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Hemoglobin Physiology: Bohr Shift, pH, Cooperativity & Sickle Cell

Exam — Blood & Hemoglobin

High-school/Pre-med/IB questions on hemoglobin structure, oxygen binding cooperativity, Bohr shift (CO_2/pH effects), alkalosis/acidosis, fetal hemoglobin, and sickle cell basics.

30 items — Printable Exam

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1 **Which statement about ADULT human hemoglobin (HbA) is correct?**

- A HbA is a monomer with one heme group, similar to myoglobin.
- B HbA is a tetramer (2 2) with four heme groups, each able to bind one O_2.
- C HbA is made of four identical subunits only.
- D HbA binds oxygen only after being transported into mitochondria.
- E HbA binds oxygen covalently and cannot release it in tissues.

2 **A single hemoglobin molecule can carry a maximum of how many oxygen molecules?**

- A 1
- B 2
- C 3
- D 4
- E 8

3 **Oxygen binds to iron in heme when the iron is in which oxidation state?**

- A Fe^{3+} only
- B Fe^{2+} (ferrous)
- C Fe^{0} (metallic iron)
- D Any oxidation state equally
- E Iron is not involved in oxygen binding

4 **The oxygen–hemoglobin dissociation curve is sigmoidal (S-shaped) primarily because hemoglobin shows:**

- A Simple diffusion of O_2 through the membrane
- B Cooperative binding: binding of one O_2 increases affinity for the next O_2
- C ATP production by red blood cells
- D O_2 binding only in the lungs and never in tissues
- E Irreversible binding of O_2 to heme

5 **Which statement best describes cooperative binding in hemoglobin?**

- A Hemoglobin binds four O_2 molecules at exactly the same strength, regardless of how many are already bound.
- B Binding of the first O_2 decreases the affinity of hemoglobin for the remaining O_2 molecules.
- C Binding of one O_2 increases hemoglobin's affinity for additional O_2 molecules.
- D Only myoglobin shows cooperativity; hemoglobin does not.
- E Cooperativity means hemoglobin binds CO_2 more strongly than O_2.

6 **Compared with hemoglobin, myoglobin is BEST described as:**

- A A tetramer with a sigmoidal binding curve
- B A monomer with a hyperbolic binding curve and generally higher O_2 affinity
- C A monomer that shows strong cooperativity
- D A protein that carries oxygen only in the blood plasma
- E A protein found only in red blood cells

7 **The Bohr effect (Bohr shift) refers to the phenomenon that increasing CO_2 or H^+ (lower pH) causes hemoglobin to:**

- A Bind O_2 more tightly (left shift)
- B Bind O_2 less tightly (right shift), promoting O_2 release in tissues
- C Carry more O_2 by increasing the number of heme groups
- D Stop binding CO_2 entirely
- E Become unable to bind any gases

8 **A RIGHT shift of the oxygen–hemoglobin dissociation curve means that at a given partial pressure of oxygen (pO_2), hemoglobin will have:**

- A Higher saturation (more O_2 bound)
- B Lower saturation (less O_2 bound)
- C Exactly the same saturation, but faster diffusion
- D No binding to O_2 at all
- E Higher affinity and stronger binding

9 **A LEFT shift of the oxygen–hemoglobin dissociation curve most directly indicates:**

- A Decreased O_2 affinity and easier unloading
- B Increased O_2 affinity and harder unloading in tissues
- C No change in affinity, only change in hemoglobin amount
- D Less cooperativity

E More oxygen binding sites per hemoglobin molecule

10 During intense exercise in muscle, CO_2 production increases and pH may decrease (lactic acid). What is the expected effect on hemoglobin's O_2 affinity in that muscle?

- A Affinity increases; O_2 unloading decreases (left shift)
- B Affinity decreases; O_2 unloading increases (right shift)
- C Affinity becomes zero; no O_2 can bind anywhere
- D Hemoglobin becomes identical to myoglobin
- E There is no effect of pH on oxygen binding

11 Which situation most likely causes a LEFT shift of the oxygen–hemoglobin dissociation curve?

- A Increased CO_2 in tissues
- B Decreased pH (acidosis)
- C Increased body temperature
- D Decreased CO_2 and increased pH (alkalosis)
- E Increased 2,3-BPG in red blood cells

12 A patient is hyperventilating due to anxiety. Their blood CO_2 falls and blood pH rises (respiratory alkalosis). What is the most likely effect on O_2 delivery to tissues?

- **A** Improved O_2 unloading because the curve shifts right
- **B** Reduced O_2 unloading because the curve shifts left
- **C** No change because pH never affects hemoglobin
- **D** Hemoglobin releases all its oxygen immediately
- **E** Hemoglobin can bind only 2 O_2 molecules in alkalosis

13 **Which statement about fetal hemoglobin (HbF) is correct?**

- **A** HbF has lower O_2 affinity than adult hemoglobin, helping it release O_2 to the fetus.
- **B** HbF has higher O_2 affinity than adult hemoglobin, helping it take O_2 from maternal blood.
- **C** HbF contains no heme groups.
- **D** HbF is a single-chain protein like myoglobin.
- **E** HbF cannot bind oxygen until after birth.

14 **Which subunit composition is correct for normal ADULT hemoglobin (HbA) and FETAL hemoglobin (HbF)?**

- **A** HbA = 2 2; HbF = 2 2
- **B** HbA = 2 2; HbF = 2 2
- **C** HbA = 4; HbF = 4
- **D** HbA = 2 2 only; HbF = 2 2
- **E** HbA = 1 1; HbF = 1 1

15 The term P50 (in hemoglobin physiology) refers to:

- A The pO_2 at which hemoglobin is 50% saturated
- B The pH at which hemoglobin releases 50% of its oxygen
- C The percent of oxygen in the atmosphere at sea level
- D The number of amino acids in a hemoglobin subunit
- E The pressure of CO_2 in venous blood

16 If the oxygen–hemoglobin dissociation curve shifts RIGHT, what happens to P50?

- A P50 decreases
- B P50 increases
- C P50 becomes zero
- D P50 has no relationship to curve shifts
- E P50 changes only with hemoglobin concentration, not affinity

17 Carbon monoxide (CO) poisoning reduces oxygen delivery to tissues mainly because CO:

- A Destroys red blood cells immediately
- B Binds hemoglobin strongly and also makes remaining sites hold O_2 more tightly (left shift)
- C Increases 2,3-BPG binding and shifts the curve right
- D Turns hemoglobin into myoglobin
- E Replaces iron with calcium in heme

18 **A patient has anemia (low hemoglobin concentration). Which statement is MOST accurate about their arterial oxygen saturation (SaO_2) vs oxygen content?**

- A SaO_2 must be low, and oxygen content must be normal
- B SaO_2 can be normal, but oxygen content can be low because there is less hemoglobin to carry O_2
- C SaO_2 and oxygen content are always identical measurements
- D Oxygen content increases because each hemoglobin binds extra O_2
- E Anemia has no effect on oxygen delivery because dissolved O_2 is enough

19 **Most oxygen in blood is transported:**

- A Dissolved in plasma
- B Bound reversibly to hemoglobin in red blood cells
- C As bicarbonate (HCO_3^-)
- D Bound to albumin
- E In the form of glucose

20 **Most carbon dioxide (CO_2) in blood is transported to the lungs mainly as:**

- A CO_2 dissolved directly in plasma
- B Carbon monoxide (CO)
- C Bicarbonate ions (HCO_3^-)
- D Oxygen bound to hemoglobin
- E Glucose bound to albumin

21 The enzyme in red blood cells that rapidly converts CO_2 and water into carbonic acid (which then forms H^+ and HCO_3^-) is:

- A Amylase
- B Carbonic anhydrase
- C Acetylcholinesterase
- D DNA polymerase
- E ATP synthase

22 Carbaminohemoglobin refers to CO_2 bound to which part of hemoglobin?

- A The iron (Fe^{2+}) in the heme group
- B The globin (protein) chains, not the heme iron
- C The red blood cell membrane
- D The phosphate group of ATP
- E The plasma protein albumin

23 At the level of tissues, the Bohr effect is useful because it:

- A Prevents oxygen release where CO_2 is high
- B Promotes oxygen release where CO_2 is high and pH is low
- C Forces hemoglobin to bind oxygen covalently
- D Stops CO_2 production in cells
- E Converts CO_2 into O_2

24 **Sickle cell disease is caused by hemoglobin molecules that tend to:**

- A Bind oxygen irreversibly in the lungs
- B Polymerize when deoxygenated, distorting red blood cells into a sickle shape
- C Lose their heme groups at high oxygen levels
- D Convert oxygen into carbon dioxide
- E Become soluble only at low temperatures

25 **The most common mutation underlying sickle cell disease is best described as:**

- A A large deletion removing the entire -globin gene
- B A point mutation causing a single amino acid substitution in the -globin chain
- C A chromosome duplication that doubles hemoglobin subunits
- D A mutation that changes iron (Fe^{2+}) into Fe^{3+} permanently
- E A mutation in mitochondrial DNA

26 **Why is deoxygenation especially important in triggering sickling in sickle cell disease?**

- A Oxygenated HbS is more likely to polymerize than deoxygenated HbS
- B Deoxygenated HbS exposes regions that promote hemoglobin–hemoglobin sticking (polymer formation)
- C Low oxygen directly breaks red blood cells apart by osmosis
- D Deoxygenation removes iron from heme

E Deoxygenation prevents hemoglobin from being a tetramer

27 Which factor would MOST likely shift the oxygen–hemoglobin dissociation curve to the RIGHT (promoting O_2 release)?

A Decreased temperature

B Decreased CO_2

C Increased pH (alkalosis)

D Increased temperature and increased CO_2 in tissues

E Fetal hemoglobin replacing adult hemoglobin

28 Which statement best explains why hemoglobin's cooperativity is useful for oxygen transport?

A It makes hemoglobin bind O_2 equally well at all pO_2 values, so delivery is constant everywhere

B It allows high saturation at high pO_2 (lungs) but significant unloading with small pO_2 drops in tissues

C It prevents any oxygen unloading until hemoglobin is completely full

D It makes hemoglobin a better oxygen storage molecule than myoglobin

E It removes the need for a pressure gradient

29 At very low tissue pO_2, myoglobin remains more saturated with O_2 than hemoglobin. The best explanation is that myoglobin:

A Has multiple subunits that increase affinity when O_2 binds

- B Has a higher O_2 affinity and does not show cooperativity, so it holds onto O_2 at low pO_2
- C Cannot bind O_2 at all, so its saturation is irrelevant
- D Binds O_2 only when CO_2 is high
- E Is found only in blood, so it must stay saturated

30 Which paired change would most likely REDUCE oxygen unloading in tissues (make hemoglobin hold onto oxygen more strongly)?

- A Increased CO_2 and decreased pH
- B Increased temperature and increased CO_2
- C Decreased CO_2 and increased pH
- D Decreased pH and increased 2,3-BPG
- E Increased CO_2 and increased 2,3-BPG

#	Ans	Answer Text
	B	
2	D	4
	B	
4	B	Cooperative binding: binding of one O_2 increases affinity for the next O...
	C	
6	B	A monomer with a hyperbolic binding curve and generally higher O_2 affini...
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8	B	Lower saturation (less O_2 bound)
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10	B	Affinity decreases; O_2 unloading increases (right shift)
	D	
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14	B	HbA = 2 2; HbF = 2 2
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16	B	P50 increases
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22	B	The globin (protein) chains, not the heme iron
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24	B	Polymerize when deoxygenated, distorting red blood cells into a sickle s...
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30	C	Decreased CO_2 and increased pH