**Nicholas’ Story**

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**Preparation:**

Prior to the case discussion in class (as a homework assignment), get acquainted to the case.

* Watch the video titled “Managing Sickle Cell Disease as a Teenager”

<https://www.youtube.com/watch?v=iKQmQHh4E2w>.

* Review the materials presented in Part 0 and answer the questions.

**Part 0: Understanding Sickle Cell Disease (SCD)**

*Box 1: Storyline*

The video that you watched described Nicholas’ experiences living with sickle cell disease (SCD). Before we explore any specific questions about Nicholas’ experiences, it may be helpful to understand what SCD is, how it is caused, and its key molecular players. This section presents a conversation between students in a classroom that introduces SCD.

a. Read the following conversation (a classroom scene) and explore the links listed herein:

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*Alex:* Seems like we need to review some biology and chemistry to really get this. Does anybody remember what causes sickle cell? I seem to remember from high school bio that it is caused by a single mutation in the gene that produces hemoglobin. Anyone else remember anything about SCD?

*Beatrice:* Yaa! Hemoglobin – that is the oxygen-transporting protein of red blood cells. Right? I remember that it has four polypeptide subunits; 2 alpha chains and two beta chains. My bio teacher said that Hemoglobin changes shape when it binds oxygen and that the amount it can hold varies with pH. That’s why it picks up oxygen in the lungs and dumps it in the muscles.

*Charlie:* Yes! We did a unit in my AP Bio class on hemoglobin and mutations. I think sickle cell is caused by one amino acid change in one of the subunits.

*Dorothy:* Really? One little amino acid change and then it can’t bind oxygen properly? How does that work?

*Charlie:* So, it makes a valine instead of a glutamate at this one position. Maybe that affects the shape of the molecule? We saw this cool animation in my high school class that shows how the mutation changes the shape. Here, let me show you. It’s on YouTube.

<https://www.youtube.com/watch?v=Y66B7PWrE00&feature=youtu.be>

*Eliza:* I read that there’s a lot of people, especially in tropical areas that carry that mutation, or something similar. I think its related to protection from malaria.

*Farah:* Yeah. I remember I did this study for my freshman seminar. There is a cool video about how Tony Alison figured out the relationship between sickle cell disease and Malaria. We should watch that you know <https://www.hhmi.org/biointeractive/making-fittest-natural-selection-humans>. Sickle cell disease affects millions of people worldwide. It is most common among people whose ancestors come from Africa; Mediterranean countries such as Greece, Turkey, and Italy; the Arabian Peninsula; India; and Spanish-speaking regions in South America, Central America, and parts of the Caribbean. Did you know that individuals with sickle cell disease have a lot of pain too – just like Nicholas. I never really understood why they have pain though.

*George:* I remember my friend, Harry, telling me about some new drug, Crizan… something, that can help reduce the pain. His aunt, Melissa Creary, helped develop the sickle cell program at CDC. She also studied communities in Brazil with high prevalence of sickle cell trait. Now she teaches at the University of Michigan. Perhaps we can email Dr. Creary and ask some questions about sickle cell disease and the causes of pain.

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Answer the following questions in a few sentences each:

Q1. What causes sickle cell disease?

Q2. What is hemoglobin? Where is it present in our body? Why is it so important for us?

Q3. What is the overall composition of hemoglobin?

Q4. How does the sickle cell mutation in hemoglobin (HbS) cause red blood cells to sickle?

Q5. What are some current medications/strategies for treating sickle cell disease?

**Part 1: The Sickle Cell Mutant**

*Box 2: Question*

In the video Nicholas describes his pain crisis as “it feels like someone is squeezing you, thumping – ba boom, ba boom”. Nicholas’ mom also talks about how he would have to be hospitalized frequently to treat his pain crisis. The first question that we will ask in this case is “**What is the molecular basis of Nicholas’ pain crisis?**”In this section we will explore the molecular basis for SCD pain crisis and some ways to reduce it.

In class, review the answers to questions in Part 0 then begin the molecular exploration.

*Box 3: Storyline*

Since we know that the pain is related to SCD, let us begin by exploring the molecule that was introduced in Part 0 as the cause of SCD.

To understand the significance of the sickle cell mutation, let us explore available molecular structures as follows:

* Where are the heme groups located in hemoglobin?
* How do they bind oxygen?
* Where is the mutation located? How does it impact the structure of mutant protein?

***Explorations using readymade virtual exhibits at the Online Macromolecular Museum***

1. Explore the Section II of the exhibit at

<http://earth.callutheran.edu/Academic_Programs/Departments/BioDev/omm/jsmolnew/hemo/hemoglobina.html#II>.

Examine the four polymer chains of hemoglobin (2 alpha chains and 2 beta chains), illustrated in ribbon representations. Carefully examine the section about heme mediated oxygen binding to understand how heme is bound to hemoglobin and how it impacts oxygen binding.

Q1. List one interaction through which a Heme group is bound to the hemoglobin structure. Include screenshots of the interaction(s) to substantiate your answer.

Q2. Where does the oxygen bind and how? Include screenshots of the interactions to substantiate your answer.

1. To learn about different kinds of covalent and non-covalent interactions, see exhibit at <http://earth.callutheran.edu/Academic_Programs/Departments/BioDev/omm/jsmolnew/bonding/chymo.html>

Hydrophobic interactions can sometimes be difficult to recognize so we will practice identifying them by exploring the section on hydrophobic interactions - now answer the following question.

Q3. List four amino acids that participate in hydrophobic interactions. Include screenshots of the interactions to substantiate your answer.

*Extra credit:* As you explore the hydrophobic residues note the PDB ID at the bottom of the page. Type the PDB ID in the top search box of the RCSB PDB website ([www.rcsb.org](http://www.rcsb.org)) to find out what this protein is.

Q3 extra: What is the protein that you are exploring?

1. To learn about the physiological impact of the structural changes resulting from the mutation of Glutamate 6 to Valine

<http://earth.callutheran.edu/Academic_Programs/Departments/BioDev/omm/jsmolnew/hemo/hemoglobina.html#III>

Explore the structures in this section and answer the following questions.

Q4. In the hemoglobin beta chain Glutamate 6 is located on the surface. How would the surface properties of the Sickle cell mutant protein change? Hint: What is the nature of the Valine side chain?

Q5. Which intermolecular forces (noncovalent interaction) leads to sickle cell hemoglobin (HbS) aggregation? Include screenshots of the interaction(s) to substantiate your answer.

**Part 2: Nicholas’ Pain Crises**

*Box 4: Storyline*

The structural explorations reveal how hemoglobin with the sickle cell mutation can aggregate.

A review article (Hematology Am Soc Hematol Educ Program. 2017 Dec 8; 2017(1): 546–555.), explains “A unique feature of SCD is vaso-occlusive crises (VOCs) characterized by episodic, recurrent, and unpredictable episodes of acute pain. Microvascular obstruction during a VOC leads to impaired oxygen supply to the periphery and ischemia reperfusion injury, inflammation, oxidative stress, and endothelial dysfunction, all of which may perpetuate a noxious microenvironment leading to pain.”

Here we will explore the relationship between aggregation of mutant hemoglobin to pain.

A glossary for some of the key words/phrases used in the explanation above is included below:

* Microvascular obstruction – small blood vessels are obstructed
* ischemia reperfusion injury - tissue damage caused when blood supply returns to tissue after a period of lack of oxygen
* inflammation - a localized physical condition in which part of the body becomes reddened, swollen, hot, and often painful, especially as a reaction to injury or infection.
* oxidative stress - a state where oxidative forces exceed the antioxidant systems due to loss of the balance between them
* endothelial dysfunction – condition when the inner lining of blood vessels fail to perform their normal functions.
* noxious microenvironment – poisonous local environment

Q5. Explain in a few sentences and with a suitable drawing how the HbS aggregation is connected to pain.

Q6. Based on your understanding of the structural basis of pain, can you suggest two approaches that can avoid the pain crises?

Q5. If you had to develop a new treatment for sickle cell disease how would you approach the problem. (Hint: use the deoxy HbS structure for inspiration).