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Blood Pressure Regulation

Study Guide — Cardiac Physiology

Pre-med/IB-style questions on the determinants of arterial blood pressure (CO, TPR, compliance), rapid neural control (baroreflex, autonomic nervous system), slower hormonal control (RAAS, ADH, ANP), and classic physiology scenarios (posture, exercise, hemorrhage, temperature).

50 items — Study Guide with Answers

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1 **Which relationship best captures the main physiological determinants of mean arterial pressure (MAP) in systemic circulation?**

A **MAP ≈ Cardiac output (CO) × Total peripheral resistance (TPR)** ✓

B MAP ≈ Stroke volume (SV) ÷ Heart rate (HR)

C MAP ≈ Venous pressure × Blood volume

D MAP ≈ Respiratory rate × Oxygen saturation

E MAP ≈ Plasma osmolality × Hemoglobin concentration

▶ **Explanation:** In basic hemodynamics, arterial pressure depends mainly on how much blood the heart pumps per minute (CO) and how strongly the systemic arterioles resist flow (TPR).

2 **Cardiac output (CO) is best defined as:**

A $CO = HR + SV$

B **$CO = HR \times SV$** ✓

C $CO = MAP \div HR$

D $CO = TPR \div MAP$

E $CO = SV \div TPR$

▶ **Explanation:** Cardiac output is the volume pumped per minute: heart rate (beats/min) times stroke volume (mL/beat).

3 **Pulse pressure is defined as:**

A Diastolic pressure − systolic pressure

B **Systolic pressure − diastolic pressure** ✓

C Mean arterial pressure − systolic pressure

D Mean arterial pressure − diastolic pressure

E Venous pressure − arterial pressure

▶ **Explanation:** Pulse pressure is the difference between systolic and diastolic pressure and reflects changes in stroke volume and arterial compliance.

4 Which vessels contribute MOST to total peripheral resistance (TPR) in the systemic circulation?

A Aorta

B Large elastic arteries

C **Arterioles** ✓

D Large veins

E Vena cava

▶ **Explanation:** Arterioles are the main "resistance vessels" because they have smooth muscle that can change radius substantially, strongly affecting resistance and thus MAP.

5 Veins are often called "capacitance vessels" because they:

A Have the highest pressure in the circulation

B Are the main site of gas exchange

C **Contain most of the blood volume and can expand easily (high compliance)** ✓

D Create most of the resistance to blood flow

E Pump blood using valves that contract

▶ **Explanation:** Veins hold a large fraction of blood volume and are highly compliant, so changing venous tone can shift blood toward or away from the heart, affecting venous return and preload.

6 **Which change would most directly decrease total peripheral resistance (TPR)?**

- A **Arteriolar vasodilation** ✓
- B Venoconstriction
- C Increased blood volume
- D Increased stroke volume
- E Increased venous valves opening frequency

▶ **Explanation:** TPR is determined mainly by arteriolar radius. Vasodilation increases radius and decreases resistance, lowering MAP if CO does not rise enough to compensate.

7 **If arterial compliance decreases (stiffer arteries) while stroke volume stays the same, the most likely change is:**

- A Pulse pressure decreases
- B **Pulse pressure increases** ✓
- C Both systolic and diastolic pressures must decrease equally
- D Mean arterial pressure must become zero
- E Heart rate must decrease to compensate instantly

▶ **Explanation:** Stiffer arteries expand less when the heart ejects blood, so systolic pressure rises more for the same stroke volume, widening pulse pressure.

8 **At normal resting heart rates, mean arterial pressure (MAP) is usually closer to diastolic pressure than systolic pressure because:**

A Diastolic pressure is always higher than systolic pressure

B **The heart spends more time in diastole than systole** ✓

C Systolic pressure does not contribute to blood flow

D MAP is defined as diastolic pressure

E Diastole occurs twice each heartbeat

▶ **Explanation:** Because diastole lasts longer than systole at rest, diastolic pressure contributes more to the time-weighted average pressure (MAP).

9 **Baroreceptors involved in rapid blood pressure regulation are located primarily in the:**

A Alveoli of the lungs and bronchioles

B Kidney cortex and renal tubules

C **Carotid sinus and aortic arch** ✓

D Liver and pancreas

E Bone marrow and spleen

▶ **Explanation:** Arterial baroreceptors are stretch receptors in the carotid sinus and aortic arch that detect changes in arterial pressure quickly.

10 **When arterial blood pressure rises suddenly, baroreceptor firing rate typically:**

A Decreases because arteries become less stretched

B **Increases because arteries become more stretched** ✓

C Stops completely because baroreceptors saturate instantly

D Changes only after several days

E Only changes if oxygen levels drop

▶ **Explanation:** Higher arterial pressure increases vessel wall stretch, which increases baroreceptor firing to the brainstem.

11 **A sudden increase in baroreceptor firing causes which immediate reflex pattern?**

A Increased sympathetic outflow and decreased parasympathetic outflow

B **Decreased sympathetic outflow and increased parasympathetic outflow** ✓

C Increased ADH release and increased renin release within seconds

D Immediate increase in red blood cell production

E No change in autonomic output because the kidney controls pressure

▶ **Explanation:** Increased baroreceptor firing signals "pressure is high," so the brainstem reduces sympathetic tone and increases parasympathetic tone, lowering HR/contractility and promoting vasodilation.

12 **A healthy person stands up quickly from lying down. What is the most immediate primary change that tends to reduce arterial pressure?**

A Increased venous return due to gravity pushing blood to the heart

B **Decreased venous return due to pooling of blood in leg veins** ✓

C Increased stroke volume due to increased preload

D Immediate increase in aldosterone secretion

E Immediate increase in red blood cell count

▶ **Explanation:** Standing causes venous pooling in the legs, decreasing venous return (preload), reducing stroke volume and cardiac output, which tends to lower MAP before reflexes compensate.

13 **In response to standing up, the baroreflex increases sympathetic activity. Which effect helps restore venous return most directly?**

A **Venoconstriction (reduced venous compliance)** ✓

B Dilation of leg arterioles to increase pooling

C Inhibition of skeletal muscle pump

D Immediate kidney excretion of more sodium

E Decreased heart rate

▶ **Explanation:** Venoconstriction decreases venous capacitance and pushes blood back toward the heart, increasing preload and helping restore cardiac output and arterial pressure.

14 **Carotid sinus massage (pressure on the neck) can slow the heart. The best explanation is:**

A It directly increases venous return, stretching the atria

B **It tricks baroreceptors into sensing higher pressure, increasing firing and boosting parasympathetic tone** ✓

C It directly inhibits the SA node by cooling the blood

D It lowers CO_2, which forces bradycardia

E It activates aldosterone release, lowering heart rate

▶ **Explanation:** Increased pressure at the carotid sinus increases baroreceptor firing. The reflex response is reduced sympathetic and increased parasympathetic activity, slowing HR.

15 **Why is the baroreceptor reflex considered a short-term (rapid) regulator rather than the main long-term controller of blood pressure?**

A Baroreceptors respond only to oxygen levels, not pressure

B **Baroreceptors reset their sensitivity around a new pressure set point over time** ✓

C Baroreceptors stop functioning after childhood

D Baroreceptors can only control blood volume, not vessel tone

E Baroreceptors regulate pH, not blood pressure

▶ **Explanation:** Baroreceptors adapt (reset) with sustained pressure changes, so they are best for buffering rapid fluctuations. Long-term control depends heavily on kidneys and hormones affecting blood volume.

16 **Which system is most important for long-term control of arterial pressure by adjusting blood volume?**

A Cough reflex

B **Kidneys (salt and water excretion/retention)** ✓

C Bone marrow (hematopoiesis)

D Skin (sweat gland contraction)

E Lymph nodes (antibody production)

▶ **Explanation:** Long-term BP regulation depends strongly on kidney control of extracellular fluid volume via sodium and water handling (including RAAS).

17 **Which situation most directly increases renin release (starting RAAS)?**

A High blood pressure stretching the afferent arteriole

B **Low renal perfusion pressure (low stretch of afferent arteriole)** ✓

C High atrial stretch

D High plasma sodium concentration with normal volume

E High blood glucose after a meal

▶ **Explanation:** Renin is released when the kidney senses low perfusion/pressure (and/or low NaCl delivery, and sympathetic 1 stimulation), initiating RAAS to restore pressure/volume.

18 **Which is a direct effect of angiotensin II that raises blood pressure quickly?**

A Vasodilation of systemic arterioles

B **Vasoconstriction of systemic arterioles** ✓

C Immediate increase in red blood cell count

D Immediate increase in bone mineralization

E Immediate destruction of aldosterone

▶ **Explanation:** Angiotensin II is a potent vasoconstrictor, raising TPR and thus MAP quickly (minutes). It also promotes aldosterone, ADH, and thirst for longer-term support.

19 **Aldosterone tends to increase blood pressure mainly by:**

A **Increasing sodium reabsorption so water follows, expanding blood volume** ✓

B Directly constricting all arterioles within seconds

C Destroying red blood cells to increase viscosity

D Lowering heart rate strongly through the vagus nerve

E Blocking kidney filtration to stop urine production permanently

▶ **Explanation:** Aldosterone increases Na^+ reabsorption (and K^+ secretion) in the distal nephron. Water tends to follow retained sodium, increasing extracellular fluid volume and supporting MAP over hours to days.

20 **ADH (vasopressin) can increase arterial pressure by:**

A Decreasing collecting duct water permeability

B **Increasing water reabsorption (and at higher levels, promoting vasoconstriction)** ✓

C Directly decreasing blood volume

D Blocking all sympathetic activity

E Increasing urine volume while concentrating urine

▶ **Explanation:** ADH raises water reabsorption in the collecting duct, increasing blood volume. At high levels, ADH can also cause vasoconstriction (hence "vasopressin").

21 **Atrial natriuretic peptide (ANP) is released when atria are stretched. Which overall effect best matches its role?**

A **Promote sodium and water excretion and oppose RAAS, lowering volume/pressure** ✓

B Increase renin and aldosterone to raise blood volume

C Increase ADH release to conserve water immediately

D Increase red blood cell production to raise blood viscosity

E Increase heart rate by increasing parasympathetic tone

▶ **Explanation:** ANP acts as a volume-reducing hormone: it promotes natriuresis (Na^+ excretion) and tends to inhibit renin/aldosterone, reducing extracellular volume and blood pressure.

22 **Which change would most likely increase mean arterial pressure (MAP) if all other variables stay the same?**

A Decrease cardiac output

B Decrease total peripheral resistance

C **Increase total peripheral resistance** ✓

D Decrease blood volume

E Increase venous compliance (more pooling)

▶ **Explanation:** MAP rises if TPR rises (with CO constant), because the same flow faces more resistance. Many real-life changes also alter CO, but the direct effect of increased TPR is increased MAP.

23 **Sympathetic stimulation usually increases arterial pressure by which combination?**

A Decreased HR, decreased contractility, vasodilation

B **Increased HR/contractility, arteriolar vasoconstriction, and venoconstriction** ✓

C Decreased HR with increased venous pooling

D Increased parasympathetic tone to arterioles

E Immediate increase in kidney filtration rate to remove volume

▶ **Explanation:** Sympathetic output increases CO (HR and contractility) and increases TPR (arteriolar constriction). Venoconstriction also supports venous return and preload.

24 **Which statement about parasympathetic control of blood pressure is most accurate at a basic level?**

A Parasympathetic nerves strongly constrict arterioles throughout the body

B **Parasympathetic effects mainly slow the heart; most systemic arterioles are controlled mainly by sympathetic tone** ✓

C Parasympathetic tone is the main long-term regulator of blood volume

D Parasympathetic nerves directly release renin from the kidney

E Parasympathetic activity directly increases aldosterone secretion

▶ **Explanation:** Parasympathetic input mainly affects the heart (HR). Most systemic arteriolar tone (and thus TPR) is primarily under sympathetic control.

25 **A sudden hemorrhage decreases arterial pressure. Which response is expected first (fastest)?**

A Kidney-mediated increase in red blood cell production

B **Baroreflex-mediated increase in sympathetic tone** ✓

C Bone growth to reduce vessel volume

D New protein synthesis of aldosterone transporters within seconds

E Complete closure of all capillaries

▶ **Explanation:** Neural reflexes (baroreflex) act within seconds to minutes. Hormonal and kidney-based changes are essential but slower.

26 **In a hemorrhage, why does the body often produce pale, cool skin?**

A Skin vasodilation increases heat loss to speed clotting

B **Sympathetic vasoconstriction reduces skin blood flow to preserve pressure and redirect blood to vital organs** ✓

C Parasympathetic activation forces blood into the skin

D ANP is released to increase skin blood flow

E The kidneys immediately stop all circulation to the skin

▶ **Explanation:** Sympathetic vasoconstriction reduces blood flow to less critical regions (like skin) to maintain MAP and perfuse vital organs (brain/heart).

27 A decrease in blood volume most directly decreases arterial pressure by reducing:

A Afterload first, then preload

B **Preload (venous return), leading to lower stroke volume and cardiac output** ✓

C Arterial compliance immediately to zero

D Red blood cell count immediately to zero

E Plasma osmolality first, then CO

▶ **Explanation:** Less blood volume lowers venous return (preload), decreasing stroke volume via Frank–Starling, reducing CO and therefore MAP.

28 Frank–Starling's law is most directly about how changes in _____ affect stroke volume.

A Afterload

B **Preload** ✓

C Blood viscosity

D Alveolar oxygen concentration

E Plasma protein concentration

▶ **Explanation:** Frank–Starling describes that increased preload (ventricular filling) generally increases stroke volume, up to physiological limits.

29 **If total peripheral resistance (TPR) rises sharply while contractility and preload are unchanged, the most immediate effect on stroke volume is usually:**

A Increase, because the heart pushes harder against resistance automatically

B **Decrease, because increased afterload makes ejection harder** ✓

C No change ever occurs

D Increase only if baroreceptors fire faster

E Switch from systole to diastole permanently

▶ **Explanation:** Higher TPR increases afterload. With the same contractility, the ventricle ejects less efficiently, tending to reduce stroke volume in the short term.

30 **A runner starts moderate dynamic exercise. Which pattern best describes typical systemic changes?**

A CO decreases; TPR increases; MAP decreases

B **CO increases; TPR decreases (vasodilation in active muscle); MAP increases slightly or stays near normal** ✓

C CO decreases; TPR decreases; MAP increases greatly

D CO increases; TPR increases; MAP always doubles

E CO is unchanged; TPR is unchanged; only breathing changes

▶ **Explanation:** Exercise increases CO strongly. TPR often falls overall because active muscles dilate arterioles. MAP usually rises modestly (or stays near normal) rather than skyrocketing.

31 **Why does total peripheral resistance (TPR) often decrease during dynamic exercise even though sympathetic activity increases?**

A Sympathetic nerves cannot reach skeletal muscle

B **Local metabolic vasodilation in active tissues can override sympathetic vasoconstriction in those beds** ✓

C Baroreceptors shut down all arterioles during exercise

D Blood becomes less viscous instantly

E Kidneys stop producing renin during exercise, causing immediate vasodilation everywhere

▶ **Explanation:** Active tissues produce metabolites (CO_2, H^+, adenosine, heat) that cause local vasodilation. This can dominate regionally and reduce overall TPR despite increased sympathetic tone.

32 **A person is in a hot environment and skin vessels dilate to lose heat. If fluids are not replaced, what is a likely consequence?**

A TPR increases strongly, causing hypertension

B **TPR decreases and dehydration reduces volume, increasing risk of low blood pressure/fainting** ✓

C Baroreceptors increase firing and raise pressure

D ANP increases to conserve sodium and water

E Systolic pressure becomes zero because the heart stops

▶ **Explanation:** Heat causes vasodilation (lower TPR). If sweating causes volume loss, CO can also fall. Together, these can drop MAP and cause dizziness or fainting.

33 **Cold exposure often increases blood pressure in the short term mainly because:**

A **Skin vasoconstriction increases TPR to reduce heat loss** ✓

B Cold directly increases blood volume immediately

C Cold turns off sympathetic nerves

D Cold increases ANP release to raise BP

E Cold lowers CO2, forcing vasoconstriction everywhere

▶ **Explanation:** To conserve heat, skin arterioles constrict, increasing systemic resistance and tending to raise MAP (especially in susceptible individuals).

34 Which variable most strongly influences diastolic blood pressure (DBP) under typical conditions?

A **Total peripheral resistance (TPR)** ✓

B Arterial oxygen content

C Red blood cell size

D Bone marrow activity

E Number of mitochondria in muscle

▶ **Explanation:** DBP depends heavily on how quickly blood "runs off" into tissues between beats. Higher arteriolar resistance slows runoff, keeping diastolic pressure higher.

35 A person has a narrow pulse pressure (small difference between systolic and diastolic). This most commonly suggests:

A Increased stroke volume

B **Decreased stroke volume** ✓

C Decreased arterial compliance as the main change

D Excessively high venous compliance

E Always normal physiology with no clinical meaning

▶ **Explanation:** Pulse pressure roughly tracks stroke volume (and compliance). Low stroke volume (e.g., reduced preload) tends to narrow pulse pressure.

36 An older adult has widened pulse pressure with an elevated systolic but relatively normal/low diastolic pressure. The best explanation is:

A Increased arterial compliance with age

B **Decreased arterial compliance (stiffer arteries) with age** ✓

C A sudden doubling of blood volume

D A sudden drop in total peripheral resistance to zero

E Increased venous compliance is the main cause of systolic rise

▶ **Explanation:** Stiffer arteries expand less during systole, raising systolic pressure and widening pulse pressure. This is a common aging-related hemodynamic pattern.

37 In sphygmomanometer (cuff) blood pressure measurement, the first Korotkoff sound is heard when cuff pressure:

A Is higher than systolic pressure

B **Just falls below systolic pressure (blood starts to spurt through during systole)** ✓

C Equals mean arterial pressure exactly

D Falls below diastolic pressure

E Is zero

▶ **Explanation:** The first tapping sounds occur when cuff pressure drops below systolic pressure, allowing intermittent flow during systole through the compressed artery.

38 **Korotkoff sounds disappear (in the usual method) when cuff pressure:**

A Is still above systolic pressure

B Is between systolic and diastolic pressure

C **Falls below diastolic pressure (flow becomes smooth/laminar again)** ✓

D Equals pulse pressure

E Equals venous pressure

▶ **Explanation:** Below diastolic pressure the artery is no longer compressed, flow becomes more laminar, and the turbulent sounds disappear.

39 **A drug blocks 1-adrenergic receptors. Which pair of effects would most directly lower arterial pressure?**

A Increased HR and increased renin

B **Decreased HR/contractility and decreased renin release** ✓

C Increased venoconstriction and increased aldosterone

D Increased ADH release and increased thirst

E Increased arteriolar vasoconstriction and increased TPR

▶ **Explanation:** 1 blockade reduces cardiac stimulation (lower CO) and reduces renin release from JG cells (less RAAS drive), both lowering MAP.

40 **Which situation best illustrates negative feedback in blood pressure control?**

A Low BP triggers baroreflex, which further lowers BP

B **High BP increases baroreceptor firing, which reduces sympathetic tone and lowers BP** ✓

C High BP increases renin release, which increases BP even more

D Low BP shuts down breathing to conserve oxygen

E Low BP causes bones to release calcium to increase pressure

▶ **Explanation:** Negative feedback means the response opposes the original change. High BP → higher baroreceptor firing → lower sympathetic tone → BP decreases toward normal.

41 **Which is the most likely immediate effect of isolated venoconstriction (with arteriolar resistance unchanged)?**

A Decrease preload and decrease stroke volume

B **Increase preload and increase stroke volume** ✓

C Decrease total peripheral resistance strongly

D Increase capillary filtration by lowering venous pressure

E Eliminate the baroreflex

▶ **Explanation:** Venoconstriction reduces venous capacitance, pushing blood toward the heart. This increases venous return (preload), increasing stroke volume via Frank–Starling.

42 **A tissue releases nitric oxide (NO) locally. The most direct vascular effect is:**

A Vasoconstriction of arterioles to increase resistance

B **Vasodilation of arterioles to increase blood flow to that tissue** ✓

C Increased renin release from the kidney

D Increased red blood cell production in bone marrow

E Closure of capillaries to prevent filtration

▶ **Explanation:** NO is a key local vasodilator. It relaxes smooth muscle, increasing vessel radius and local flow. This is local control, not endocrine RAAS control.

43 **Which statement best describes "autoregulation" of blood flow in an organ (e.g., brain, kidney) at a basic level?**

A **The organ keeps its blood flow relatively constant despite moderate changes in MAP by adjusting arteriolar tone** ✓

B The organ cannot change blood flow because arteries have no muscle

C Autoregulation is controlled only by aldosterone

D Autoregulation means blood flow always increases when pressure increases

E Autoregulation occurs only in veins, not arteries

▶ **Explanation:** Many organs can maintain relatively stable flow by intrinsic mechanisms (myogenic and metabolic responses) that adjust arteriolar diameter when perfusion pressure changes.

44 **A metabolically active muscle produces more CO2 and H^+. The local effect on arterioles supplying that muscle is most likely:**

A Vasoconstriction to reduce oxygen delivery

B **Vasodilation to increase blood flow and oxygen delivery (active hyperemia)** ✓

C No change because only nerves control vessels

D Immediate increase in ADH

E Immediate decrease in venous return

▶ **Explanation:** Local metabolites signal a need for more blood flow. Increased $CO2/H^+$ generally promotes vasodilation in active tissues, increasing perfusion to match demand.

45 A large rise in arteriolar resistance upstream of capillaries in a tissue tends to cause which change in that tissue's capillary hydrostatic pressure and filtration?

A Capillary pressure increases; filtration increases

B Capillary pressure decreases; filtration decreases ✓

C Capillary pressure increases; filtration decreases

D Capillary pressure becomes unrelated to arterioles

E Capillary pressure always equals venous pressure

▶ **Explanation:** Constriction of arterioles reduces pressure transmitted to downstream capillaries, lowering capillary hydrostatic pressure and reducing filtration (less fluid pushed out).

46 In right-sided heart failure, venous pressure rises. Which effect best explains why swelling (edema) in legs can worsen?

A Lower venous pressure pulls fluid into capillaries

B Higher venous pressure increases capillary hydrostatic pressure, promoting filtration into tissues ✓

C Higher venous pressure directly increases plasma protein concentration

D Higher venous pressure closes lymphatic vessels permanently

E Edema forms because red blood cells leave capillaries to raise osmotic pressure

▶ **Explanation:** Raised venous pressure backs up into capillaries, raising capillary hydrostatic pressure and pushing more fluid out into interstitial space, contributing to edema.

47 **After a large salty meal with little water intake, which signal is most likely to rise first?**

A Renin (RAAS) because salt directly triggers renin release

B **ADH because plasma osmolality rises** ✓

C ANP because atria are immediately stretched before absorption

D Erythropoietin because blood becomes salty

E Insulin because salt is a carbohydrate

▶ **Explanation:** Increased plasma osmolality is a strong trigger for ADH (and thirst). RAAS is more strongly driven by low effective volume/renal perfusion, not high salt itself.

48 **A person has low plasma proteins (e.g., low albumin). Fluid leaves blood into tissues more easily, reducing effective circulating volume. Which compensatory pattern is most likely?**

A RAAS decreases and ANP increases

B **RAAS increases and ADH may increase to defend volume/pressure** ✓

C Baroreceptors increase firing and lower sympathetic tone

D The body responds only by increasing bone growth

E Renin must fall because blood volume outside vessels increased

▶ **Explanation:** Low oncotic pressure promotes edema and can lower effective arterial blood volume. The body responds as if volume is low: sympathetic tone/RAAS/ADH can increase to support MAP.

49 **Which statement best distinguishes "mean arterial pressure" (MAP) from "pulse pressure" (PP)?**

A **MAP reflects average driving pressure for blood flow; PP reflects the pulsatile difference between systolic and diastolic pressures** ✓

B PP is the average pressure; MAP is the difference between systolic and diastolic

C MAP depends only on compliance; PP depends only on blood volume

D MAP is measured only in veins; PP is measured only in capillaries

E MAP and PP are identical values in all people

▶ **Explanation:** MAP is the time-averaged pressure that drives organ perfusion. Pulse pressure is SBP − DBP and relates strongly to stroke volume and arterial compliance.

50 **Which scenario best matches the idea of "pressure natriuresis" supporting long-term blood pressure control?**

A **Higher arterial pressure tends to increase kidney sodium excretion over time, reducing volume and helping bring pressure down** ✓

B Higher arterial pressure always decreases kidney filtration so no sodium can be excreted

C Lower arterial pressure triggers ANP release to excrete sodium

D Higher arterial pressure increases red blood cell count instantly to normalize pressure

E Pressure natriuresis means the lungs exhale sodium when pressure rises

▶ **Explanation:** Pressure natriuresis is the tendency for higher arterial pressure to promote greater sodium (and water) excretion by the kidneys, reducing extracellular volume and lowering pressure long-term.