**Nicholas’ Story**

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**Section II: Hydroxyurea to the Rescue**

*Box 8: Question*

In the video Nicholas says hydroxyurea changed his life. His mother explained that since he started the hydroxyurea treatment, Nicholas has been able to be more active and have a regular schedule with sports, school, and friends. The second question that we will ask in this case is “**What does hydroxyurea do and how does it help Nicholas have a more regular life?**” In this section we will explore the molecular impact of using hydroxyurea.

**Part 1: What does Hydroxyurea do?**

*Box 9: Storyline*

In the video we learned how Hydroxyurea, an approved drug for treating Sickle Cell Disease, changed Nicholas’ life. Here we will learn about the chemical nature of the drug and how it helps in managing complications of SCD.

1. Search for hydroxyurea in DrugBank (a curated resource that provides a wide variety of information of drugs and drug-like molecules). Look for information about this drug in DrugBank (<https://www.drugbank.ca/drugs/DB01005>), then refer to it to answer the following questions?

Q1. What is the chemical structure of hydroxyurea? Draw or paste a picture of this molecule below and describe its function (as listed in DrugBank).

Q2. What does hydroxyurea do to help manage sickle cell disease? Feel free to consult the scientific literature and data resources (e.g. the DrugBank) to answer this question.

*Box 10: Concept*

In the late 1940s Janet Watson reported that babies with sickle cell disease showed lesser sickling and it took longer for the sickling to appear compared to their carrier mothers. She suggested that there was something in the fetal hemoglobin that protects the babies in utero from the harmful effects of sickle cell disease. (see: <https://doi.org/10.1016/0002-9343(48)90029-1>)

Q3. Why do you think that there is a need for adult and fetal hemoglobins ?

Q3. Why do you think that babies and fetuses have a different type of hemoglobin? (Hint: Fetal hemoglobin’s oxygen dissociation curve is left-shifted compared to HbA.)

**Part 2: Fetal and Adult Hemoglobin**

*Box 11: Storyline*

Since hydroxyurea is able to increase production of the fetal hemoglobin (HbF), here we will explore the structure of HbF and compare it with that of the sickle cell hemoglobin (HbS). These comparisons may help understand how Hydroxyurea changed Nicholas’ life.

Note: both adult and fetal hemoglobin chains undergo conformational changes upon binding oxygen so when comparing these structures take care that they are in the same conformational state – e.g., both deoxy hemoglobin.

a. We will begin our discussion of fetal and adult/sickle cell hemoglobin by learning about the composition of these molecules.

*Box 12: Concept*

Adult hemoglobin is a tetramer made up of two α-globin and two β-globin protein chains, while the fetal hemoglobin tetramer has two γ-globin chains instead of the β-globin chains.

Although the β- and γ-globin chains are similar in structure and function, subtle differences between these proteins allow the adult and fetal hemoglobin molecules to bind oxygen.

The sickle cell mutation is in the β-globin protein so the fetal Hb is unaffected by this mutation.

b. Query the PDB archive to find any human fetal hemoglobin structures in the PDB archive. Go to the RCSB Protein Data Bank (<https://www.rcsb.org/>) and type fetal hemoglobin in the top search box and run a search.

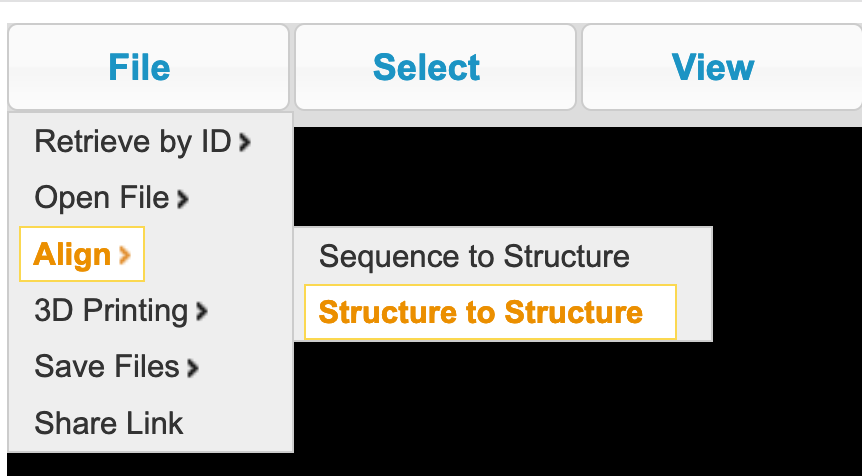
Q1. Did you find any structure of fetal deoxy-hemoglobin in the PDB? What is/are the PDB ID(s)? List all that you think may be relevant.

c. Explore and compare the structures using web-based visualization tools (NCBI’s iCn3D)

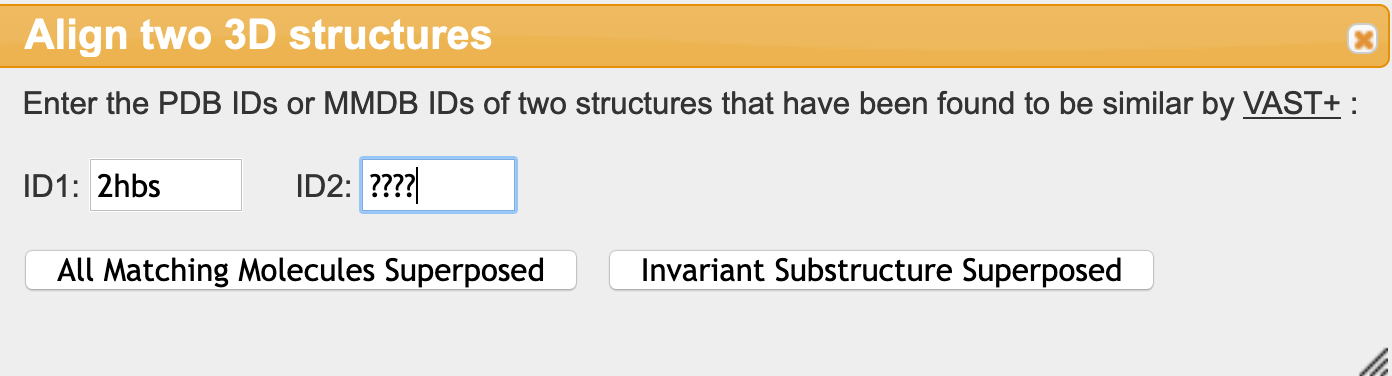
* Open the NCBI - iCn3D modeling software

(<https://www.ncbi.nlm.nih.gov/Structure/icn3d/full.html>).

* Open the File > Align > Structure to Structure.

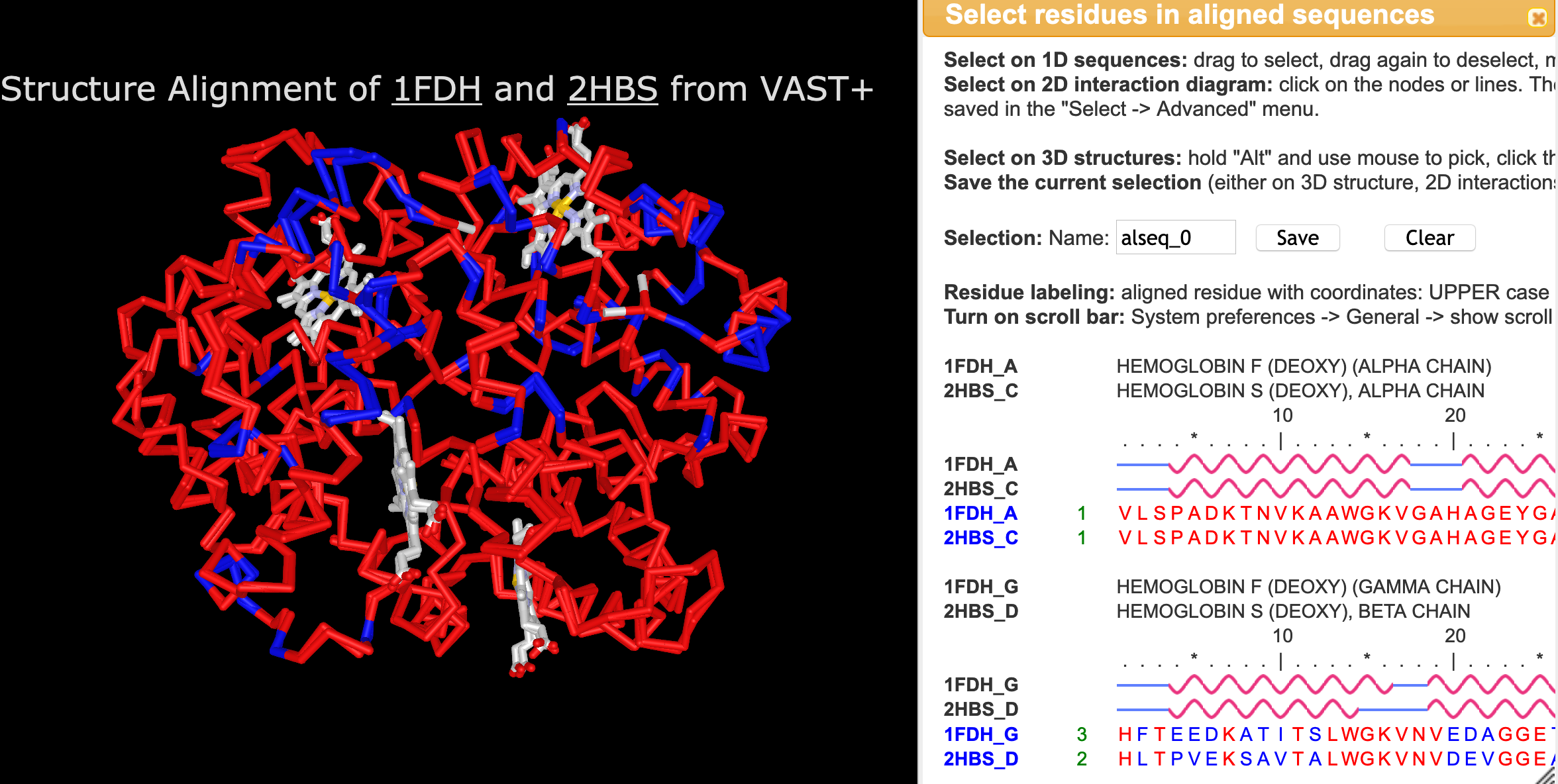


* This should open a window >> type in the IDs of the 2 PDB entries that you wish to compare. Type them in as shown below.



* Click on the button “All Matching Molecules Superposed” to see the HbS and HbF structures aligned.
  + Note the identical amino acids are shown in red – both in the sequence and graphical windows. Amino acids that vary in the  and  globin proteins are shown in blue.

*For your reference, the windows should appear as shown below:*



Q2. In which chains and where in these chains are the residues that are different in the two structures located? Support your answer with an image of the superimposed structures

Q3. How well aligned are the structures in these regions? Support your answer with an image of the superimposed structures.

Q4. The hydrophobic patch where the V6 side chain binds in low oxygen conditions includes residues between amino acids 80 and 90. From the Sequence alignment window can you find any one amino acid that is different in the  and  globin proteins.

* Display the different residue(s) identified above.
  + Select residues that you identified above by clicking and dragging on the amino acid one letter code in the sequence alignment window.
  + Show side chain of these amino acid by clicking on Styles >> Side chains >> Ball and Stick.
  + Zoom in on these amino acids click on View >> Zoom in Selection.
  + Color the amino acid side chains by CPK colors by clicking on Colors >> Atom.

Q5. Which of these amino acids can form hydrogen bonds? Compare the size of these side chains – which one is larger? Support your answer with an image.

Keep the differences between these residues in mind. It will come in handy for discussing the scenario presented in the assessment.

**Part 3: Changing Nicholas’ life**

*Box 13: Storyline*

The structural explorations reveal that the HbF structure is similar to the HbS structure barring a few minor differences. However, what is the benefit of increasing HbF concentration in Nicholas’ blood? Here we will explore how this changed Nicholas’ life.

Q1. How does having a higher amount of HbF benefit Nicholas?

Q2. Based on what you know about what hydroxyurea does, why do you think that Nicholas could be more active now?