Attacks the Heart

1. **LDL Oxidized**
   Oxidized LDL cholesterol creates the "injury" by burrowing into the artery wall. Cigarette smoking, high blood pressure, and high blood sugar make the injury worse.

2. **Monocytes Migrate**
   In response to the injury, the immune system sends in a team of inflammatory cells, including white blood cells called monocytes.

3. **Monocytes → Macrophages**
   Monocytes migrate into the artery wall, where they turn into macrophages. The macrophages' job: gobble up the LDL cholesterol.

4. **Fatty Streak**
   The macrophages, now stuffed with LDL cholesterol, form a "fatty streak" in the artery wall.

5. **Fibrous Plaque**
   Over the decades, more cholesterol, connective and elastic tissue, calcium, and cell debris accumulate and turn the fatty streak into plaque. As the artery tries to heal itself, smooth muscle cells migrate in to cover the plaque, forming a fibrous cap around it.

6. **Cap Breakdown**
   Macrophages kill the smooth muscle cells and release enzymes that break down the fibrous cap.

7. **Cap Rupture**
   The cap ruptures.

8. **Clot Formation**
   When a clot forms around the rupture, blood flow is blocked, which triggers a heart attack. (If the blocked artery feeds the brain, the blockage triggers a stroke.)
SO FAR, NO ONE HAS FOUND A MAGIC BULLET TO STOP ALZHEIMER’S DISEASE, WHICH GUMS UP THE BRAIN WITH PROTEIN CLUMPS AND TANGLES. BUT IT’S NOT JUST CLUMPS AND TANGLES.

DAMAGE TO THE BRAIN’S BLOOD VESSELS—OFTEN DUE TO HIGH BLOOD PRESSURE, SMOKING, OR DIABETES—CAN ALSO PLAY A ROLE, NOT JUST IN DEMENTIA BUT IN MILDERS MEMORY LOSS AS WELL.

HERE’S HOW TO KEEP A CLEAR HEAD FOR AS LONG AS POSSIBLE.

“IN FACT, SOME OF THE SYMPTOMS WE THINK OF AS NORMAL BRAIN AGING MAY BE DUE TO INJURY TO THE BRAIN’S BLOOD VESSELS,” HE NOTES.

RESEARCHERS KNOW THE MAJOR THREATS. “THE BIG RISKS FOR VASCULAR BRAIN INJURY ARE SMOKING, HIGH BLOOD PRESSURE, AND DIABETES,” SAYS REED.

THE CAUSES OF ALZHEIMER’S PATHOLOGY ARE MORE MURKY. BUT NEW EVIDENCE SUGGESTS THAT INSULIN MAY PLAY A ROLE.

HERE’S HOW TO KEEP YOUR BRAIN IN GOOD WORKING ORDER.

1. WATCH YOUR BLOOD PRESSURE

“THERE’S A WEALTH OF EVIDENCE THAT HIGH BLOOD PRESSURE IS A RISK FACTOR FOR LATE-LIFE COGNITIVE IMPAIRMENT,” SAYS KNOPMAN.
MRI Hyperintensities, Hypertension & Dementia

NAHL CSPI, Jan-Feb 2014
Middle Cerebral Artery Branches

...Cerebral vasculature! Oh my!

The Window to the CV System?
Renal Vasculature

Figure 37-1 Devices for percutaneous transluminal coronary interventions. A, Coronary balloon. B, Rotational atherectomy burr (Rotablator). C, Coronary stent.
CABG = Coronary Artery Bypass Graft

Double?
Triple?
Quadruple?
Quintuple?
Did you know?

- Every 40 seconds, someone has a heart attack in the US!
- ~630,000 Americans die of heart disease each yr – that’s 1 in every 4 deaths. Heart disease is the leading cause of death for both men and women.
- Heart disease costs the US ~ $200 billion per yr in health care, medications & lost productivity. By 2035, CVD costs are projected to top $1 trillion annually.

Heart Disease Death Rates, 2011-2013
Adults, Ages 35+, by County

Rates are spatially smoothed to enhance the stability of rates in counties with small populations.

Data Source: National Vital Statistics System
National Center for Health Statistics

https://www.cdc.gov/dhdsp/data_statistics/fact_sheets/fs_heart_disease.htm
Procedures and heart attack deaths
Per 10,000 population

Angioplasties

Bypasses

Heart attack deaths

As noninvasive techniques improve, the rate for bypass surgery goes down.

SOURCES: THOMAS THOM, NATIONAL HEART, LUNG, AND BLOOD INSTITUTE; GAUTAM GOWRISANKARAN, WASHINGTON UNIVERSITY IN ST. LOUIS; SALIM YUSUF, McMASTER UNIVERSITY, THE INTERHEART STUDY.
Healing the Heart

Beauty on the Border 66  Curse of Nigerian Oil 88
Hawaii’s Unearthly Worms 118  Forests of the Tide 132
Artificial heart = $125,000 - $250,000!

5400 await transplants, but only 2000 - 2600 donors are available…
Questions + Discussion
Additional Resource Slides: Development, ♥‘s Electrical Highway, Coordinated Events...
Fetal Circulation
≡ Aqua Animal
Bypass Lungs
$R \rightarrow L \bigheart$ Shunt

G&H 2016 fig 84-4, G&H 2011 fig 83-4
(Automatically) Shock the Heart then it Contracts!
Intrinsic Regulation: Autorhythmic
(a) Normal pacemaker activity: Whole train will go 70 mph (heart rate set by SA node, the fastest autorhythmic tissue).

(b) Takeover of pacemaker activity by AV node when the SA node is nonfunctional: Train will go 50 mph (the next fastest autorhythmic tissue, the AV node, will set the heart rate).

(c) Takeover of ventricular rate by the slower ventricular autorhythmic tissue in complete heart block: First part of train will go 70 mph; last part will go 30 mph (atria will be driven by SA node; ventricles will assume own, much slower rhythm).
Extrinsic Regulation: Nervous

NB: + Extrinsic Hormonal e.g. Adrenal Epi + NE
Electrical Events Precede Mechanical Events!