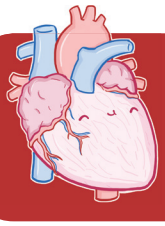

NOTES
BLOOD PRESSURE REGULATION

REGULATION OF ARTERIAL PRESSURE

- Must be maintained at a constant level of ~100mmHg
- Changes in blood pressure activate baroreceptors and/or chemoreceptors (fast response) and renin-angiotensin-aldosterone system (slow response), causing a series of events that eventually bring blood pressure back to normal (discussed later)
- Central mechanisms regulating blood pressure are cardiac output, peripheral resistance, and blood volume

Cardiac output and peripheral resistance relate to blood pressure

- P_a = *cardiac output* x *TPR*
  - P_a = mean arterial pressure
  - Cardiac output = cardiac output (mL/min)
  - TPR = total peripheral resistance (mmHg/mL/min)
- Mean arterial pressure varies directly with cardiac output and total peripheral pressure, can be changed by altering one or both
- Blood pressure varies directly with blood volume because cardiac output depends on blood volume
  - Cardiac output is equal to stroke volume (ml/min) times heart rate (beats/min)
  - Normal is 5–5.5L/min
- P_a is regulated by two mechanisms
  - *Baroreceptor reflex*: neurally mediated (short-term, fast response)
  - *Renin-angiotensin-aldosterone system*: hormonally mediated (long-term, slow response)

MEASURING BLOOD PRESSURE

- *Auscultatory method*: an indirect method of measuring pressure by listening to Korotkoff sounds in the brachial artery using a sphygmomanometer

1. Wrap blood pressure cuff around upper arm just above elbow
2. Rapidly inflate cuff until pressure in it exceeds systolic pressure (up to around 180mmHg) to stop blood flow
3. Press lightly with the stethoscope bell over the brachial artery just below edge of cuff
4. Reduce cuff pressure slowly and listen with stethoscope for sounds in the brachial artery while simultaneously observing the mercury gauge
   - The first tapping sound (Korotkoff sound) represents systolic pressure
   - When the tapping sound disappears, it represents diastolic pressure

HOMEOSTATIC IMBALANCES IN BLOOD PRESSURE

Normal blood pressure in adults

- Affected by age, weight, sex and race
- *Systolic pressure:* 90–120mmHg
- *Diastolic pressure:* 60–80mmHg

Hypertension

- Chronically elevated blood pressure
  - *Systolic pressure:* > 140mmHg
  - *Diastolic pressure:* > 90mmHg

Hypotension

- Low blood pressure
  - *Systolic pressure:* <90mmHg
  - *Diastolic pressure:* <60mmHg
- Often normal variation
- Acute hypotension
  - Can be a sign of circulatory shock
- Orthostatic hypotension
  - Temporary drop in blood pressure caused by rapidly standing up from a sitting or lying position
  - Common in the elderly
- Chronic hypotension
  - Often a sign of an underlying condition

BARORECEPTORS

osms.it/baroreceptors

BARORECEPTOR REFLEX

- Short term, fast neural response to change in blood pressure
- Alters peripheral resistance and cardiac output
- Mediated by baroreceptor cells
  - Specialized nerve endings called mechanoreceptors, located in aortic arch and carotid sinus; sensitive to pressure or stretching
  - Most sensitive to rapid pressure changes
- *Carotid sinus baroreceptors*: responsive to both decreases and increases in pressure
- *Aortic arch baroreceptors*: predominantly responsive to increases in pressure
- Change in blood pressure activates reflex arc
  - Baroreceptors → afferent neurons → brain stem centers → processing information and generating response → efferent neurons → changes in the heart and blood vessels
  - Increase of blood pressure → stretching of baroreceptors → depolarizing receptor potential (higher rate action potential)
  - Decrease of blood pressure → decreased stretch of baroreceptors → hyperpolarizing potential (lower rate action potential)
- Sensitivity can be altered as a result of some diseases
- *Chronic hypertension*: result is adaptation of baroreceptors
  - Baroreceptors are adjusted to monitor pressure changes at higher setpoint
- *Atherosclerosis*: carotid sinus syndrome
  - Baroreceptors are more sensitive; even light pressure on the carotid sinus can cause extreme bradycardia

INTEGRATED FUNCTION OF BARORECEPTORS

Response to increased P_a

- ↑ *firing rate:* carotid sinus nerve (glossopharyngeal nerve, CN IX), aortic arch nerve afferent fibers (vagus nerve, CN X)
- Glossopharyngeal, vagus nerve fibers synapse in nucleus tractus solitarius of medulla, (transmits blood pressure information)
- Nucleus tractus solitarius governs coordinated response series; returns P_a down to normal levels
  - ↑ parasympathetic outflow to heart
  - ↓ sympathetic outflow to heart, blood vessels
- Decrease in sympathetic activity
  - Complements increase in parasympathetic activity → decrease in heart rate
  - Decrease in cardiac contractility
  - Decreased heart rate + decreased cardiac contractility → decrease in cardiac output→ decrease of P_a (P_a = cardiac output × TPR)
  - Arteriolar vasodilation → decrease in TPR → decrease of P_a (P_a = cardiac output × TPR)
  - Vasodilation of veins → increased compliance of veins → increased unstressed volume → decreased stressed volume → reduction in P_a
- Once P_a reduced back to the set-point pressure (i.e., 100 mmHg), activity of the baroreceptors and the cardiovascular brainstem centers return to baseline level

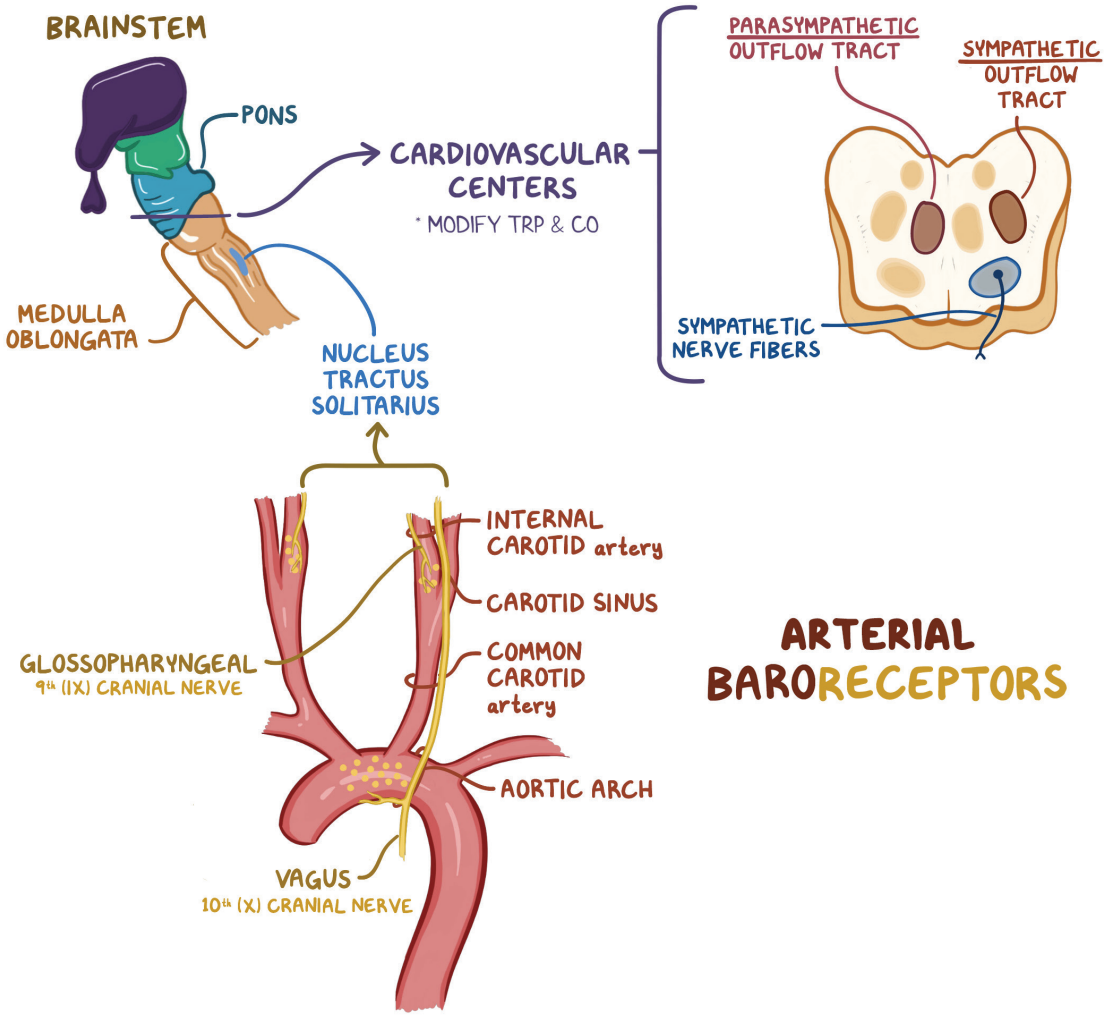

Figure 15.1 Locations of arterial baroreceptors and pathways that transmit their signals.

CARDIOPULMONARY (LOW PRESSURE) BARORECEPTORS

- Located in the vena cava, pulmonary arteries and atria
- These baroreceptors are volume receptors - they detect changes in blood volume
- Increased blood volume and subsequent increases in venous and atrial pressure are detected by cardiopulmonary baroreceptors which generates several responses

Cardiopulmonary baroreceptors responses

- Secretion of atrial natriuretic peptide (ANP), a polypeptide hormone secreted by the myocytes in the atrial wall
  - ANP causes generalized vasodilation
  - This vasodilatation in the kidney increases glomerular filtration rate which results in increased Na^{2+} and H_2O filtration and excretion → decreased blood volume
- Decreased secretion in ADH
  - Decreased water reabsorption in the collecting ducts → decreased blood volume
- Increase of heart rate (Bainbridge reflex)
  - Increased cardiac output → increased renal perfusion → increased Na^+ and H_2O excretion

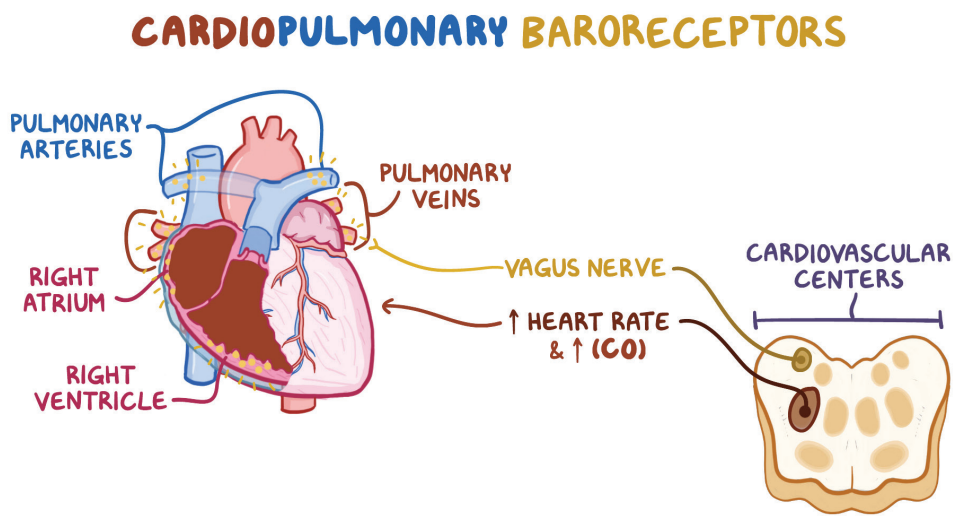

Figure 15.2 Locations of cardiopulmonary baroreceptors and pathway that transmits their signals.

CHEMORECEPTORS

osms.it/chemoreceptors

CHEMORECEPTOR REFLEX

- Blood pressure regulation pathway that involves chemoreceptors for O_2 in the aortic and carotid bodies
- Central and peripheral chemoreceptors

PERIPHERAL CHEMORECEPTORS

- Located in carotid bodies (near common carotid artery bifurcation, in aortic bodies along aortic arch)
- Very sensitive partial pressure of O_2 decreases
  - Also sensitive to partial pressure of CO_2 increases (pCO_2), pH decreases
- Reflex arc
  - Decreased pO_2 → chemoreceptors (afferent neurons) increase firing of action potential (hyperpolarization potential) → efferent neurons → increased sympathetic outflow → arterial vasoconstriction in skeletal muscle, renal and splanchnic circulation → increased total peripheral pressure
- These chemoreceptors are also involved in control of breathing
  - Decrease of pO_2 causes an increase in ventilation which decreases the parasympathetic outflow to heart → ↑ heart rate → ↑ cardiac output

CENTRAL CHEMORECEPTORS

- Located in the medulla
- *Most sensitive:* CO_2, pH
- *Less sensitive:* O_2
- Reflex arc
  - Decrease in brain blood flow → increased pCO_2, decreased pH → chemoreceptors (afferent neurons) increase firing of action potential (hyperpolarization potential) → efferent neurons → increased sympathetic outflow → arterial vasoconstriction in skeletal muscle, renal and splanchnic circulation → increased total peripheral pressure

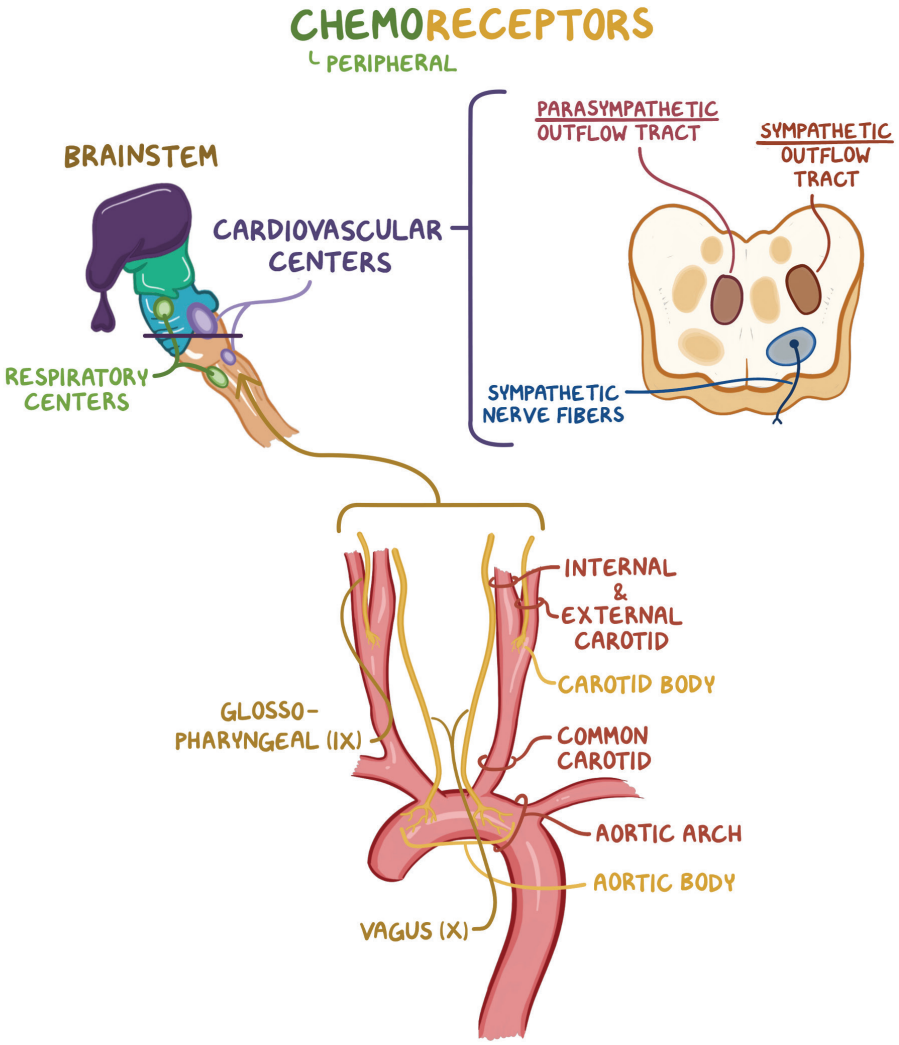

Figure 15.3 Locations of peripheral chemoreceptors and locations in the brainstem to which they transmit their signals.

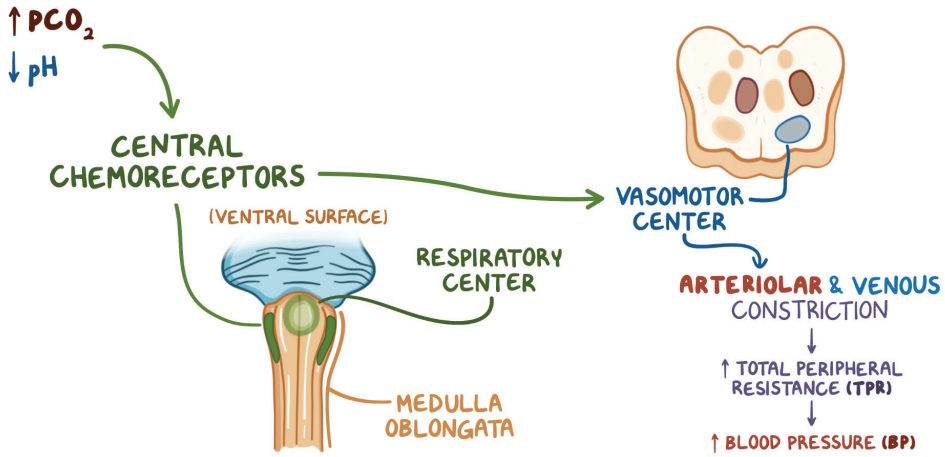

Figure 15.4 Central chemoreceptors are located in the medulla of the brainstem and are most sensitive to changes in CO_2 and pH levels.

RENIN-ANGIOTENSIN ALDOSTERONE SYSTEM

osms.it/renin-angiotensin_aldosterone_system

- Hormonally mediated, slow regulation of blood pressure
- Regulates P_a by regulating blood volume

Direct renal mechanism

- Increase of P_a causes increased filtration rate in the tubules
- In this situation, the kidney cannot reabsorb filtrate fast enough → more fluid leaves the body in urine → blood volume and blood pressure drops

Indirect renal mechanism

- Renin-angiotensin aldosterone system
- Decrease of P_a and/or decrease of Na^+ concentration causes decrease in kidney perfusion which in turn causes a series of events
- Cells of the macula densa sense the change in blood volume/osmolarity and in turn stimulate renin production
  - Renin is an enzyme secreted by juxtaglomerular cells of the juxtaglomerular apparatus of the nephron
  - Renal sympathetic nerves and beta-1 agonists also cause renin production
- Renin converts angiotensinogen to angiotensin I
- Angiotensin-converting enzyme (ACE) in the lungs and kidneys converts angiotensin I to angiotensin II
  - Stimulates the synthesis and secretion of aldosterone in the glomerulosa cells of the adrenal gland
  - Aldosterone causes Na^+ reabsorption to increase in principal cells of renal distal tubule, collecting duct
  - Increased Na^+ concentration → increased osmolarity → increased ECF and blood volume
- Angiotensin II
  - Stimulates Na^+- H^+ exchange → increased Na^+ reabsorption
  - Stimulates antidiuretic hormone (ADH) secretion
  - Acts on hypothalamus (stimulates thirst, water intake)
  - Causes vasoconstriction of the arterioles → increased total peripheral resistance (TPR)

Antidiuretic hormone (ADH)

- Hormone produced in hypothalamus, secreted by pituitary gland's posterior lobe
- Stimulated by low blood volume, increase of serum osmolarity and angiotensin II
- Receptors for ADH
- *V1 receptors:* vasoconstriction of arterioles
- *V2 receptors:* increase water reabsorption by principal cells of the renal collecting duct

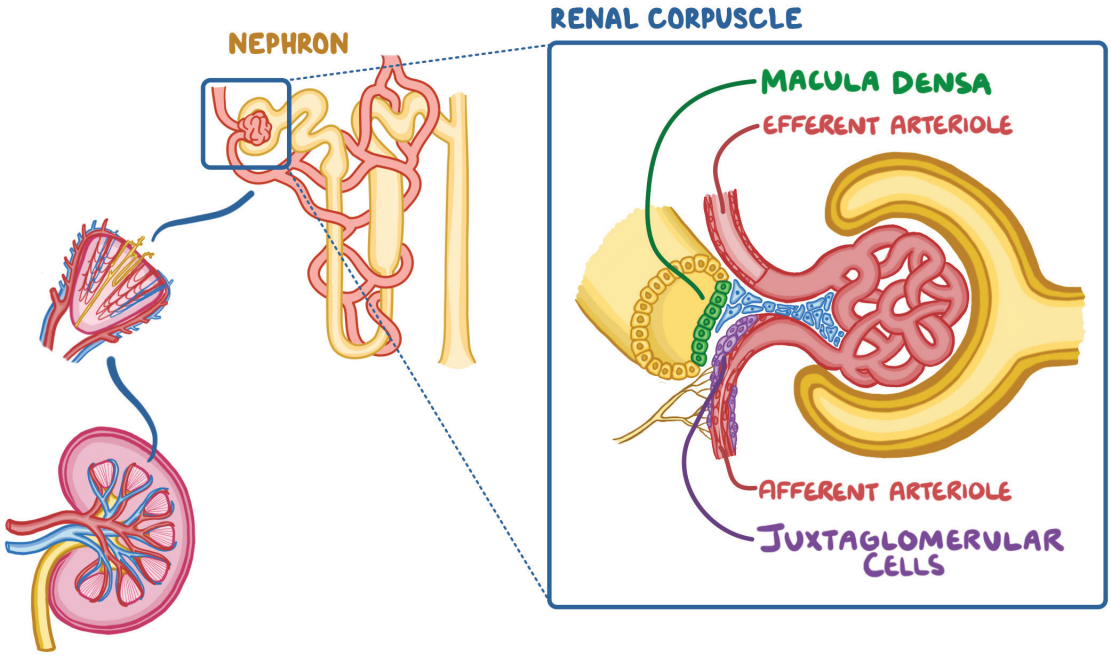

Figure 15.5 Macula densa cells are chemoreceptors located in the distal convoluted tubule. When they sense a ↓ in P_a and/or Na^+, Cl^-, they stimulate renin production by nearby juxtaglomerular cells. Renin initiates angiotensin II activation, which acts in multiple areas to increase blood pressure.

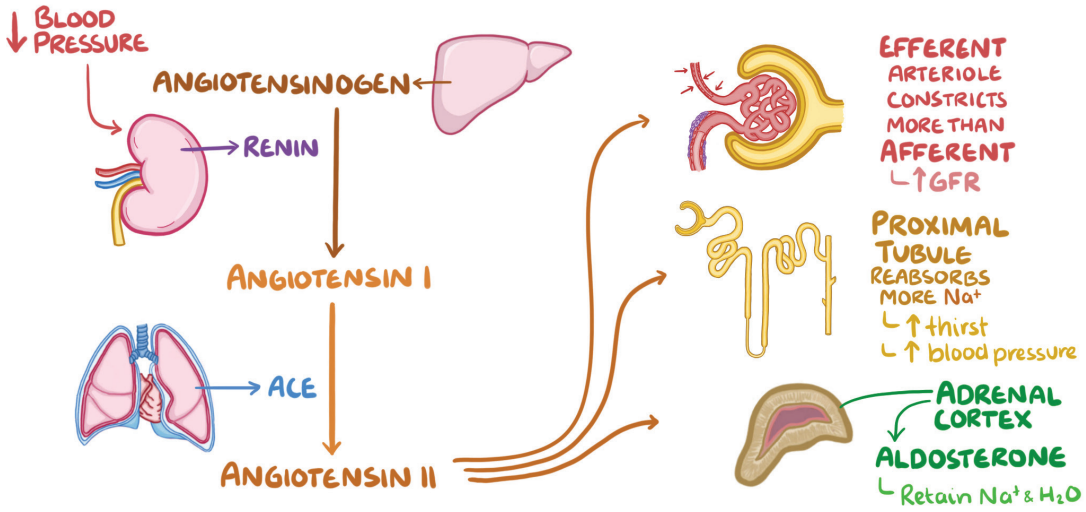

Figure 15.6 RAAS system summary.