

Using RCSB.org Mol*

Exploring Hemoglobin Structures

A. Explore the structure of Deoxy Hemoglobin

1. Open the structure summary page for PDB ID 2dn2 (deoxy hemoglobin)
 - Click on the Structure tab or hyperlink below the snapshot to view the structure in Mol*
 - In the Controls panel, explore hiding and displaying the various components
 - Display Symmetry options
 - Change the representation of polymers to Molecular Surface
 - Change the color or the surface - Chain ID vs Entity ID
 - Explore the surface representation details >> Advanced options
 - Save images and animations
 - Hide the molecular surface representations
 - In the default mode of Mol*, click on the Arginine 141 (last residue of polymer chain A) by clicking on R141 in the Sequence panel.

List all the amino acids (polymer chain ID and residue number) that interact with this amino acid.

To measure the distance between the oppositely charged amino acid side chain that is closest to the R141 side chain (selected above).

- Activate the selection mode
- Change the selection level to Atoms/Coarse Elements
- Click on two atoms between which the distance is to be measured
- In the Controls panel, click on Measurements >> +Add >> Distance (top 2 selection items).
- Note the distance.

B. Explore the structure of Oxyhemoglobin

2. Open the structure summary page for PDB ID 2dn1 (oxy hemoglobin)
 - Click on the Structure tab or hyperlink below the snapshot to view the structure in Mol*
 - In the Controls panel, explore the Structure Type Model Vs Assembly
 - Display Symmetry options
 - Change the representation of polymers to Molecular Surface
 - Change the color or the surface - Chain ID vs Entity ID
 - Explore the surface representation details >> Advanced options
 - Save images and animations

- Compare the images created for PDB IDs 2dn1 and 2dn2.

Are they similar or different?

- *Explore later - Examine the neighborhood of R141 in Chain A in this structure. Are the interactions the same?*

Explore where the oxygen binds in the structure

- Select the ligand OXY ligand from the sequence panel and create a new component in Spacefill representation.

What is in the neighborhood of the oxygen?

- Go back to the structure summary page, scroll down to the small molecules section.
- Click on the Interactions pulldown menu in the 3D interactions column to open the Mol* page showing the ligand (OXY) bound to the polymer chain selected. View this with and without the (electron) Density.

Which residues form non-covalent interactions with the Heme that binds the Oxygen in the hemoglobin alpha and beta chains?

C. Explore the structure of Sickle Cell Hemoglobin

3. Open the structure summary pages of PDB ID 2hbs (Deoxy sickle cell hemoglobin or HbS) and PDB ID 5e6e (Carbonmonoxy HbS) in two separate tabs.

Note: Carbonmonoxy hemoglobin adopts a relaxed conformation like the oxyhemoglobin and is often used in crystallography to represent the oxygenated state of hemoglobin.

- Display the molecular surfaces showing hemoglobin alpha chains in one color and the beta chains in another color (as described for the oxy and deoxy hemoglobin)

Do you see any similarities between the hemoglobin structures and HbS structures?

Since the sickling phenomenon is observed in deoxyHbS (taut conformation) how can the relaxed conformation of HbS be favored?

4. Open the structure summary page of PDB ID 5e83 (Carbonmonoxy HbS with bound GBT440 or Voxelotor)
 - Click on the Structure tab or hyperlink below the snapshot to view the structure in Mol*
 - Display the protein chains as molecular surfaces and color the chains by entity ID - i.e. each distinct type of protein chain has a different color.
 - Locate the drug molecule. Click on the drug molecule to examine how it interacts with the protein (via covalent or non-covalent bonds?)
5. Open in a fresh tab or reload the structure summary page for PDB ID 2hbs (Deoxy sickle cell hemoglobin)

- Click on the Structure tab or hyperlink below the snapshot to view the structure in Mol*
- In the Controls panel, explore the Structure Type Model Vs Assembly. Are these different? What do they represent?
- In the default mode click on the amino acid Val6 in Chain H either by clicking in the 3D Canvas or using the sequence panel.

List 3 amino acids that are in the neighborhood of this amino acid.

- Locate the amino acid T87 in chain B and display it in the ball and stick format (as a new component).
- For an alternative way to explore these interactions,
 - activate the selection mode
 - click on the V6 residue in polymer chain H
 - in the horizontal menu that appears in the 3D canvas select the Set selection option



- Click on Manipulate select and then Surrounding Residues (5 Å) of selection
- For the amino acids that are selected in this step (shown with a green highlight), select the Create component or Cube icon in the horizontal menu to display these residues with a molecular surface.
- For the new component created, color the surface by hydrophobicity.

Note the location of the amino acid T87's side chain.

D. Explore the structure of Fetal Hemoglobin

6. Open the structure summary pages for PDB IDs 1fdh (deoxy fetal hemoglobin HbF) and 4mqj (carbonmonoxy HbF) in two different tabs of the browser window.
 - In each case, click on the Structure tab or hyperlink below the snapshot to view the structure in Mol*
 - Display the surface of the proteins to view the relaxed and taut conformations of HbF

Do you see any similarities between the hemoglobin, HbS, and HbF structures?

The mutation in HbS is located on the beta hemoglobin chain. Are there any mutations in the gamma hemoglobin chain that can cause a diseased state?

7. Open in a fresh tab or reload the structure summary page for PDB ID 1fdh
 - Scroll down to the Entity 2 details in the Macromolecules section.
 - In the subsection "UniProt & NIH Common Fund Data Resources" click on the Explore <UniProt ID> box. This should open a group summary page for that

UniProt ID. All structures in the PDB that have the UniProt ID P69892 should be listed here.

- Click on the Explore Sequence Alignment in 3D hyperlink at the top of the page.
- Examine the sequences in the left hand panel to identify any structures with mutations in the hemoglobin gamma chain (e.g., Toms River mutation)

List the mutation. Explore the structure summary page for that structure to learn if it causes any disease?

E. Comparing HbS and HbF

Are the structures of hemoglobin gamma and hemoglobin beta identical?

8. Open the Pairwise Structure Alignment tool (<https://www.rcsb.org/alignment>)
 - Type in the PDB IDs 2hbs (hemoglobin beta, chain B) and 1fdh (hemoglobin gamma, chain B). Note both of these structures are in the deoxy or tense/taut conformation.
 - Use the default option to compare the two structures.

How similar or different are these structures?

- The amino acid at the location corresponding to T87 in the hemoglobin beta chain inspired the engineering of an antisickling mutant of adult hemoglobin.

What is this amino acid (in the gamma hemoglobin)? Why do you think that this amino acid is antisickling?

Hint: Think about the location of this residue in the PDB ID 2hbs and its location respective to the Valine mutation.

F. Explore the structure of BCL11A

Learn about BCL11A, its structure and function.

9. Open the structure summary page of PDB ID 6ki6 (structure of BCL11A in complex with gamma-globin -115 HPFH region)

*Explore the structure in Mol**

- Click on the the Structure tab or hyperlink below the snapshot to view the structure in Mol*

How many Zn ions do you see in the structure?

- Click on any of the zinc ions in the structure to examine the interactions in its neighborhood.

Explore Sequence Annotations in 3D

- Go back to the structure summary page and click on the Sequence Annotations tab below the image of the structure on the top left corner. Alternatively, click on

the Sequence tab on the top of the page and click on the Explore Sequence Annotations in 3D hyperlink on the top of the page

- This should open the side-by-side view of the sequence of the protein in the structure and its various annotations in the left panel and the 3D structure displayed in Mol* on the right.

How many zinc finger domains do you see in this structure?

Explore the Sequence Alignment in 3D

- Go back to the structure summary page for PDB ID 6ki6
- Scroll down to the Entity 1 details in the Macromolecules section.
- In the subsection “UniProt & NIH Common Fund Data Resources” click on the Explore <UniProt ID> box. This should open a group summary page for that UniProt ID. All structures in the PDB that have the UniProt ID Q9H165 should be listed here.
- Click on the Explore Sequence Alignment in 3D hyperlink at the top of the page.
- Note that the AlphaFold structure is shown by default.
- Turn on the polymer chain corresponding to the PDB ID 6ki6

Where does the DNA bind?