Pathophysiology for the Educator

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Thank you

iSimulate

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Cellular

4

The Education Standards

	EMR	EMT	AEMT	Paramedic
Anatomy and Physiology	Uses simple knowledge of the anatomy and function of the upper airway, heart, vessels, blood, lungs, skin, muscles, and bones as the foundation of emergency care.	Applies fundamental knowledge of the anatomy and function of all human systems to the practice of EMS.	Integrates complex knowledge of the anatomy and physiology of the airway, respiratory and circulatory systems to the practice of EMS.	Integrates a complex depth and comprehensive breadth of knowledge of the anatomy and physiology of all human systems

&

	EMR	EMT	AEMT	Paramedic
Pathophysiology	Uses simple knowledge of shock and respiratory compromise to respond to life threats.	Applies fundamental knowledge of the pathophysiology of respiration and perfusion to patient assessment and management.	Applies comprehensive knowledge of the pathophysiology of respiration and perfusion to patient assessment and management.	Integrates comprehensive knowledge of pathophysiology of major human systems.

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Hierarchy of the body

Order of Preservation

Brain → Heart → Kidney

Order of Sacrifice

Brain ← Heart ← Kidney

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Cellular Respiration

- Three distinct but interconnected reactions :
  - Glycolysis
  - Citric acid cycle (Kreb's)
  - Electron transport chain
- Aerobic cellular respiration = with oxygen
- Anaerobic cellular respiration = without oxygen

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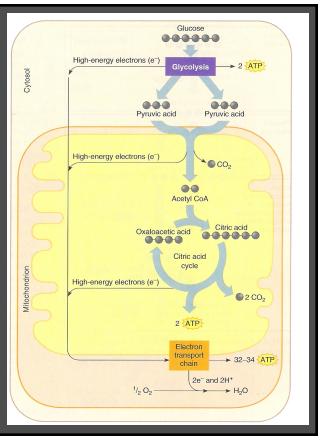
What is the ultimate goal of emergency care?

- Maintain perfusion of cells
  - Oxygen
  - Glucose
- Byproducts
  - ATP
  - Heat
  - CO_2
  - H_2O



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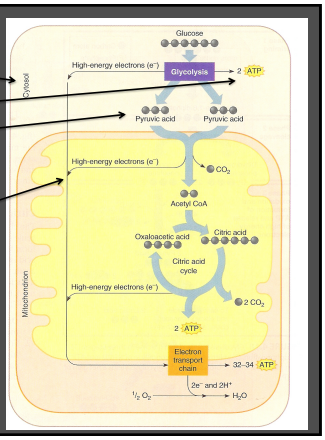
Glycolysis

2 molecules of ATP

2 pyruvic acid molecules

High-energy electrons

Process is anaerobic



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Citric Acid Cycle

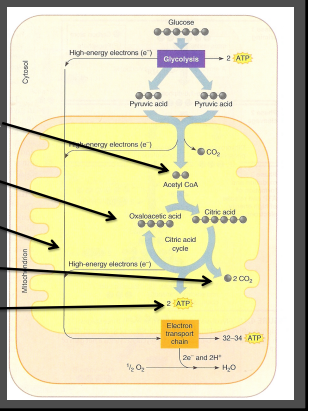
Pyruvic acid + coenzyme = Aceytl CoA

Combine with oxaloacetic acid to form citric acid

High energy electrons released

CO2 produced

2 molecules of ATP



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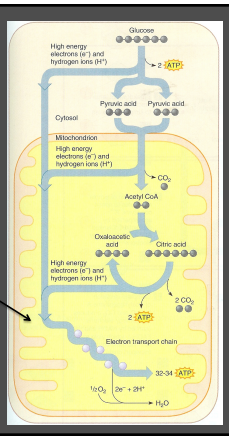
Electron Transport Chain

High energy electrons require oxygen for transport along the chain to form ATP

By-products:

32-34 molecules of ATP
H20
CO2
Heat



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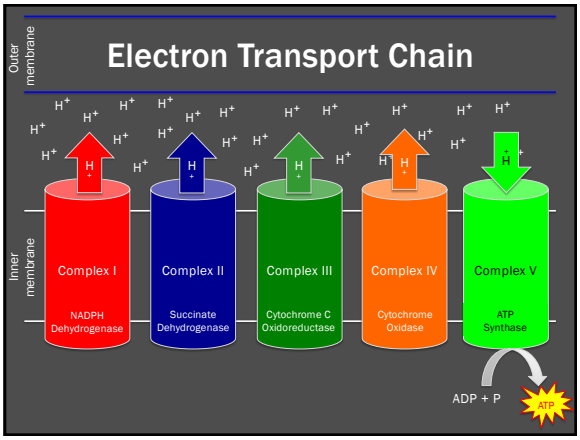
Electron Transport Chain



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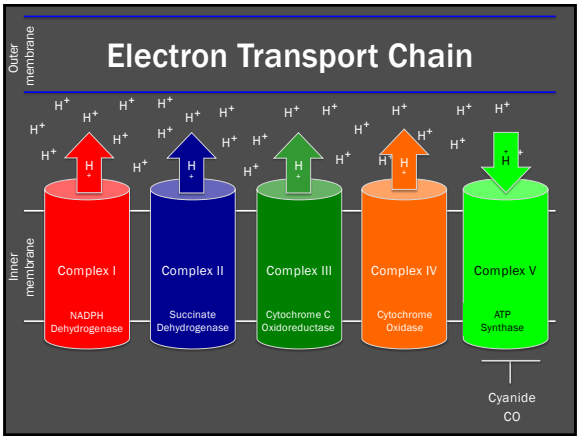

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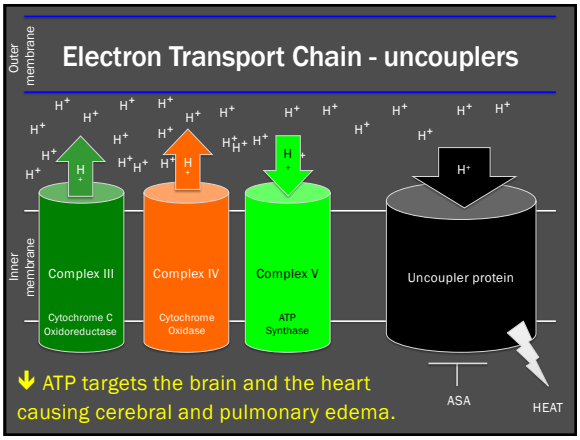

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ASA toxicity

- At high concentrations salicylate uncouples oxidative phosphorylation
- Uncoupling decreases ATP formation
- ATP consumption > ATP production
- ATP imbalance causes hypermetabolism and metabolic acidosis
- Hypermetabolism stimulates ventilation
- Metabolic acidosis is balanced by respiratory alkalosis
- The patient is sedated and paralyzed, stops ventilating
- Acidosis worsens, pH goes down
- Salicylate rapidly moves into the brain and heart
- Patient dies

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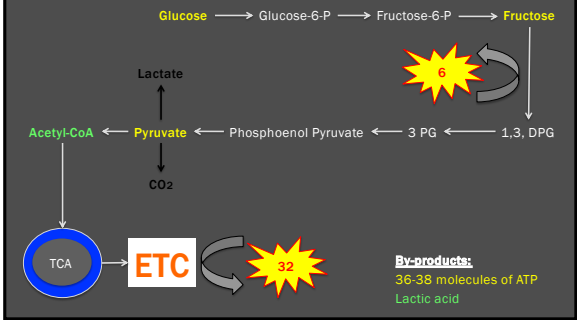
Aerobic Metabolism



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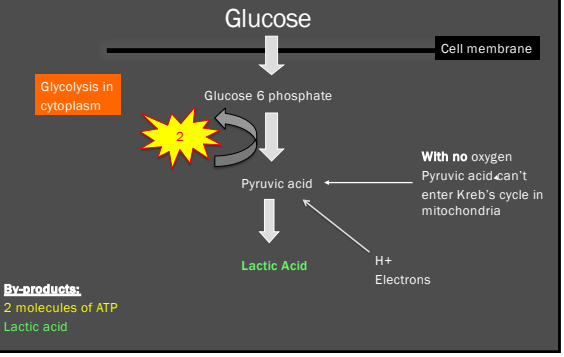
Anaerobic Metabolism



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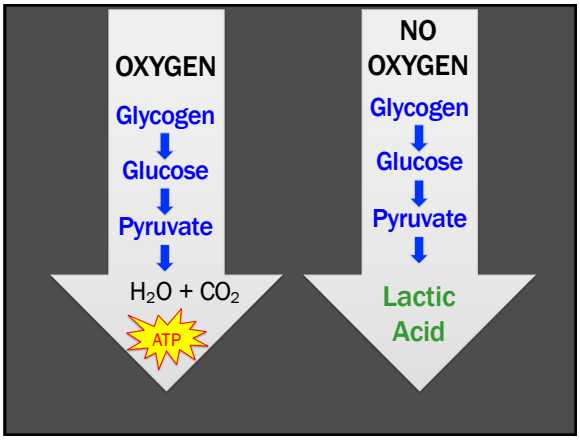

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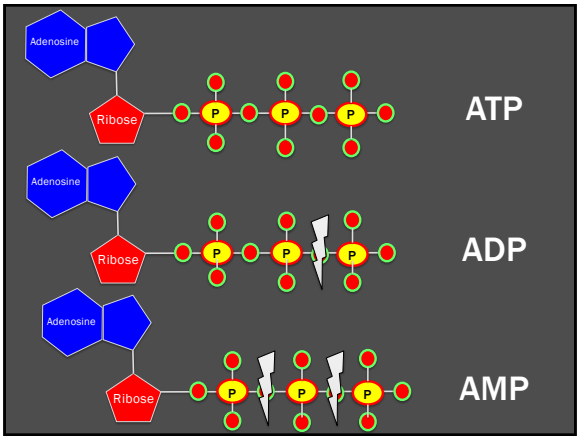

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Lactic Acid

- Buildup of lactic acid
  - Inhibits glycolysis
  - ATP production declines
- Lactic acid diffuses into the blood
- If oxygen levels are returned to normal
  - Liver converts lactic acid back into pyruvic acid
  - Pyruvic acid enters the aerobic metabolism pathway
- If oxygen levels remain low
  - Lactic acid levels continue to increase

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Primary Effects of Acid

- Inactivate enzyme systems
- Disrupt cell membrane integrity
- Loss of electrical or contractile function

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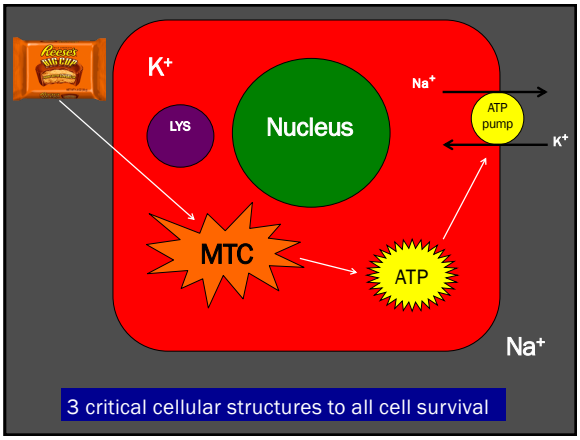

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CELL DIES

MTC swells – No ATP for the pump – Nucleus swells

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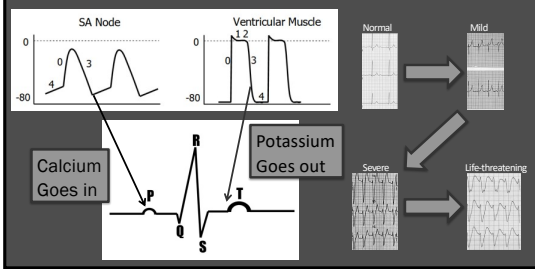
Cardiac Arrhythmia's

- Ventricular dysrhythmias
- Asystole



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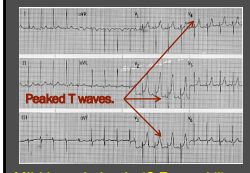
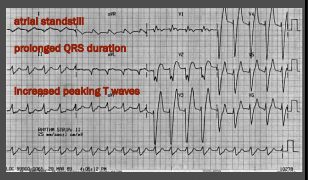
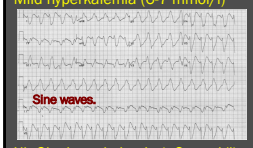
Cardiac Arrhythmia's – ECG changes



Mild hyperkalemia (6-7 mmol/l)



Severe hyperkalemia (8 – 9 mmol/l)



Uh Oh - hyperkalemia (>9mmol/l)

Treat the Hyper-K^+ and Resuscitate per ACLS if pulseless

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Acid Base Balances

Buffering Component - Instant

Carbonic acid is converted to CO_2 + H_2O in lungs by carbonic anhydrase

Bicarbonate — Carbonic acid (A weaker acid) — Carbon Dioxide

$H^+ + HCO_3 \longleftrightarrow H_2CO_3 \longleftrightarrow H_2O + CO_2$

Hydrogen ions — Water (remains relatively constant)

Respiratory Component - Quick; minutes.

☐☐ Respirations = ☐ ☐☐CO_2 ☐☐H^+ ☐ ☐☐pH

☐☐ Respirations = ☐ CO_2 ☐☐H^+ ☐☐pH

Renal (metabolic) component – slow; days.

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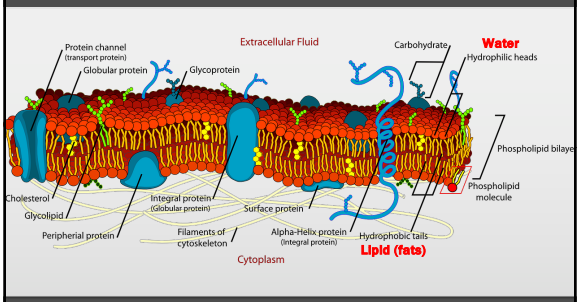
All cells look like this



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Solubility properties

- Fat (lipid) soluble
  - Basic pH (NH_3+ to NH_2)
  - Can cross membranes
  - Uncharged (neutral)
  - Non-polar
  - Lipophilic
  - Processed by liver
  - Nuclear or cytoplasmic receptors
  - Requires carrier protein
  - Long half-life
  - High volume of distribution
  - Small molecule

- Water soluble
  - Acidic pH (COOH to COO^-)
  - Does not cross membranes
  - Charged
  - Polar
  - Hydrophilic
  - Processed by kidneys
  - Cell surface receptors
  - Has no carrier protein
  - Short half-life
  - Low volume of distribution
  - Large molecule

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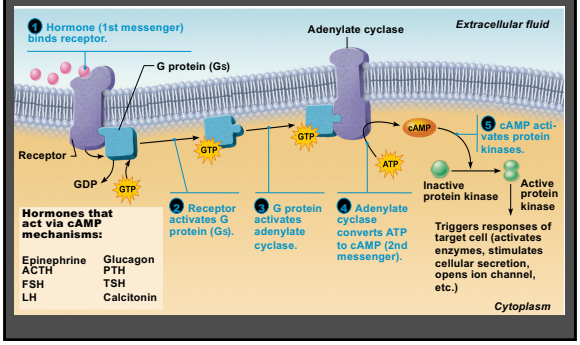
Water soluble drugs



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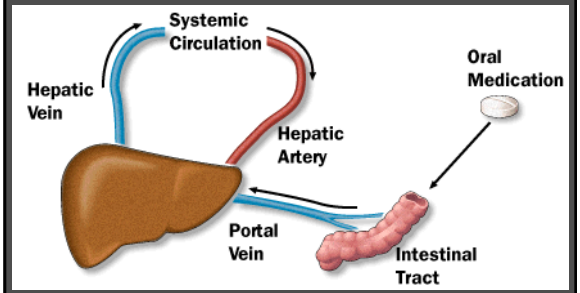
Fat soluble drugs



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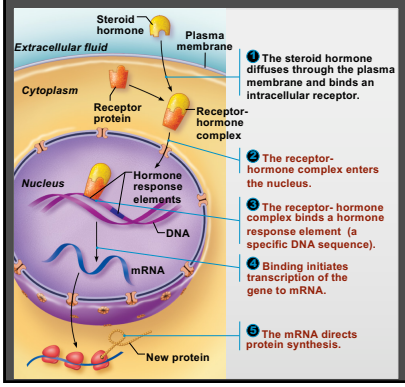
Fat soluble drugs



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Cardiac

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The Education Standards

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	EMR	EMT	AEMT	Paramedic
Cardiovascular	Simple depth, simple breadth Anatomy, signs, symptoms and management • Chest pain • Cardiac arrest	**EMR Material PLUS:** Anatomy, physiology, pathophysiology, assessment, and management of Fundamental depth, foundational breadth • Acute coronary syndrome ○ Angina pectoris ○ Myocardial infarction • Aortic aneurysm/dissection • Thromboembolism Simple depth, simple breadth • Heart failure • Hypertensive emergencies	**EMT Material PLUS:** Anatomy, physiology, pathophysiology, assessment, and management of Complex depth, foundational breadth • Acute coronary syndrome ○ Angina pectoris ○ Myocardial infarction Fundamental depth, simple breadth • Heart failure • Hypertensive emergencies	**AEMT Material PLUS:** Anatomy, physiology, epidemiology, pathophysiology, psychosocial impact, presentations, prognosis, and management of Complex depth, comprehensive breadth • Acute coronary syndrome ○ Angina pectoris ○ Myocardial infarction • Heart failure • Non-traumatic cardiac tamponade • Hypertensive emergencies • Cardiogenic shock • Vascular disorders ○ Abdominal aortic aneurysm ○ Arterial occlusion ○ Venous thrombosis • Aortic aneurysm/dissection, • Thromboembolism • Cardiac rhythm disturbances Fundamental depth, foundational breadth • Infectious diseases of the heart ○ Endocarditis ○ Pericarditis • Congenital abnormalities

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Effective Pathophysiology Education is all about **FINDING THE PATTERN** and helping your students to see it!

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Paramedic
AEMT Material PLUS: Anatomy, physiology, epidemiology, pathophysiology, psychosocial impact, presentations, prognosis, and management of Complex depth, comprehensive breadth • Acute coronary syndrome ○ Angina pectoris ○ Myocardial infarction • Heart failure • Non-traumatic cardiac tamponade • Hypertensive emergencies • Cardiogenic shock • Vascular disorders ○ Abdominal aortic aneurysm ○ Arterial occlusion ○ Venous thrombosis • Aortic aneurysm/dissection, • Thromboembolism • Cardiac rhythm disturbances Fundamental depth, foundational breadth • Infectious diseases of the heart ○ Endocarditis ○ Pericarditis • Congenital abnormalities

Cardiovascular Objectives

1. We are not making cardiologists
2. We need to teach them solid foundations:
   - Physiology
   - Pathology
   - Integrate Physiology into Assessment and management
3. Encourage decision making and reinforce creative thinking

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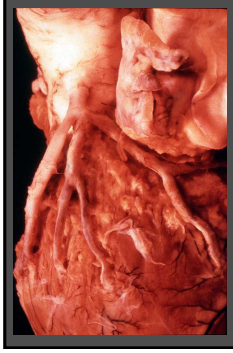
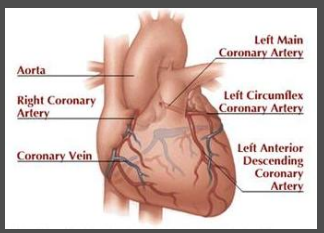
Cardiac Anatomy





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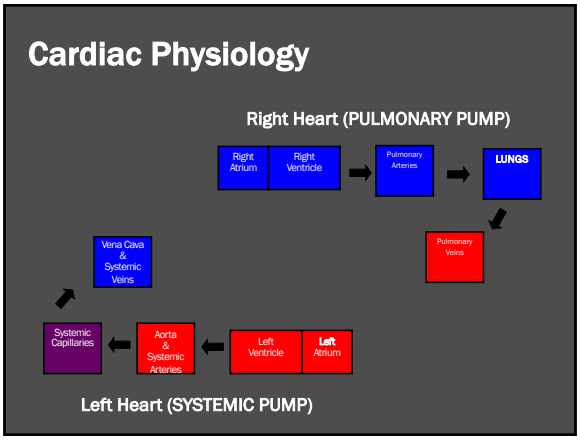

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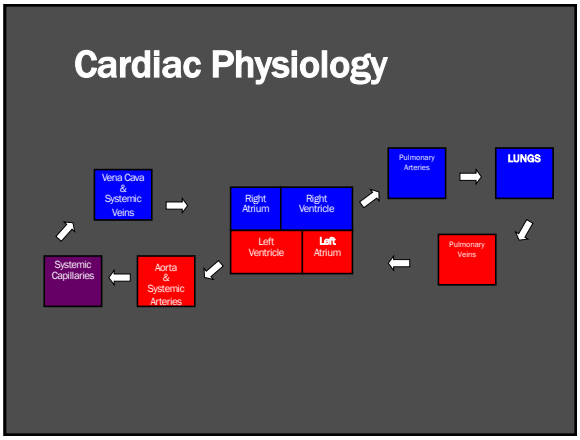

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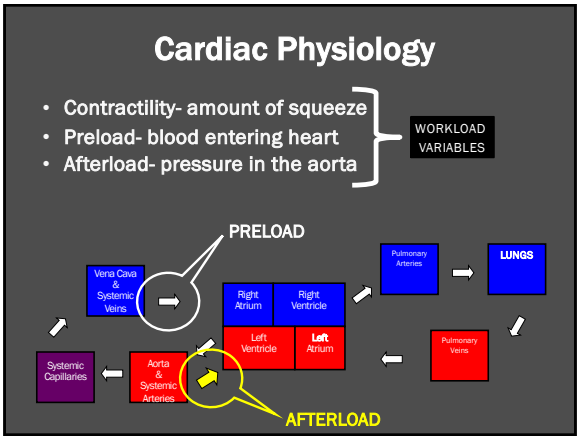

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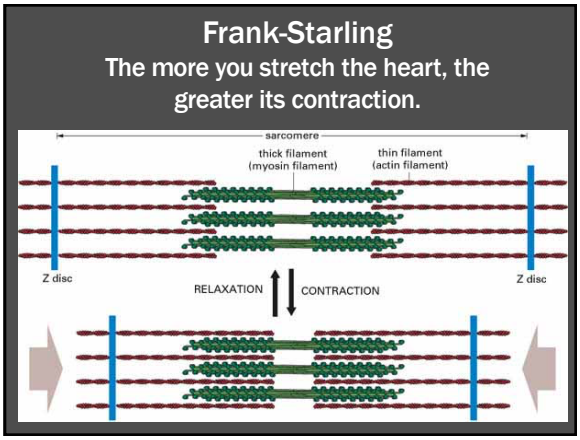

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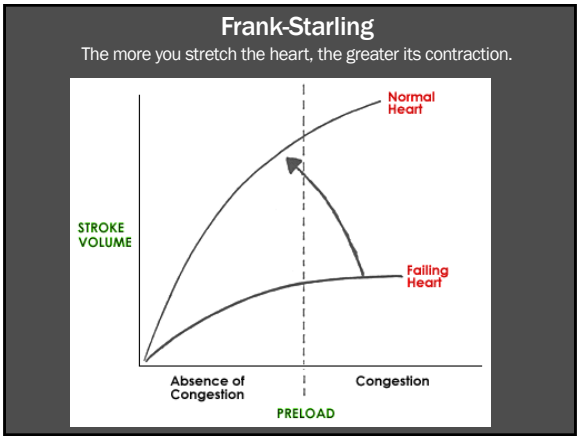

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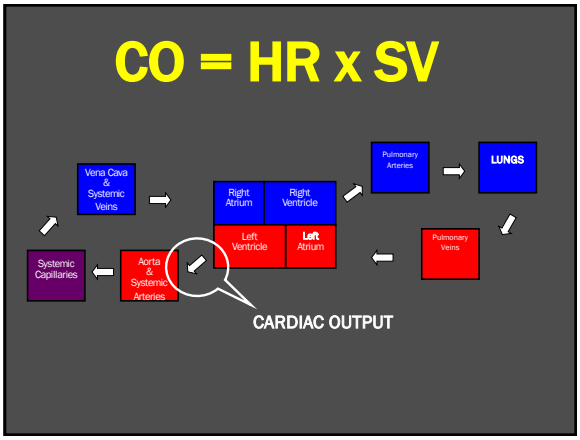

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BP = CO x SVR

Systolic Pressure
- Measure of LV function
- Close measure of CO
- Equal to resistance

SBP

Diastolic Pressure
- Measure of SVR
- Equal to volume

DBP

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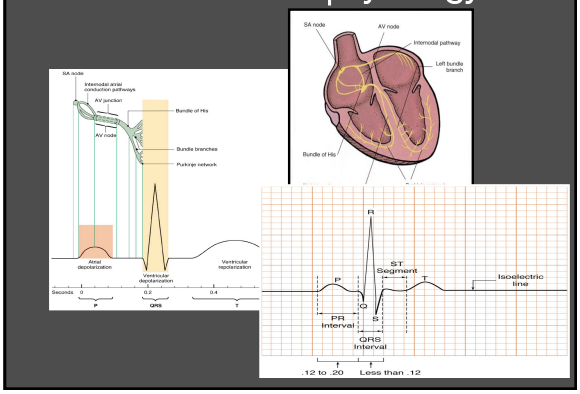
Cardiac Electrophysiology



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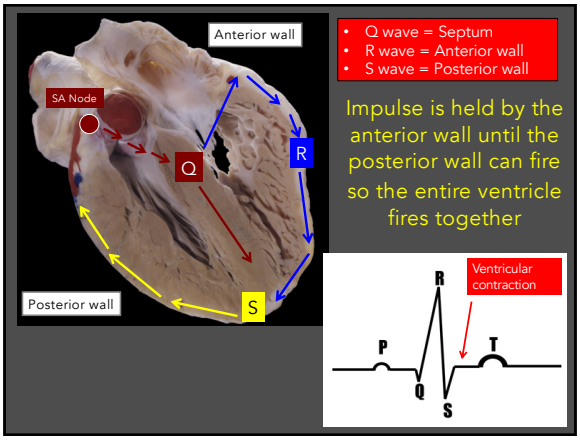

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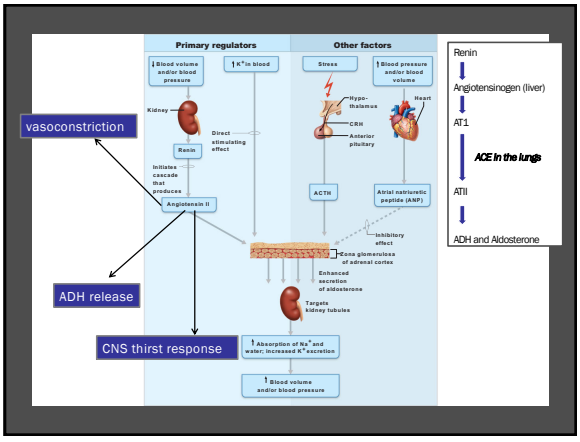

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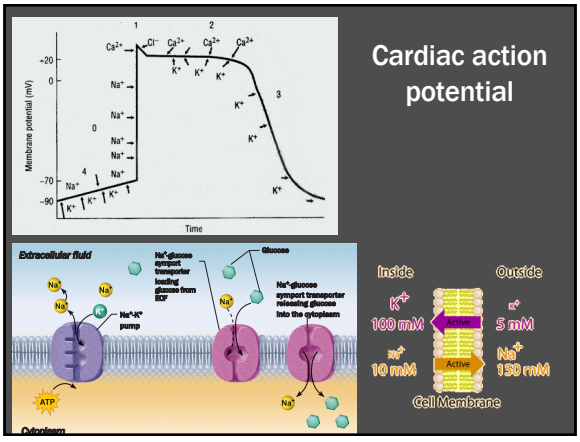

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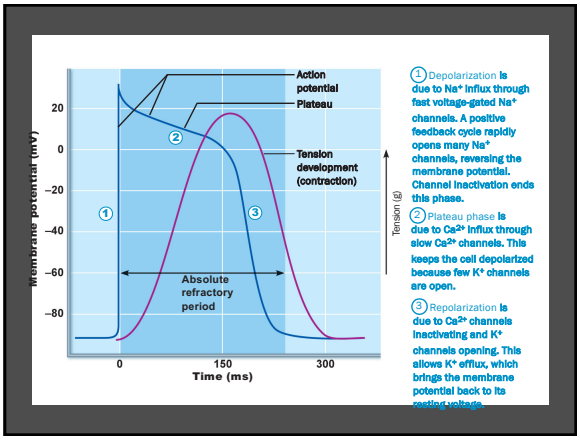

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Heart Physiology: Electrical Events

- Intrinsic cardiac conduction system
  - A network of noncontractile (autorhythmic) cells that initiate and distribute impulses to coordinate the depolarization and contraction of the heart

AUTOMATICITY

Na^+ promotes automaticity

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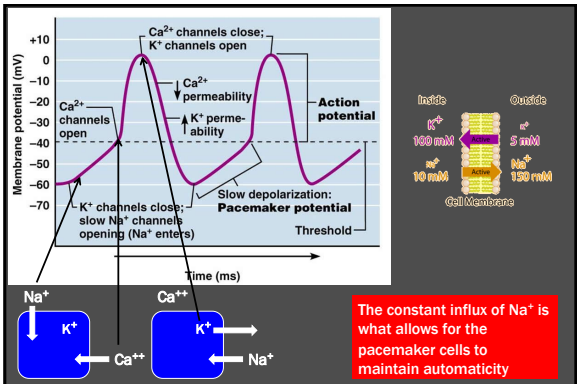

The constant influx of Na^+ is what allows for the pacemaker cells to maintain automaticity

Pacemaker action potential

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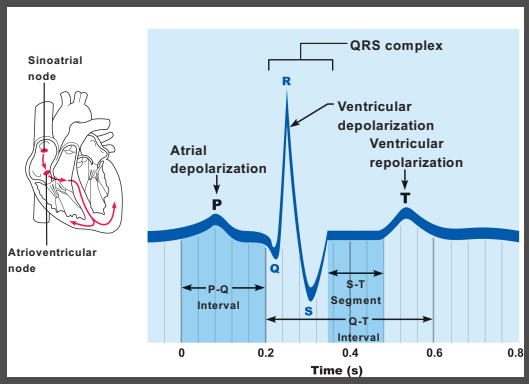

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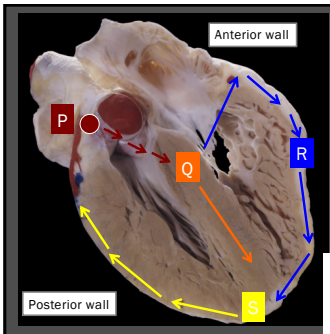
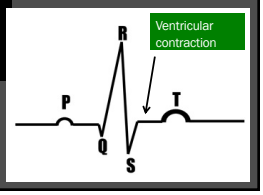


- Q wave = Septum
- R wave = Anterior wall
- S wave = Posterior wall

Impulse is held by the anterior wall until the posterior wall can fire so the entire ventricle fires together



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Acute Coronary Syndrome

Acute MI
Angina Pectoris

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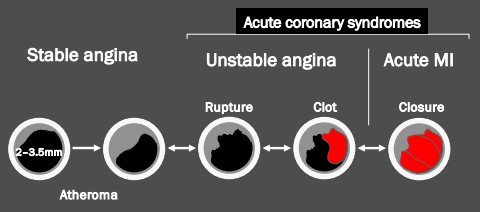
Pathophysiology



Fuster V, et al. N Engl J Med. 1992; 326:242-250, 310-318; Yeghiazarians Y, et al. N Engl J Med. 2000; 342:101-114.

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CASE

- 50 yo male
- Hx of HTN and dyslipidemia
- Current CC:
  - –30 minutes of excrutiating 11/10 CP, nausea, vomiting, diaphoresis, SICK GUY!

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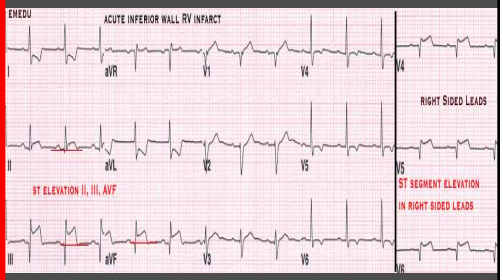
CASE



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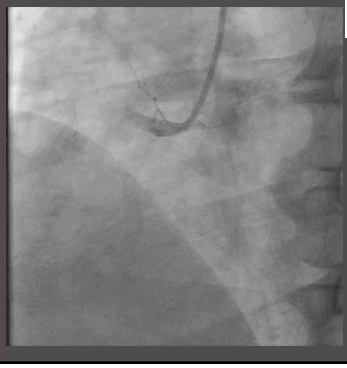
CASE

Squirting the RCA



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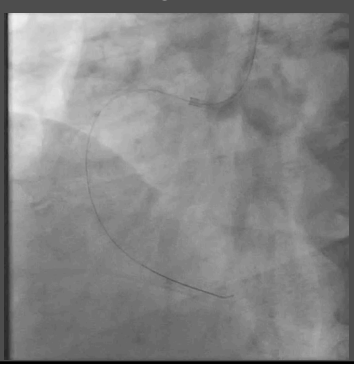
CASE

Post stenting of the RCA



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CASE

5 min post stenting, patient is completely pain free and ready to go home…

CASE CLOSED

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The Basics of Heart Failure

- Systolic dysfunction
  - – Can't contract
- Diastolic dysfunction
  - – Can't relax

ONLY distinguishable by Echo
- SHF- Low EF and dilation
- DHF –Normal EF

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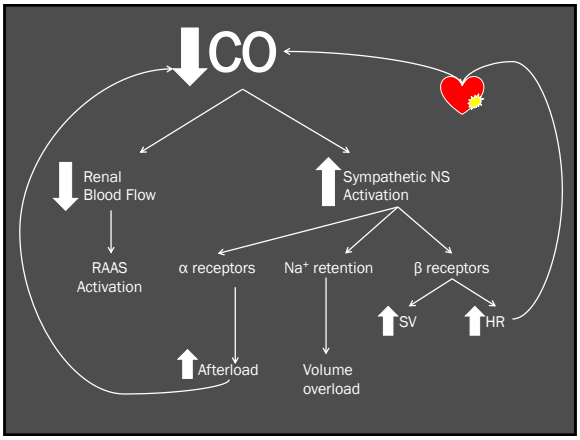

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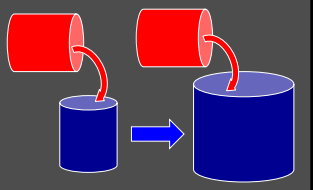
Systolic Dysfunction – Can't Contract

Infarction
Dilation
Regurgitation
CHF



After an infarct, no one becomes more efficient

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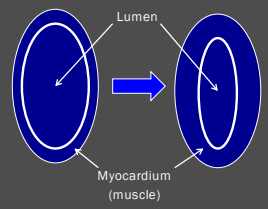
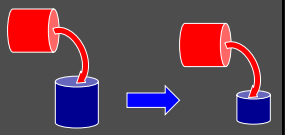
Diastolic Dysfunction – Can't Relax

HTN/Ischemia
Hypertrophy
Loss of capacity
CHF





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The Basics of CHF

- In CHF, all three components are not working:
  - Contractility- not squeezing
  - Preload- too much fluid
  - Afterload- too much pressure

All 3 of these parameters must be corrected to improve cardiac function

CO = HR x SV

BP = CO x SVR

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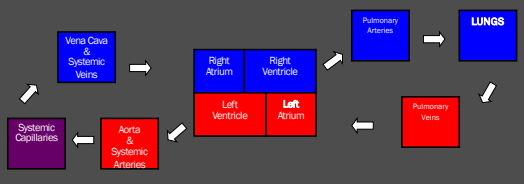
Clinical Signs of Heart Failure

- Right Sided Symptoms
  - Systemic edema
- Left Sided Symptoms
  - Pulmonary Edema

Left Heart Failure often leads to Right Heart Failure



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Renal

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The Education Standards

	EMR	EMT	AEMT	Paramedic
Pathophysiology	Uses simple knowledge of shock and respiratory compromise to respond to life threats.	Applies fundamental knowledge of the pathophysiology of respiration and perfusion to patient assessment and management.	Applies comprehensive knowledge of the pathophysiology of respiration and perfusion to patient assessment and management.	Integrates comprehensive knowledge of pathophysiology of major human systems.

	EMR	EMT	AEMT	Paramedic
Genitourinary/Renal	Simple depth, simple breadth • Blood pressure assessment in hemodialysis patients	**EMR Material PLUS:** Simple depth, simple breadth Anatomy, physiology, pathophysiology, assessment, and management of • Complications related to ○ Renal dialysis ○ Urinary catheter management (not insertion) • Kidney stones	**EMT Material PLUS:** Fundamental depth, simple breadth Anatomy, physiology, pathophysiology, assessment, and management of • Complications related to renal dialysis • Kidney stones	**AEMT Material Plus:** Anatomy, physiology, epidemiology, pathophysiology, psychosocial impact, presentations, prognosis, and management of Complex depth, comprehensive breadth • Complications of ○ Acute renal failure ○ Chronic renal failure ○ Dialysis • Renal calculi Fundamental depth, foundational breadth • Acid base disturbances • Fluid and electrolyte • Infection • Male genital tract conditions

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Kidney Functions

- Removal of toxins, metabolic wastes, and excess ions from the blood
- Regulation of blood volume, chemical composition, and pH
- Gluconeogenesis during prolonged fasting
- Endocrine functions
  - Renin: regulation of blood pressure and kidney function
  - Erythropoietin: regulation of RBC production
- Activation of vitamin D

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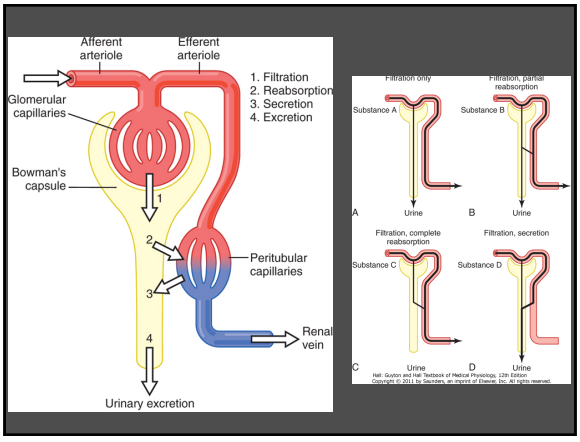

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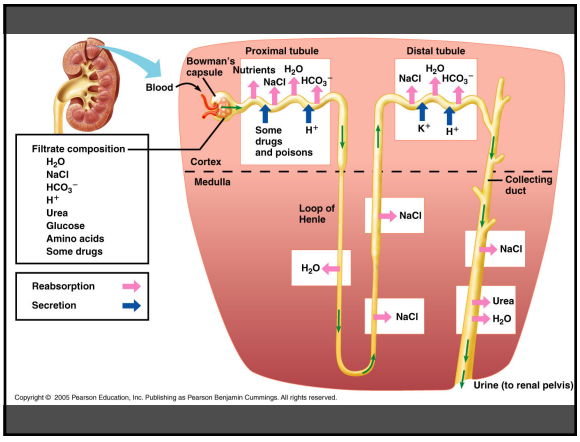

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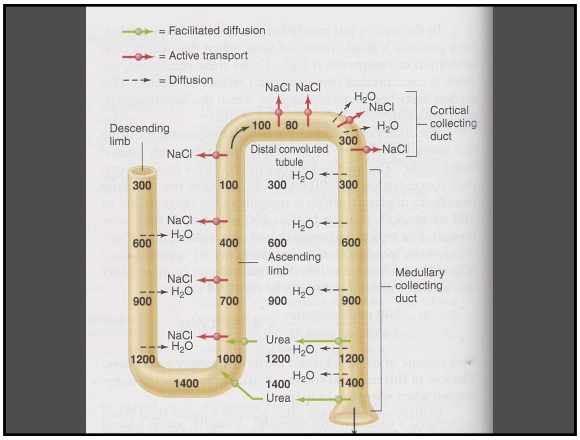

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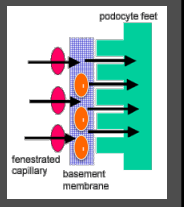
Glomerular Filtration

- Passive mechanical process driven by hydrostatic pressure
- Governed by (and directly proportional to)
  - Total surface area available for filtration
  - Filtration membrane permeability
  - Net filtration pressure
  - Particle size
  - Charge on the particle



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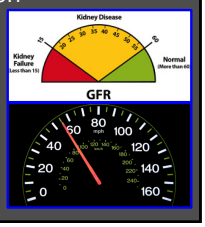
Glomerular Filtration

- Passive mechanical process driven by hydrostatic pressure – primarily
- Indirectly measured by creatinine and creatinine clearance calculation

Stage of Disease	Description	GFR* (mL/min per 1.73 m²)
1	Kidney damage with normal or increased GFR	≥90
2	Kidney damage with mildly decreased GFR	60–89
3	Moderately decreased GFR	30–59
4	Severely decreased GFR	15–29
5	Kidney failure	<15 (or undergoing dialysis)



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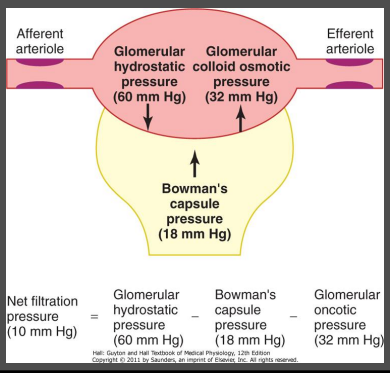
Glomerular Filtration



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Opposite forces affecting GFR

- Prostaglandin E_2
  - Vasodilator that counteracts vasoconstriction by norepinephrine and angiotensin II
  - Prevents renal damage when peripheral resistance is increased

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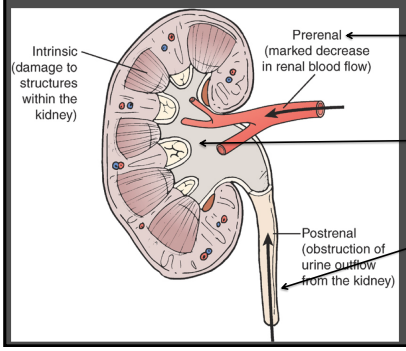
BUN:Creatinine ratio

(in the setting of renal failure / elevated creatinine)



- Pre-renal
  - >20:1
  - Heart failure
  - Shock
  - Blood loss
- Renal
  - <10:1
  - Infections
  - Toxins/Drugs
  - Direct trauma
- Post-renal
  - 10-20:1
  - Urinary tract obstructions

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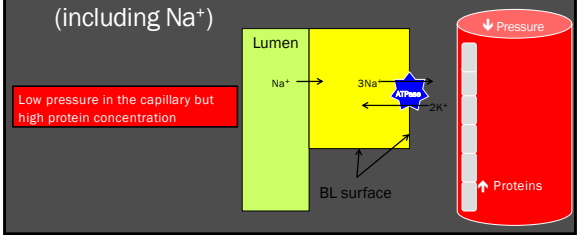
Sodium Reabsorption

- Low hydrostatic pressure (low pressure) and high osmotic pressure (lots of proteins) in the peritubular capillaries
- Promotes bulk flow of water and solutes (including Na^+)



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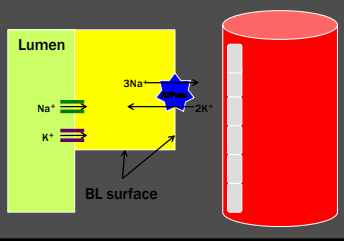
Reabsorptive Capabilities of Renal Tubules and Collecting Ducts

- Mechanism of **aldosterone**
  - Targets collecting ducts (principal cells) and distal DCT
  - **Promotes synthesis of luminal Na^+ and K^+ channels**
  - **Promotes synthesis of basolateral Na^+-K^+ ATPases**



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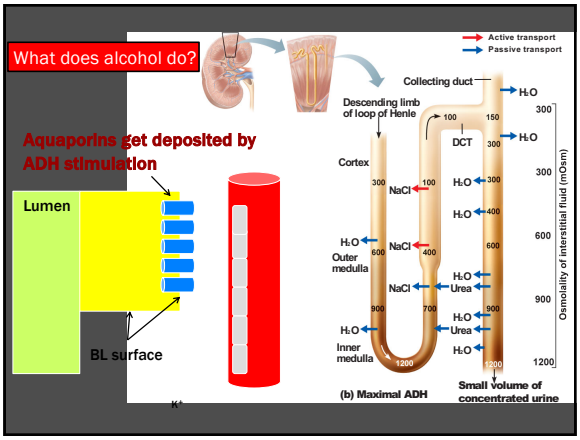
What does alcohol do?
Aquaporins get deposited by ADH stimulation
Lumen
BL surface
Active transport
Passive transport
Collecting duct
Descending limb of loop of Henle
DCT
Cortex
Outer medulla
Inner medulla
NaCl
Urea
H₂O
Osmolality of interstitial fluid (mOsm)
(b) Maximal ADH
Small volume of concentrated urine

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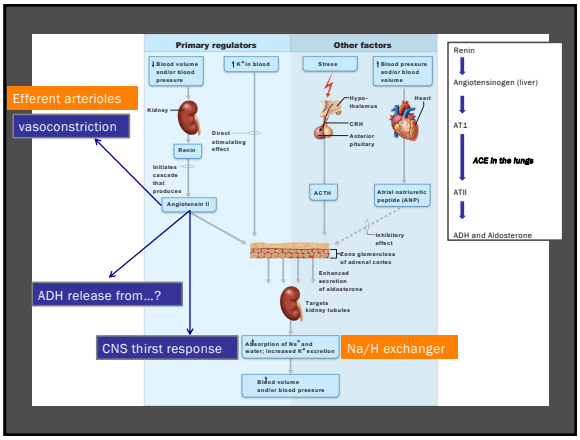
Efferent arterioles
vasoconstriction
ADH release from...?
CNS thirst response
Na/H exchanger
Primary regulators
Other factors
Renin
Angiotensinogen (liver)
AT1
ACE in the lungs
ATII
ADH and Aldosterone

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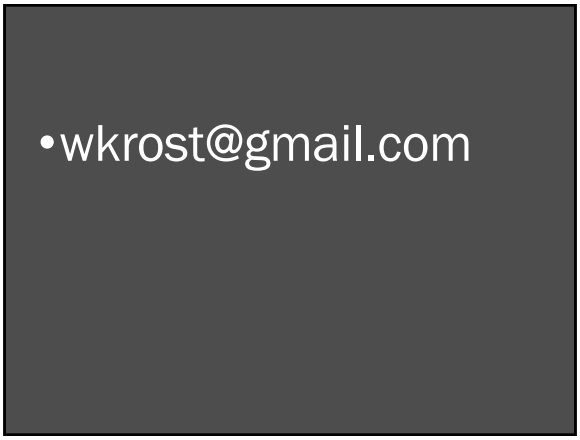
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