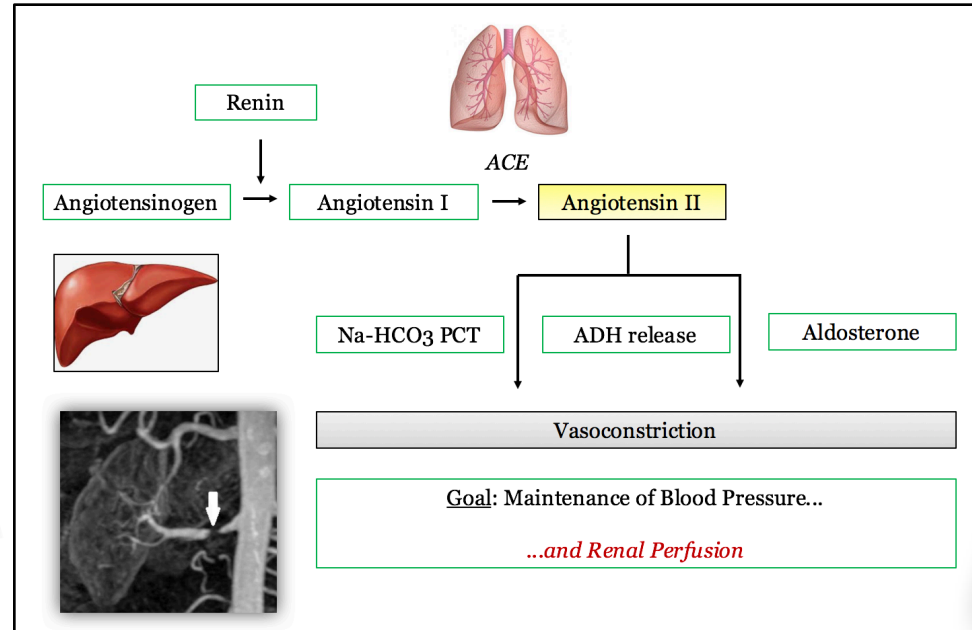


# Blood Pressure (Dys)Regulation for the USMLE Step One Exam



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University of Massachusetts Medical School  
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# Blood Pressure Regulation: *the Kidneys*

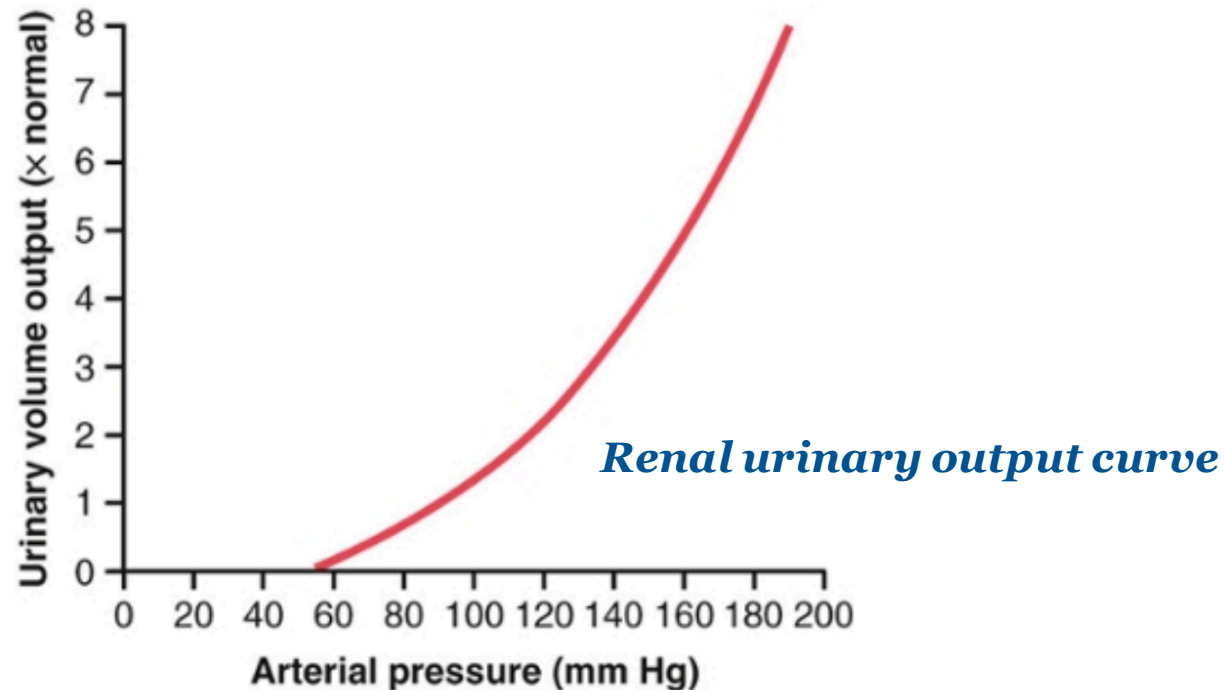
- Timing:
  - Minutes (**low BP**): ATII (vasoconstriction)
  - Hours (hi BP): Pressure natriuresis (sodium)/diuresis (water)
  - Days (**low BP**): Aldosterone

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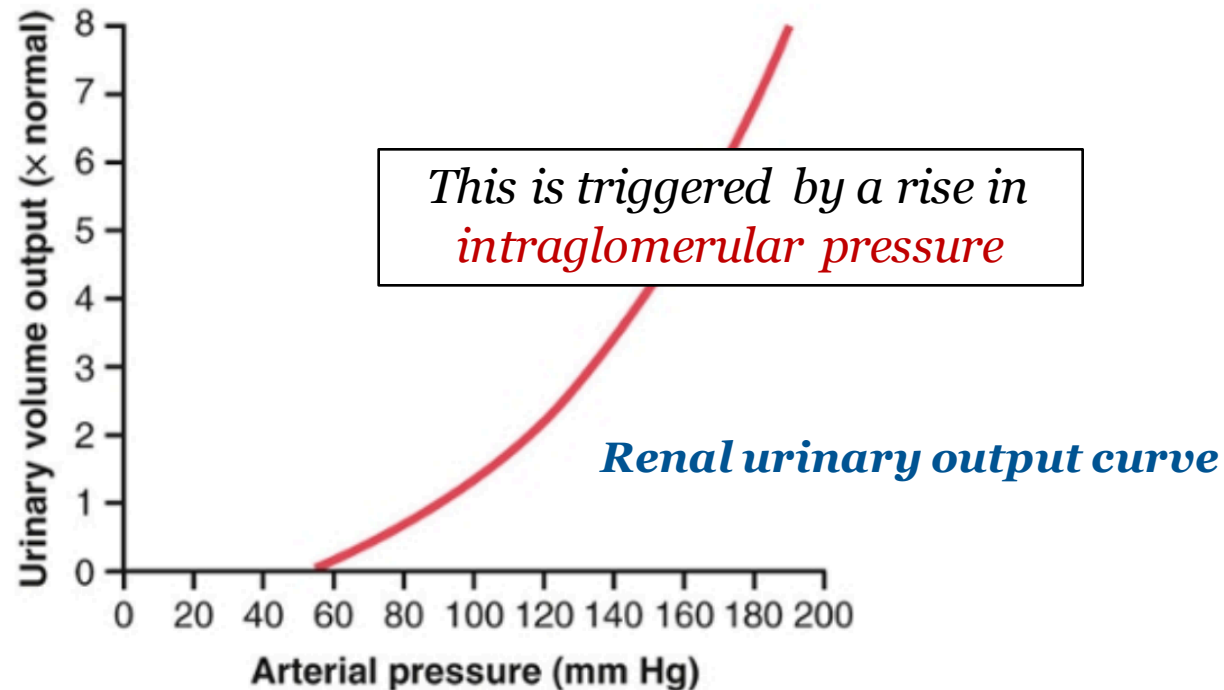
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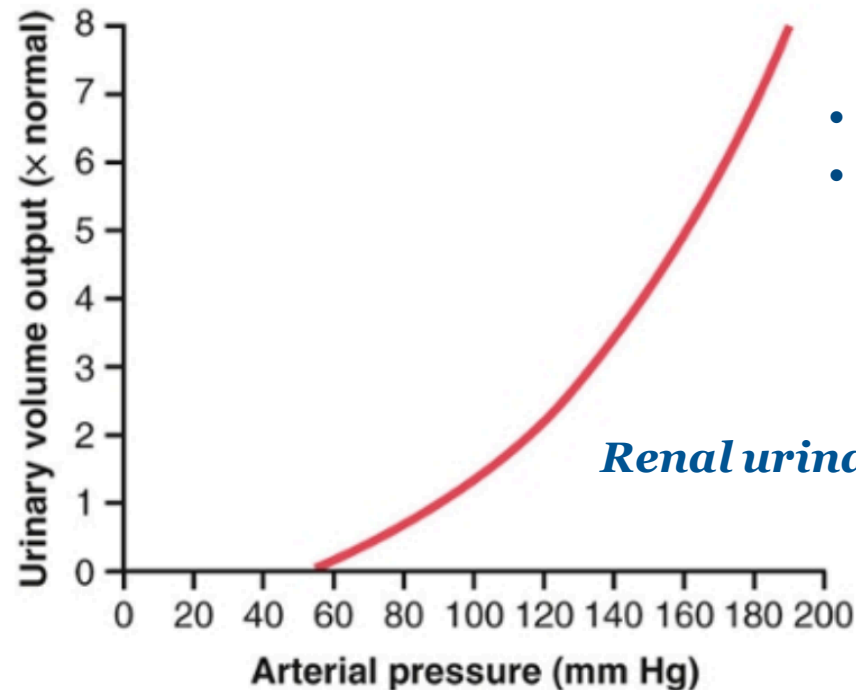
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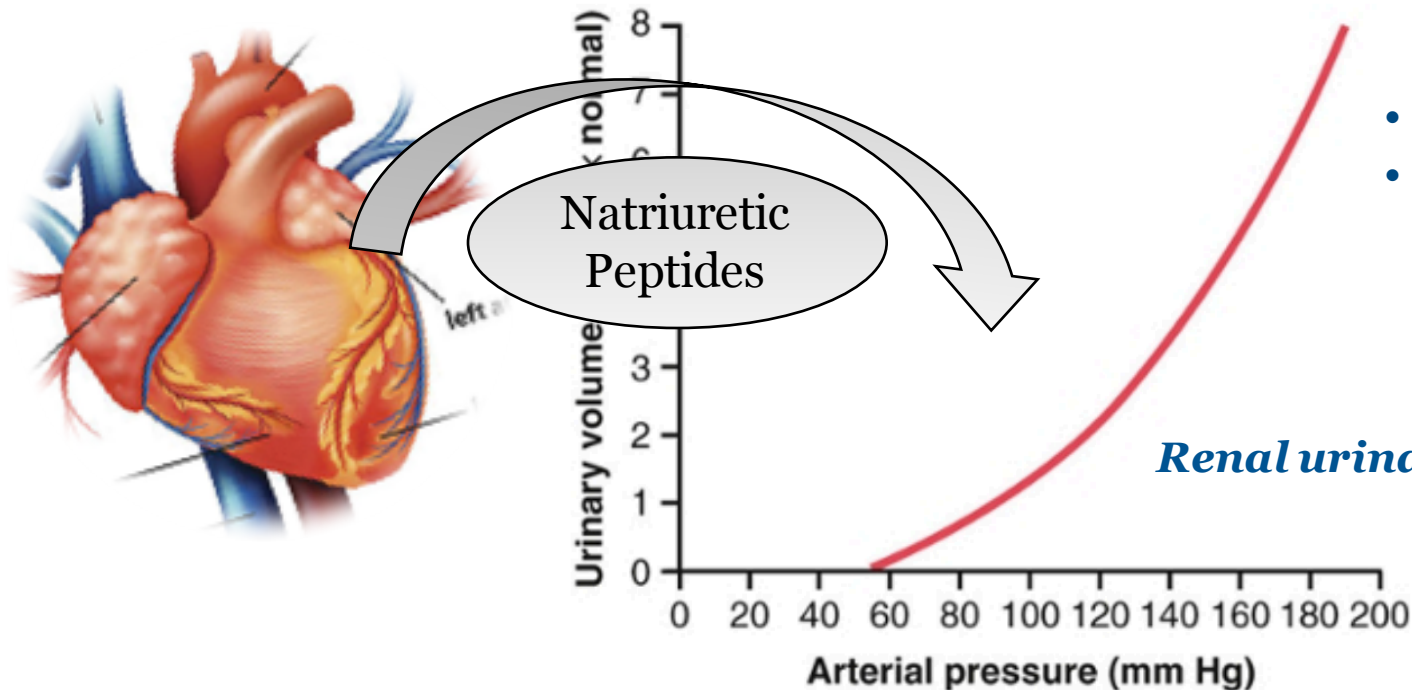


- *SIADH (euvolemia)*
- *Hyperaldosteronism (eunatremia)*

*Renal urinary output curve*

# Blood Pressure Regulation: the Kidneys

- Timing:
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  - Located at the *hilum* of the glomerulus

# Blood Pressure Regulation: the Kidneys



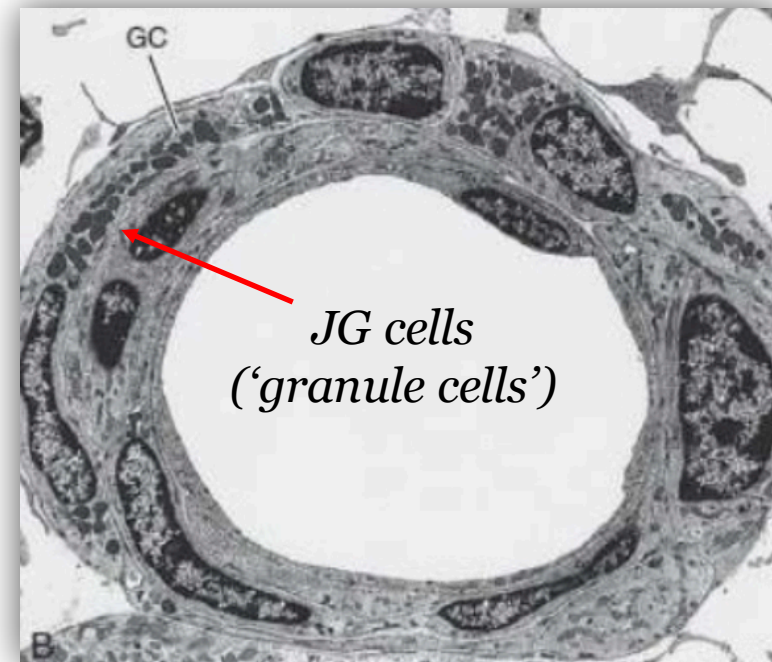
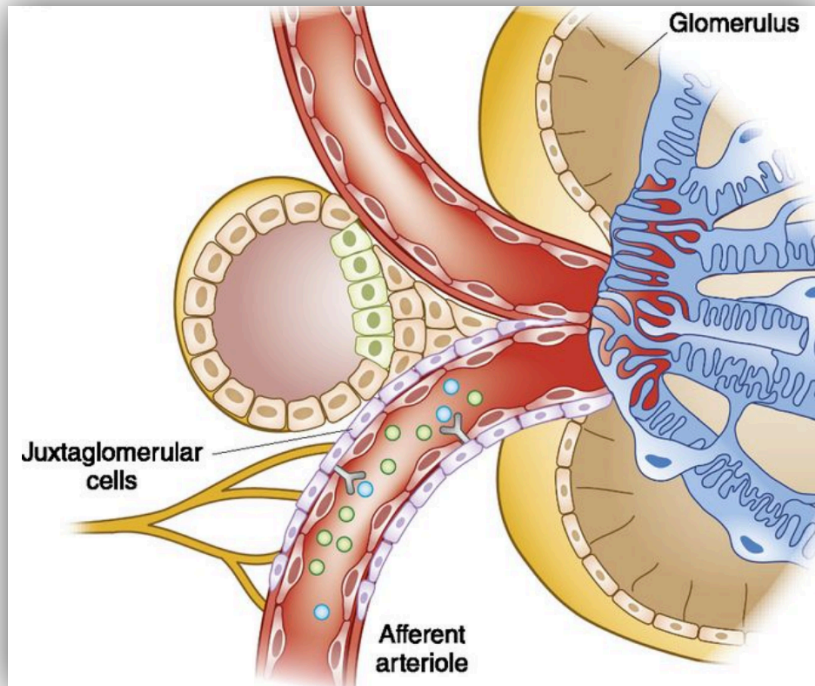
- Mechanism of Action: Juxtaglomerular apparatus (JGA)
  - Located at the hilum of the glomerulus

# Blood Pressure Regulation: the JGA

- Juxtaglomerular cells
- Macula densa
- Extraglomerular mesangial cells
  - *Forms a syncytium via actin and microtubules but exact role unclear*

# Blood Pressure Regulation: the JGA

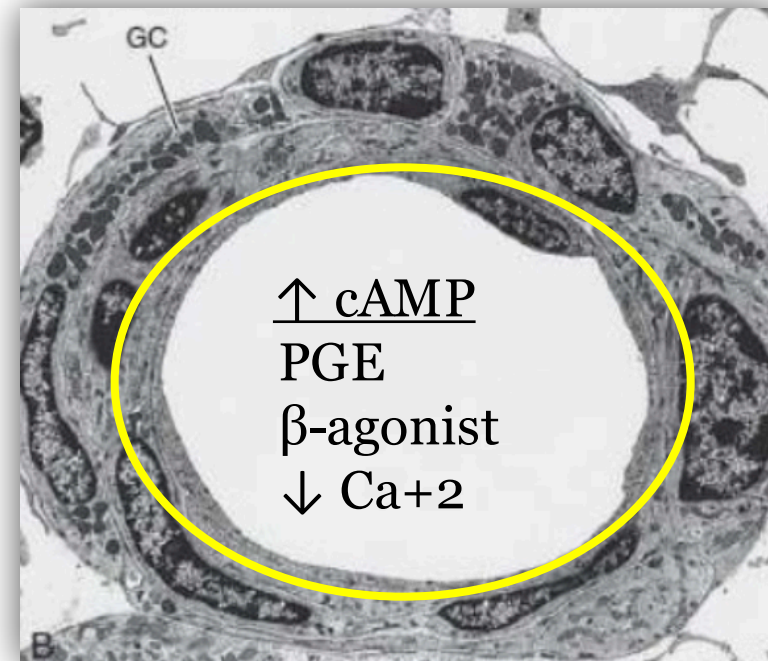
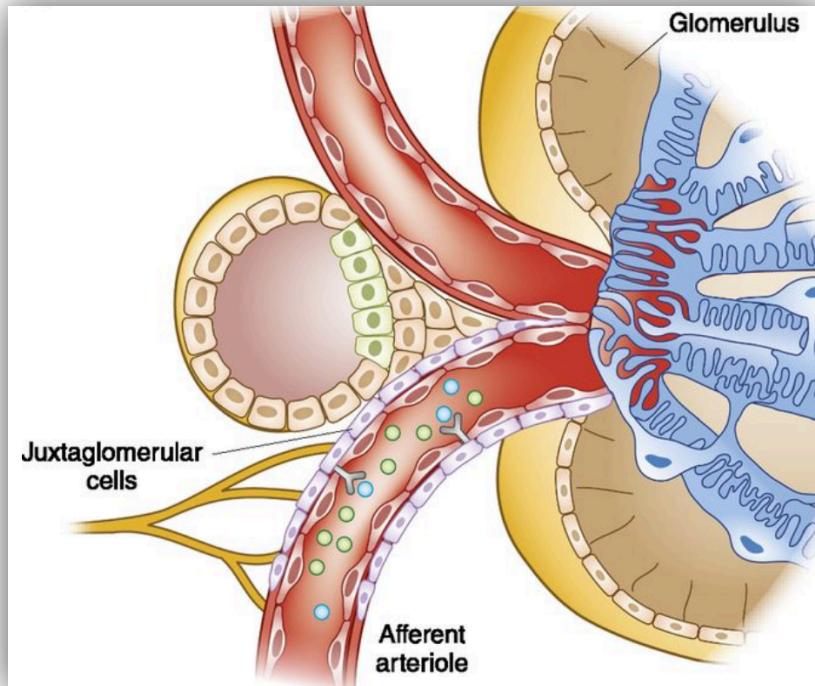
- Juxtaglomerular cells
  - Description: *Modified smooth mm cells* located in the walls of the terminal portion of the afferent arteriole
  - Function: Synthesize, store and secrete renin





# Blood Pressure Regulation: the JGA

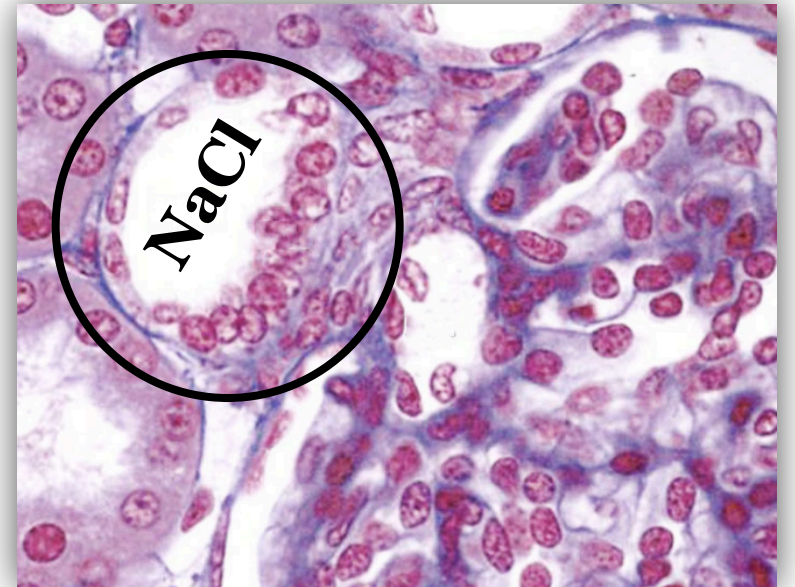
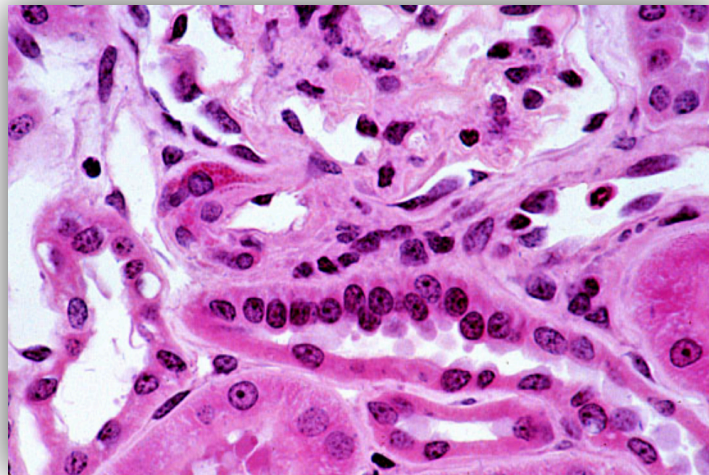
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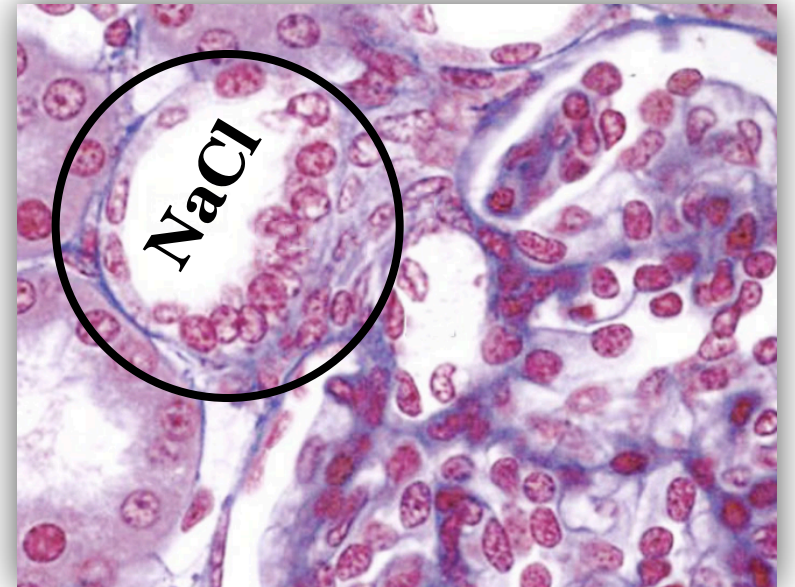
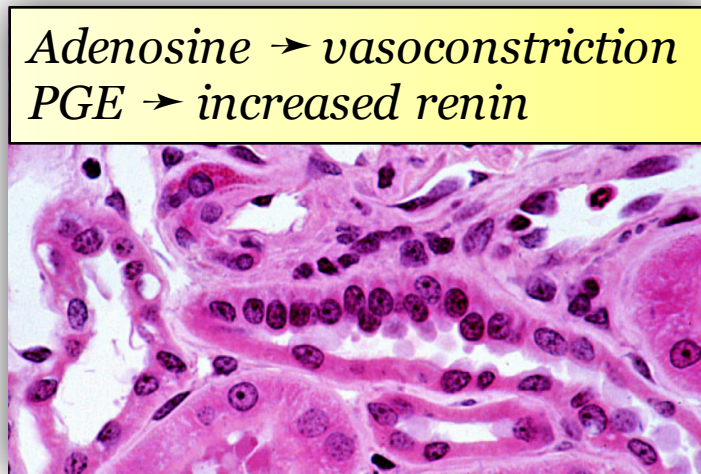
# Blood Pressure Regulation: the JGA

- Macula densa
  - Description: a collection of *modified epithelial cells* located in the DCT
  - Function: Detects [NaCl] in the tubule
    - Elevated *tubular* concentration → afferent arteriolar vasoconstriction (*tubuloglomerular feedback*)
    - Low *tubular* concentration → renin release



# Blood Pressure Regulation: the JGA

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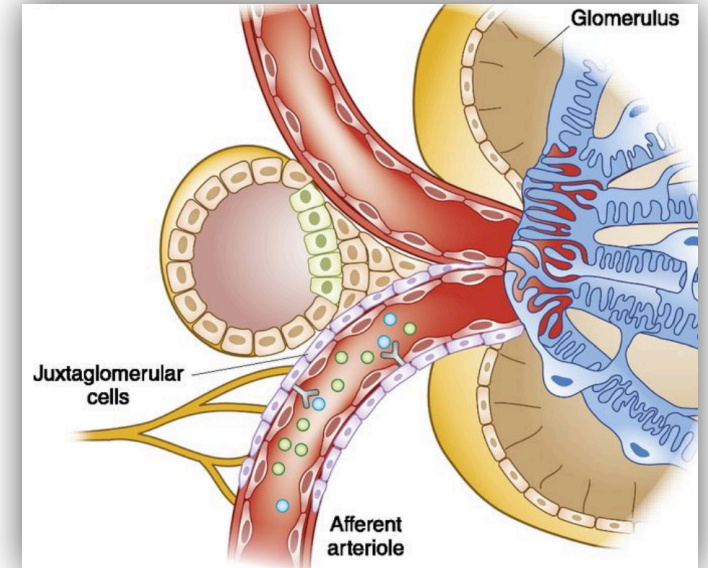


# Regulators of the the JGA: Renin Release

- Myogenic (baroreceptor, autoregulation) response
  - Stretch inhibits renin release
- Renal nerves/ $\beta$ -1 adrenoreceptors
  - Sympathetic nervous system efferent
- Macula densa
  - NaCl delivery
    - Decreased [NaCl] stimulates renin release
    - Increased [NaCl] inhibits release (afferent arteriole vasoconstriction)

# Regulators of the the JGA: Renin Release

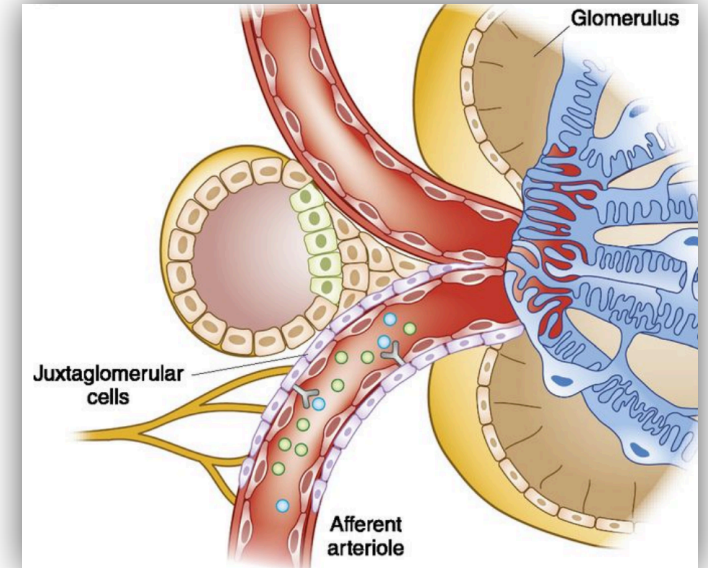
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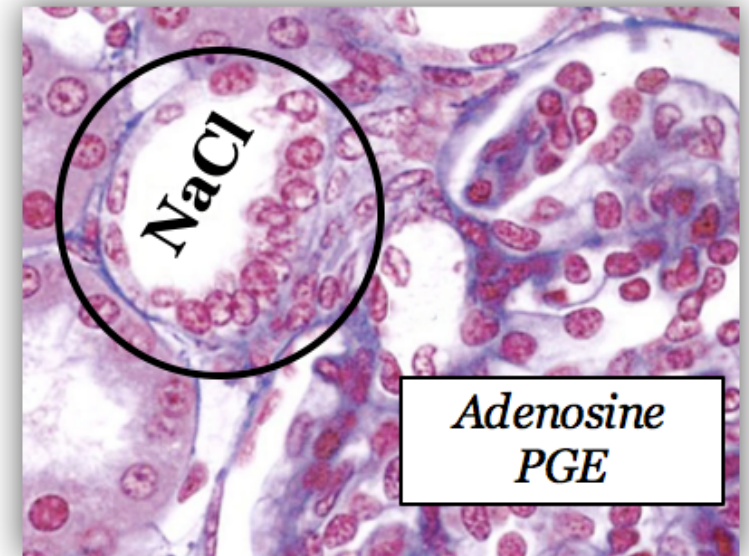
# Regulators of the the JGA: Renin Release

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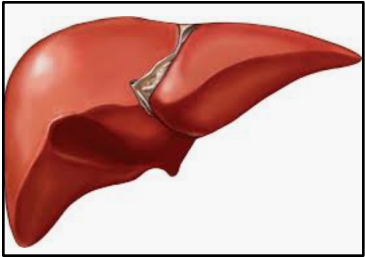
Renin

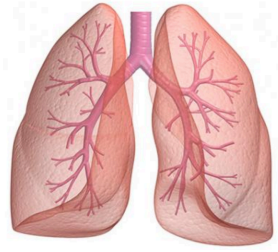


Angiotensinogen



Angiotensin I





Renin



*ACE*

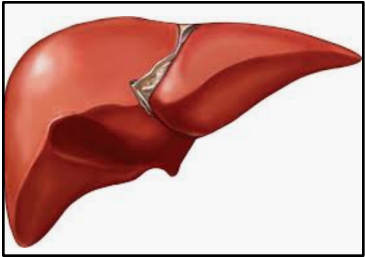
Angiotensinogen



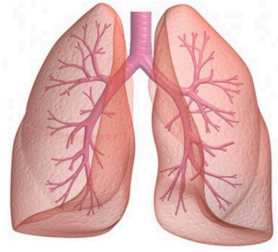
Angiotensin I



Angiotensin II







Renin



Angiotensinogen



Angiotensin I

*ACE*



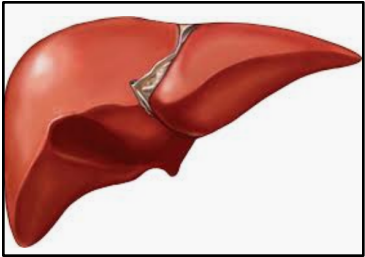
Angiotensin II

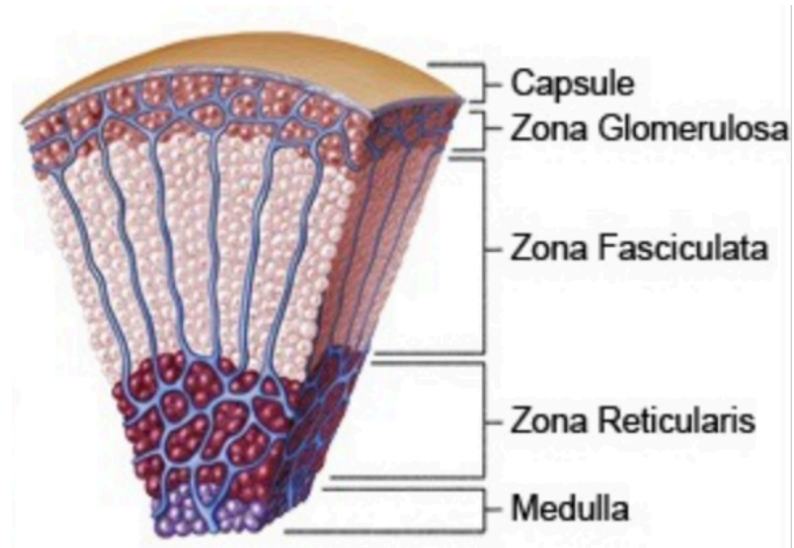
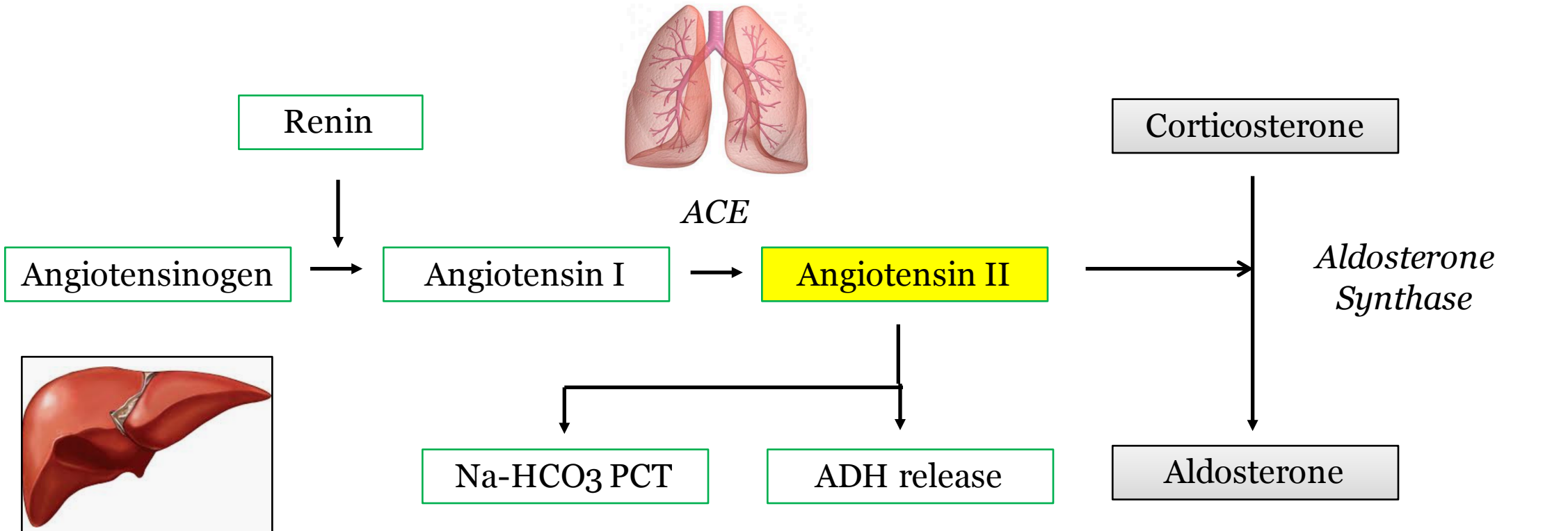


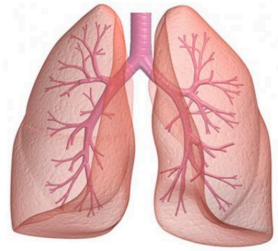
Na-HCO<sub>3</sub> PCT



ADH release







Renin

*ACE*

Angiotensinogen

Angiotensin I

Angiotensin II



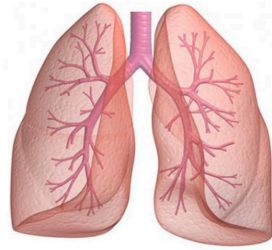
*Na-HCO<sub>3</sub> PCT*

*ADH release*

*Aldosterone*

Vasoconstriction

FAMILY FEUD	
1	Vasoconstriction
2	<i>Aldosterone</i>
3	<i>Na-H<sup>+</sup> ATPase</i>
4	<i>ADH</i>



Renin



Angiotensinogen

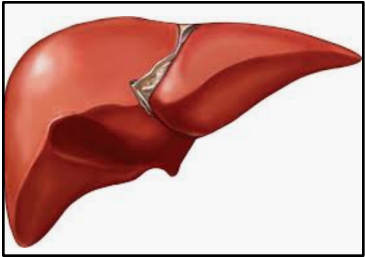


Angiotensin I

*ACE*



Angiotensin II



*Na-HCO<sub>3</sub> PCT*

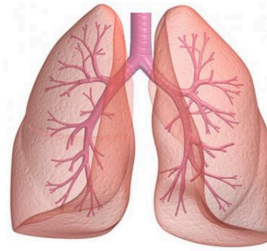
*ADH release*

*Aldosterone*



Vasoconstriction

Goal: Maintenance of Blood Pressure



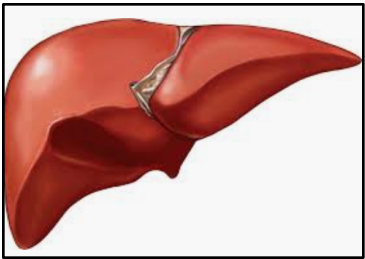
Renin

ACE

Angiotensinogen

Angiotensin I

Angiotensin II



*Na-HCO<sub>3</sub> PCT*

*ADH release*

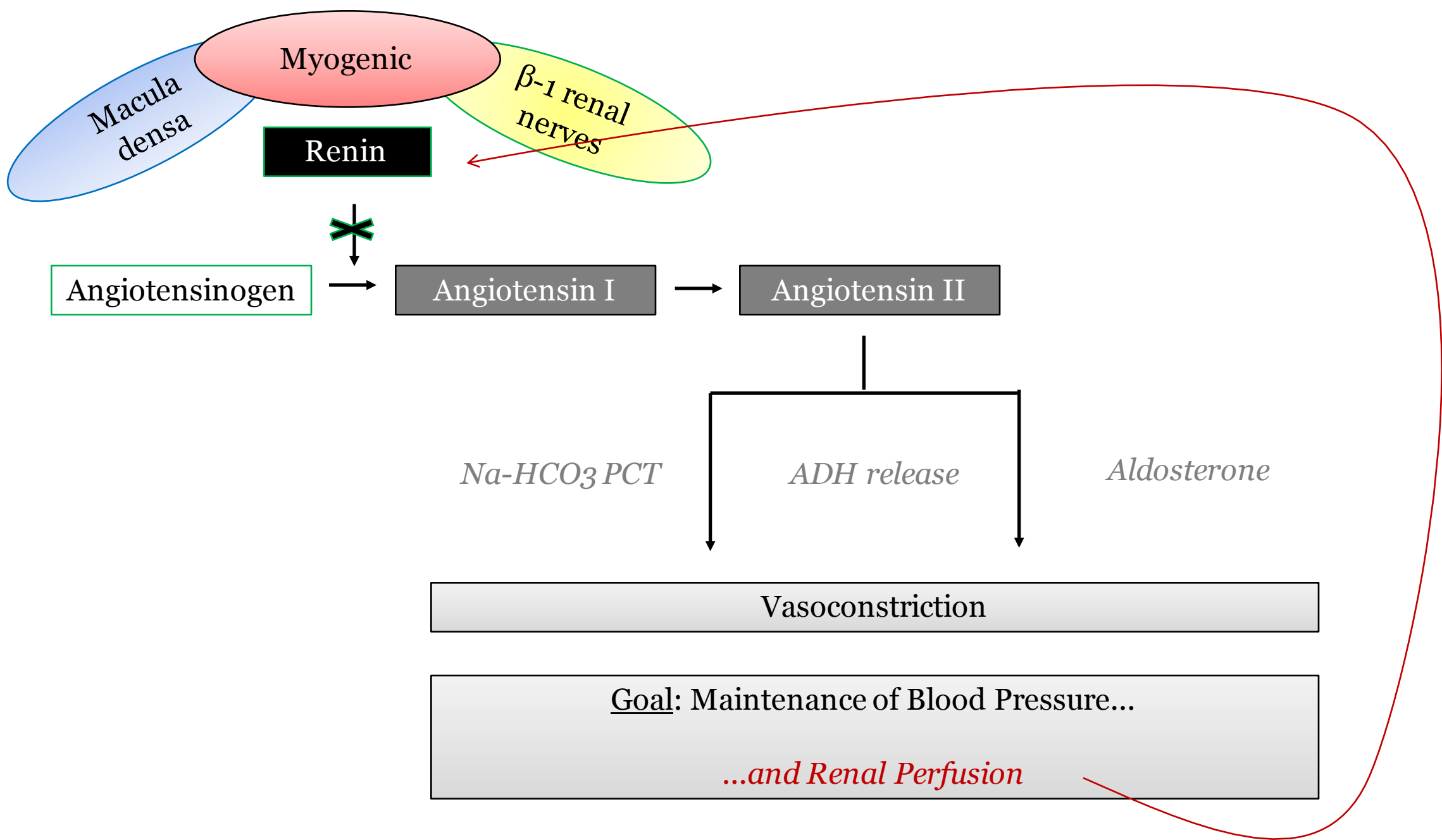
*Aldosterone*

Vasoconstriction

Goal: Maintenance of Blood Pressure...

*...and Renal Perfusion*





# Blood Pressure/HTN Series

- Blood Pressure Regulation
  - Autonomic nervous system
  - Juxtaglomerular apparatus
  - *Special Situations: BP Trivia (for USMLE)*
- Renovascular HTN
  - Physiologic response
  - Pathology
  - Demographics
- Endocrinopathies
  - Mineralocorticoids (i.e. aldosterone, cortisol)
  - Catecholamines



---

**Oh Behave!**

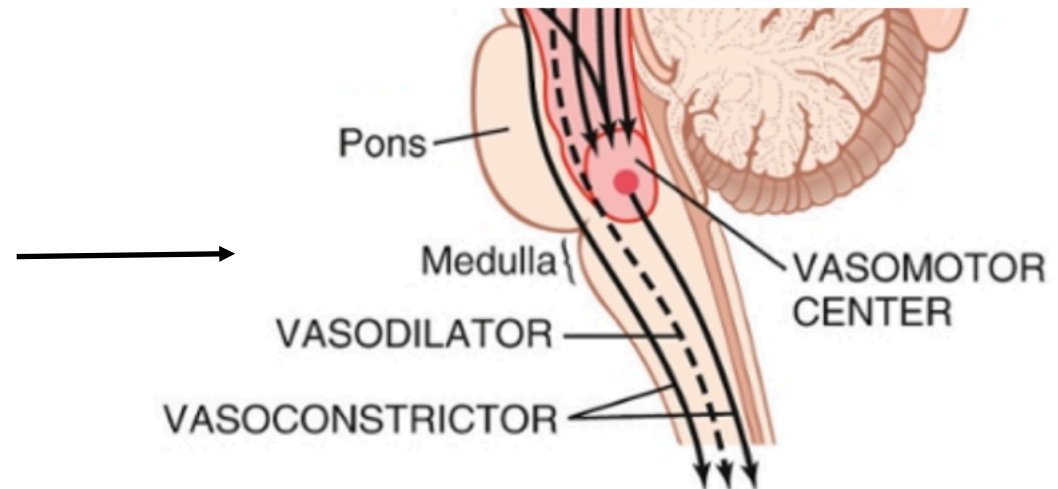
# Special Cases in BP Regulation

- Cerebral Ischemia
  - Central *vasomotor* center and vasoconstriction
- Aortic Coarctation
  - *Imbalance* between ANS and renal perfusion
- Aortic Compliance
  - Relationship between *volume* and *pressure*
- Exercise
  - The role of *local mediators*



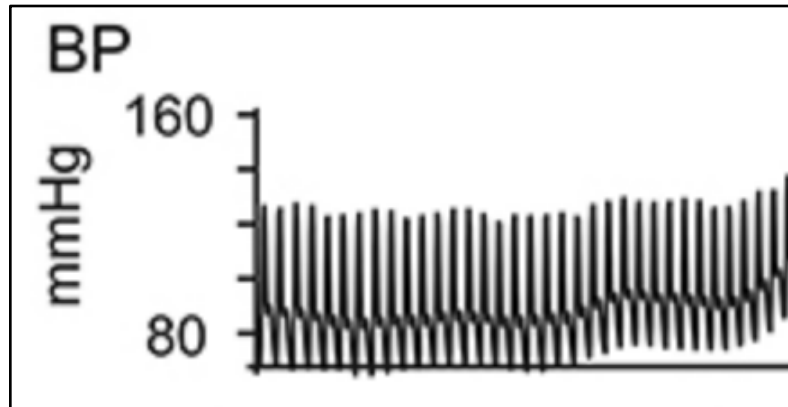
# Special Cases in BP Regulation

- Cerebral Ischemia
  - Hypoperfusion/injury to brain can directly trigger the *vasomotor* center to increase *sympathetic outflow* → may be very dramatic



# Special Cases in BP Regulation

- Aortic Coarctation: Why is the patient hypertensive?
  - ANS: *resets* at higher value after 1-2 days



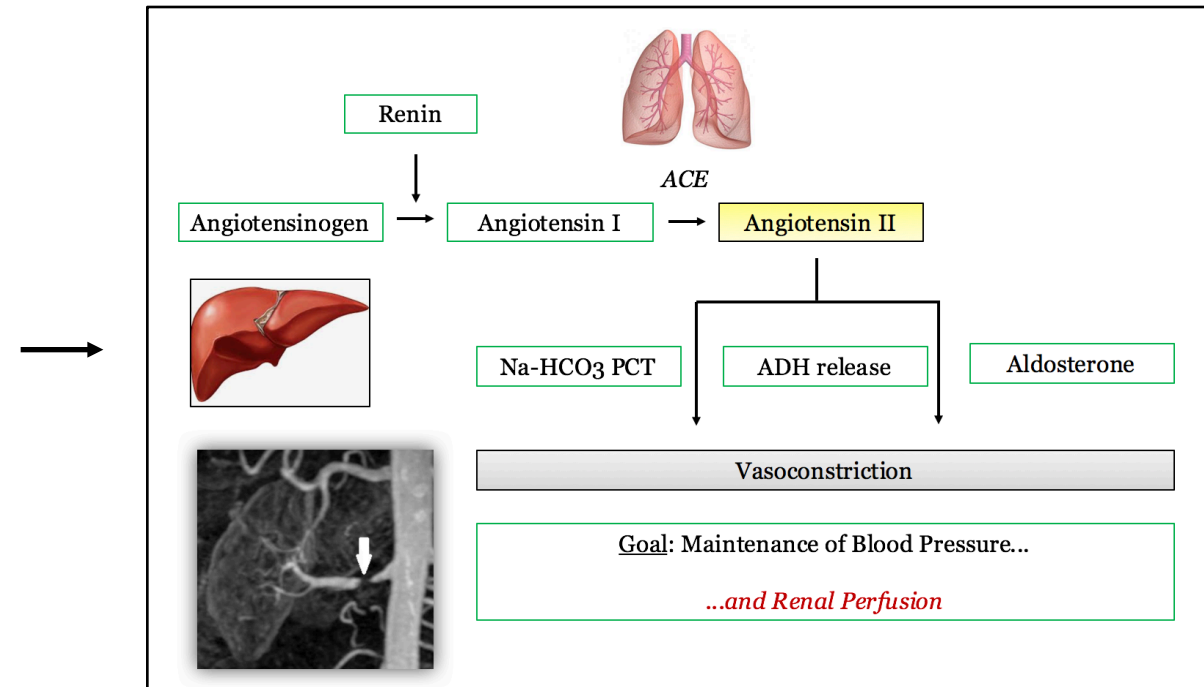
*Mayer waves*

# Special Cases in BP Regulation

- Aortic Coarctation: Why is the patient hypertensive?
  - ANS: *resets* at higher value after 1-2 days
  - **Activation of RAAS**: dissonance between systemic BP and renal perfusion

## Regulators of the the JGA: Renin Release

- **Myogenic** (baroreceptor, autoregulation) response
  - Stretch inhibits renin release
- Renal nerves/ $\beta$ -1 adrenoreceptors
  - Sympathetic nervous system efferent
- **Macula densa**
  - NaCl delivery
    - **Decreased [NaCl] stimulates renin release**
    - Increased [NaCl] inhibits release (afferent arteriole vasoconstriction)



# Special Cases in BP Regulation

- Aortic Compliance:

- If blood **volume** increases and *vascular capacitance is not altered*, arterial **pressure** will also rise ( $Compliance = \Delta V / \Delta P$ )

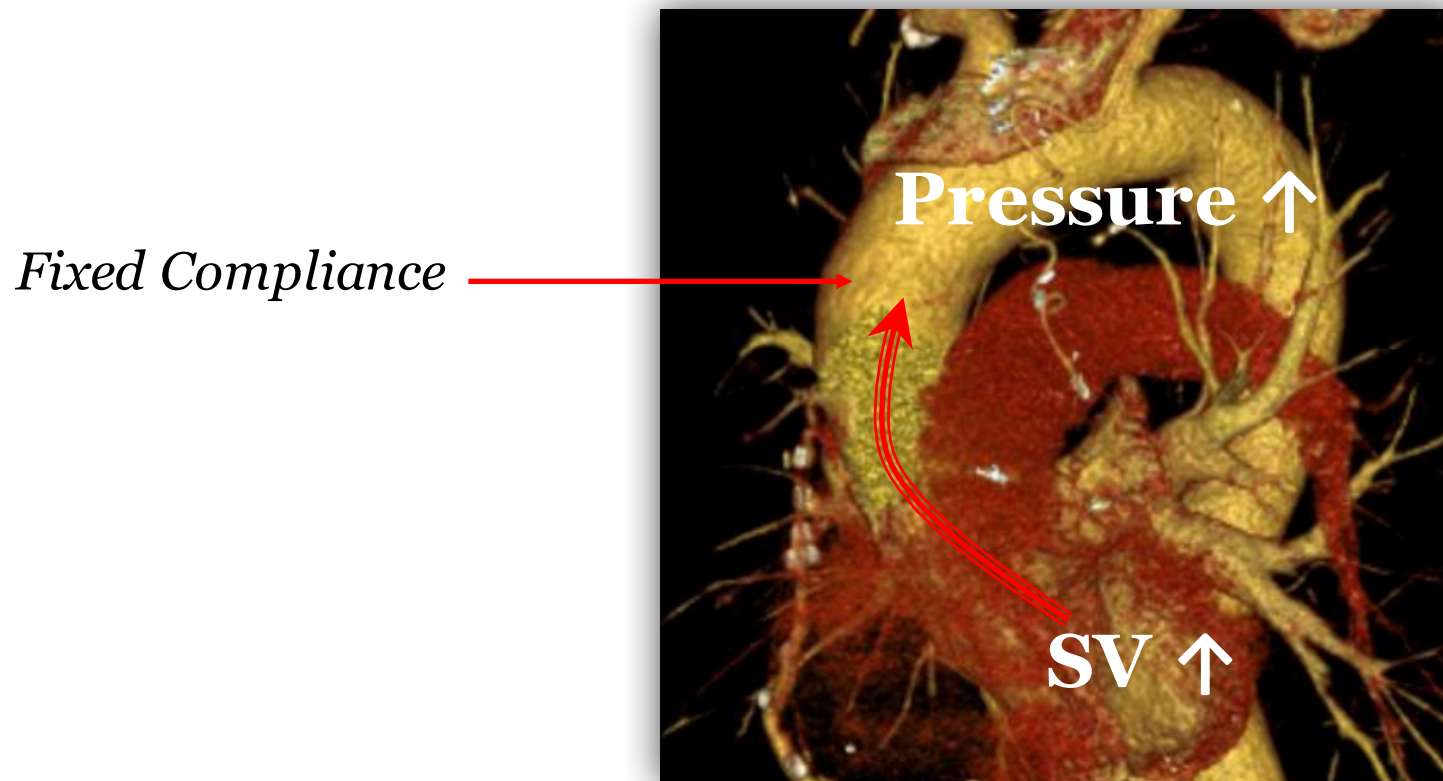
*Fixed Compliance*



# Special Cases in BP Regulation

- Aortic Compliance:

- If blood **volume** increases and *vascular capacitance is not altered*, arterial **pressure** will also rise ( $Compliance = \Delta V / \Delta P$ )



- Pulse Pressure:
- Aortic regurgitation
  - Anemia

# Special Cases in BP Regulation

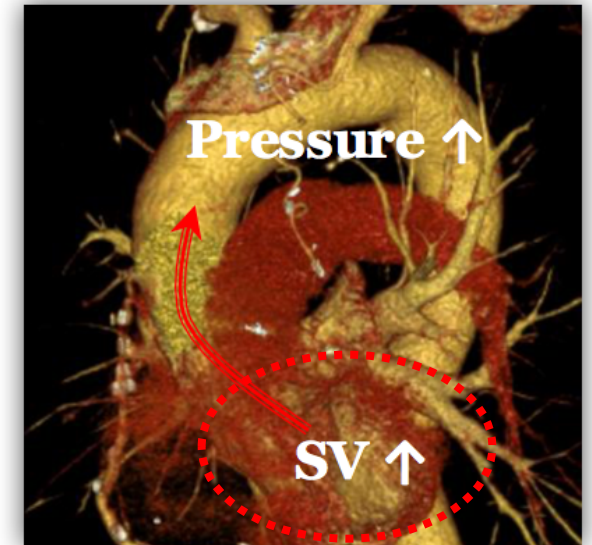
- Exercise and Local Mediators
  - SNS activation:  $\beta$ -1,  $\alpha$ -1 effects
  - Epinephrine:  $\beta$ 1,  $\beta$ 2 (*vasodilation*)
  - Local mediators: lactate, adenosine,  $K^+$   $\rightarrow$  vasodilation skeletal mm



Vasodilate  
Lactate, Adenosine,  $K^+$



Result:  
 $\downarrow$   $TPR_{\Omega}$  (Afterload)



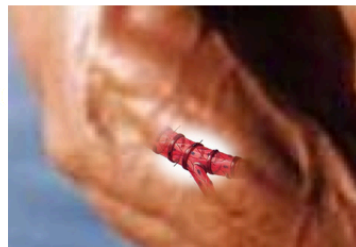


# Special Cases in BP Regulation

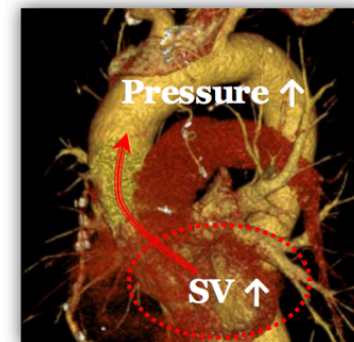
- Exercise and Local Mediators
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  - Epinephrine:  $\beta$ 1,  $\beta$ 2 (*vasodilation*)
  - Local mediators: lactate, adenosine,  $K^+$   $\rightarrow$  vasodilation skeletal mm
- Net Effect
  - Increase in MAP due to  $\Delta$ 's in HR, SV but not  $TPR_{\Omega}$



Vasodilate  
Lactate, Adenosine,  $K^+$



Result:  
 $\downarrow TPR_{\Omega}$  (Afterload)



# Special Cases in BP Regulation

- Cerebral Ischemia
  - Hypoperfusion/injury to brain can directly trigger the *vasomotor center* to increase sympathetic outflow → may be very dramatic
- Coarctation
  - ANS: *resetting* of baroreceptors
  - Activation of the *RAAS*
- Aortic Compliance
  - If blood volume increases and vascular capacitance is not altered, arterial pressure will also rise (*Compliance* =  $\Delta V / \Delta P$ )
- Exercise
  - SNS activation: BP rises due to SV not  $TPR_{\Omega}$ 
    - Vasodilation (vascular supply to skeletal mm): lactate, adenosine, K<sup>+</sup>
    - Epinephrine:  $\beta$ -2 agonist (vasodilate)
    - *Local mediators*: adenosine, lactate, K<sup>+</sup>



# Blood Pressure/HTN Series

- Blood Pressure Regulation
  - Autonomic nervous system (immediate: seconds)
    - ✓ Restore pressure
    - ✓  $\beta$ -agonism: *stimulate renin*
  - Juxtaglomerular Apparatus [gradual: minutes (ATII) - days (aldosterone)]
    - ✓ Restore volume
    - ✓ ATII: *pressure*
- *Renovascular HTN*
  - Physiologic response
  - Pathology
  - Demographics
- Endocrinopathies
  - Mineralocorticoids (i.e. aldosterone, cortisol)
  - Catecholamines

# Blood Pressure (Dys)Regulation for the USMLE Step One Exam



**Oh Behave!**

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