Myoglobin and Hemoglobin

The basics of Myoglobin and Hemoglobin

1. Myoglobin is which of the following:
    a. Tetramer
    b. Trimer
    c. Dimer
    d. Monomer
2. Hemoglobin is which of the following:
    a. Tetramer
    b. Trimer
    c. Dimer
    d. Monomer
3. Which term most accurately describes heme in myoglobin and hemoglobin?
    a. Substrate
    b. Ligand
    c. Prostetic group
    d. Catalyst
4. The proximal and distal ligands in myoglobin and hemoglobin are:
    a. Prolines
    b. Histidines
    c. Phenylalanines
    d. Tyrosines
5. What type of bond/interaction does the distal ligand form with O_2 in myoglobin and hemoglobin?
    a. Van der Waals interaction
    b. Polar covalent bond
    c. Non-polar covalent
    d. Hydrogen bond

Harder questions:

6. Which of the following is **incorrect** regarding deoxyhemoglobin?
    a. It has a lower affinity for oxygen than oxyhemoglobin
    b. It is in the T state
    c. Its stabilized by basic conditions
    d. It does not have oxygen bound
7. Which of the following events promotes a transition of T to R state in hemoglobin?
    a. Binding of oxygen to a heme
    b. Releasing of oxygen from a heme
    c. Decreasing the pH of the solution that the hemoglobin is in
    d. Binding of an allosteric regulator that stabilizes the deoxyhemoglobin state
8. For myoglobin, what it p_{50} equal/equivalent to?
    a. The k_a of myoglobin
    b. The oxygen pressure where 50% of myoglobin is saturated with oxygen
    c. The value of pO_2 at which θ (fractional saturation) is equal to 1
    d. The concentration of myoglobin when pressure is equal to 50 torr
9. Which is **not** a requirement for a protein to exhibit cooperativity?
    a. More than 1 binding site
    b. The subunits/binding sites are able to interact
    c. The subunits are connected by covalent bonds
10. Which of the following statements is **false**?
    a. Hemoglobin has a Hill coefficient greater than 1
    b. The Hill coefficient must not exceed the number of binding sites that a protein has
    c. When the Hill coefficient is equal to 1, ligand binding is non-cooperative
    d. When the Hill coefficient is greater than 1, the binding of one ligand decreases the affinity to the next ligand

ANSWER KEY

1. Myoglobin is which of the following:
    a. Tetramer
    b. Trimer
    c. Dimer
    d. Monomer

Myoglobin is a monomer, meaning that it is made up of 1 polypeptide chain. This means that technically, myoglobin does not have quaternary structure. A dimer is when 2 polypeptide chains interact, a trimer is when 3 interact, and a tetramer is when 4 interact.

2. Hemoglobin is which of the following:
    a. Tetramer
    b. Trimer
    c. Dimer
    d. Monomer

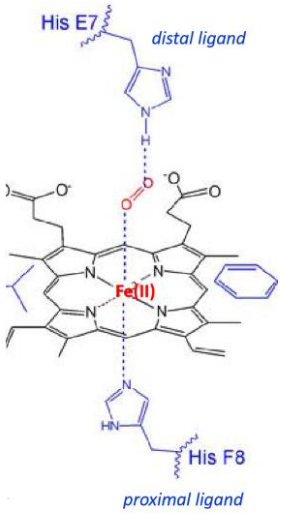
Hemoglobin is a tetramer, meaning that 4 different polypeptide chains (commonly called subunits) interact together to form the protein.

3. Which term most accurately describes heme in myoglobin and hemoglobin?
    a. Substrate
    b. Subunit
    c. Prostetic group
    d. Inhibitor

Heme is a prostetic group, meaning it is a group that it strongly binds to the protein and plays a role in the catalytic function of a protein. Heme could also be considered a cofactor, which is a broader term describing a non-protein part of a protein that plays a role in catalysis. A substrate is the molecule upon which an enzyme acts (in this case, oxygen). A subunit is a polypeptide chain that makes up a larger protein,

which heme is not since heme is not a polypeptide. An inhibitor is something that binds to a protein and inhibits its function, which is not what heme does.

4. The proximal and distal ligands in myoglobin and hemoglobin are:
    a. Prolines
    b. Histidines
    c. Phenylalanines
    d. Tyrosines



5. What type of bond/interaction does the distal ligand form with O_2 in myoglobin and hemoglobin?
    a. Van der Waals interaction
    b. Polar covalent bond
    c. Non-polar covalent
    d. Hydrogen bond

The distal ligand forms a hydrogen bond with the bound oxygen. The distal histidine is the hydrogen bond donor, and the oxygen (specifically the lone pairs on the oxygen) are the hydrogen bond acceptors. While all molecules have Van der Waals interactions, that is not the most important interaction here. The distal histidine does not form a covalent bond with the oxygen.

6. Which of the following is **incorrect** regarding deoxyhemoglobin?
    a. It has a lower affinity for oxygen than oxyhemoglobin
    b. It is in the T state
    c. It is stabilized by basic conditions
    d. It does not have oxygen bound

Deoxyhemoglobin describes deoxygenated hemoglobin, so it is hemoglobin without oxygen bound. This describes the T state. The T state has lower affinity for oxygen compared to the R state of hemoglobin (also called oxyhemoglobin). Based on the Bohr effect, we know that acidic conditions stabilize the T state and basic conditions

destabilize the T state. C is the answer as deoxyhemoglobin, the T state of hemoglobin, is not stabilized by basic conditions but is instead stabilized by acidic conditions.

7. Which of the following events promotes a transition of T to R state in hemoglobin?
    a. Binding of oxygen to a heme
    b. Releasing of oxygen from a heme
    c. Decreasing the pH of the solution that the hemoglobin is in
    d. Binding of an allosteric regulator that decreases the affinity for oxygen

The T state transitions to the R state when oxygen binds to the hemes. Releasing of oxygen results in an R to T state transition. Decreasing the pH stabilizes the T state, prevent T to R state transitions. An allosteric regulator binds to a site other than the active site and changes the affinity for the substrate. If this regulator binds and decreases the oxygen affinity, this decreases the chance oxygen binding, which in turn decreases the chance of transitioning to R state.

8. For myoglobin, what it p_{50} equal/equivalent to?
    a. The k_a of myoglobin
    b. The oxygen pressure where 50% of myoglobin is saturated with oxygen
    c. The value of pO_2 at which θ (fractional saturation) is equal to 1
    d. The concentration of myoglobin when pressure is equal to 50 torr

The k_d of myoglobin is what is equivalent to p_{50}, not the k_a. p_{50} is equivalent to the value of pO_2 at which θ (fractional saturation) is equal to 0.5, not 1. p_{50} is equal to an oxygen partial pressure, not the concentration of myoglobin.

9. Which is **not** a requirement for a protein to exhibit cooperativity?
    a. More than 1 binding site
    b. The subunits/binding sites are able to interact
    c. The subunits are connected by covalent bonds

A and B are the main requirements for cooperativity. C is not required, as subunits can interact with each other even when they are connected non-covalently. In reality, most proteins in the cell do not have covalent disulfide bonds as the cellular environment is reducing.

10. Which of the following statements is **false**?
    a. Hemoglobin has a Hill coefficient greater than 1
    b. The Hill coefficient must not exceed the number of binding sites that a protein has
    c. When the Hill coefficient is equal to 1, substrate binding is non-cooperative
    d. When the Hill coefficient is greater than 1, the binding of one substrate decreases the affinity to the next substrate

A Hill coefficient greater than 1 indicates positive cooperativity, which means that the binding of one substrate increases the affinity to the next substrate. A is true, as hemoglobin often has n = 3. B is true and is a rule for the hill coefficient. C is true as when n = 1, binding of one substrate does not affect the affinity of binding for the next substrate, which describes non-cooperative binding.