**Gaucher disease: An Inherited Metabolic Disorder Caused by a Mutation in Acid b-Glucosidase**

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Focus concept

Mutations in the acid b-glucosidase enzyme, a hydrolase required for the degradation of glucosyl ceramides in the lysosomes, lead to a build-up of substrate resulting in the symptoms of Gaucher disease.

Abstract

This case focuses on a woman in her 20s who was recently diagnosed as having Gaucher disease, a diagnosis that comes with much relief for her, as she finally has an explanation for the symptoms of the disease that have plagued her entire life. Gaucher disease is a genetic disease involving a mutation in the acid b-glucosidase enzyme, a hydrolase required for the degradation of glucosyl ceramides in the lysosomes. The inability to degrade glucosyl ceramides leads to their build up in the spleen, liver, lungs, bones, and brain, which causes the symptoms observed in these patients—enlarged liver and spleen, liver malfunction, skeletal disorders, and neurological complications. A study of the acid b-glucosidase enzyme, involving the construction of mutants, and of small molecule inhibitors, leads to a greater understanding of how the enzyme works, and can also lead to the development of therapeutic agents to treat the disease. Inhibiting an enzyme with decreased function may seem counterintuitive as a treatment strategy, but research has shown that these compounds can bind to a mutated enzyme and act as molecular chaperones, shepherding the enzyme to the lysosome (where the inhibitor dissociates at the low pH), resulting in an increased amount of enzyme delivered to the lysosome.

Prerequisites

* Protein structure and function relationships
* Intermolecular forces involved in stabilizing protein structure
* Enzyme structure and catalytic mechanisms
* Lysosomal enzyme synthesis pathway (for a review, see [4.8B Lysosomes in Biology LibreTexts](https://bio.libretexts.org/Bookshelves/Microbiology/Microbiology_(Boundless)/04%3A_Cell_Structure_of_Bacteria_Archaea_and_Eukaryotes/4.08%3A_Other_Eukaryotic_Components/4.8B%3A_Lysosomes))

Learning objectives

At the conclusion of this case study, students will be able to…

* Describe how changes in the amino acids in an enzyme’s active site alters enzyme activity
* Identify intermolecular forces between the substrate and the amino acid side chains in an enzyme active site and explain why these forces are essential to enzyme activity
* Explain how a non-functional protein leads to a disease state
* Explain how small molecule inhibitors can inhibit an enzyme as a therapeutic agent to treat disease

Research question

How can we use what we know about the molecular structure of the acid b-glucosidase enzyme to design drugs to inhibit this enzyme, with the goal of treating Gaucher’s disease?

Lila’s story

Cristela, a university student in her junior year, was studying for a biochemistry exam in her room on a Sunday evening when she heard the front door of the apartment open. Lila, her apartment-mate, was returning from spending a few days at home with her family for the Rosh Hashanah holiday. Lila was carrying a large grocery bag in addition to her suitcase and Cristela ran to help her. “I brought lots of goodies from home that I know you will love,” Lila told Cristela as she began to take items out of the grocery bag. “Apples, honey, and pomegranates, which are traditional foods eaten at Rosh Hashanah. And my mom made a special challah, with honey and raisins.” Cristela’s tight-knit Catholic family had emigrated from Guatemala when she was a baby, and Cristela had not encountered Jewish customs until she’d met Lila at orientation during their first year.

“But that’s not the best part of my time away,” said Lila, as she continued to unpack. “What’s that?” mumbled Cristela, mouth full of the sweet, delicious challah bread. Lila laughed to see her friend’s obvious enjoyment of her mother’s baking. “I went to see my doctor when I was home, and I finally have a diagnosis for this condition that has been plaguing me for my entire life. I have Type I Gaucher disease. Apparently, it’s a genetic disease, although no one else in my immediate family has it. But my dad remembered an aunt of his who had symptoms similar to mine.” Lila had been in poor health most of her life, largely because the many physicians who treated her throughout her childhood mis-diagnosed her condition as either lupus or leukemia. As a child, Lila was prone to fractures and had the classic signs of the disease–enlarged abdomen (due to an enlarged liver and spleen), skeletal abnormalities, and severe fatigue due to anemia. Despite Cristela’s efforts to help her, Lila often missed class because of her symptoms. “I am so relieved to at last have a proper diagnosis that I can manage with drug treatment and lifestyle changes. My doctor had never seen a Gaucher patient in her practice before, but she’s been consulting with other physicians, as well as research scientists, to devise a treatment plan for me.”

Cristela’s interest was immediately piqued. “Gaucher disease is a lysosomal storage disease, right? I remember my biochemistry professor mention this briefly when we were discussing glycolipids.”

“If you say so!” laughed Lila, who was a global studies major. “My doctor tells me that I’m not a suitable candidate for ERT because of my allergies, which is fine with me, because that involves injections once every two weeks. Instead, she prescribed the drug Zavesca, which I can take orally.”

“That’s great,” said Cristela. “I’m so glad that you’re finally getting the help you need. And I can use my biochemistry knowledge to answer any questions you have!”

Background

Acid b-glucosidases (also known as glucocerebrosidases or GCases) catalyze the hydrolysis of d-glucosyl-*N*-acylsphingosine, also known as glucosylceramide. The structure of this compound is shown in Figure 1. The enzyme featured in this case study (EC 3.2.1.45) is a membrane-associated lysosomal hydrolase that is essential for catalyzing the hydrolysis of glucocerebrosides, a normal process in which the cell disposes of its obsolete parts. The breakdown products can be recycled for the synthesis of new biomolecules, but there is some recently published data that indicate that the breakdown products might also serve as signaling molecules that influence the aging process.



**Figure 1**: d-glucosyl-*N*-acylsphingosine (also known as glucosylceramide), the substrate for the acid b-glucosidase enzyme. The R group is typically a fatty acyl chain. Products are d-glucose and *N*-acylsphingosine (ceramide). If the acid b-glucosidase enzyme is nonfunctional, d-glucosyl-*N*-acylsphingosine accumulates.

The acid b-glucosidase enzyme is a single chain, three-domain, 497-amino acid residue 62-kDa protein. Synthesis of the protein begins on cytosolic ribosomes, which are directed to the ER following the emergence of an N-terminal sequence that is removed in the endoplasmic reticulum (ER) as the enzyme makes its journey from the ER to the lysosomes where it functions (Fig. 2). The glucosidase is glycosylated in the ER, a necessary structural requirement for proper protein folding. Disulfide bonds stabilize the protein. The glucosidase is directed to the lysosomes by binding to a mannose-6-phosphate receptor, which targets the enzyme to this organelle.

Diagram

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**Figure 2**: The acid b-glucosidase that is the subject of this case study is synthesized on ER-bound ribosomes. Synthesis begins on cytosolic ribosomes, but when a lysosome-targeting signal emerges, the ribosome is directed to the ER, where it binds to a specific receptor. Synthesis is completed, and the glucosidase is threaded through a transporter to the interior of the ER. In the ER lumen, the glucosidase (triangle) is glycosylated and acquires a mannose-6-phosphate marker (shown as a red circle labeled with a P). Molecular chaperones in the ER assist in proper protein folding. The glucosidase is then transferred to the *cis*-Golgi, where it binds to the mannose-6-phosphate receptor (shown in magenta as a half-circle). The glucosidase-receptor complex buds off from the *trans* Golgi and fuses with the late endosome, where the glucosidase dissociates from the receptor at the low pH of the endosome. Finally, the glucosidase is delivered to the lysosome (a membrane-bound organelle containing digestive enzymes; its function is to rid the cell of obsolete parts) where it has a half-life of about 60 hours. Glycosylation of the enzyme is critical to this survival time in the acidic environment (pH ~ 5) in the lysosome. Proper folding of the protein is also required for successful progression through the pathway, as improperly folded proteins may be retro translocated back into the cytosol for degradation by the proteasome (from Filocamo and Marrone, *Human Genomics* **5(3)**, 156-159, 2011. © All rights reserved).

Patients with Gaucher disease have a non-functional acid b-glucosidase enzyme, which results in the accumulation of d-glucosyl-*N*-acylsphingosine in the spleen, liver, lungs, bones, and brain, which causes the symptoms observed in these patients—enlarged liver and spleen, liver malfunction, skeletal disorders, and neurological complications. While the genetic disease is most common in the Ashkenazi Jewish population, the disease has a world-wide distribution, affecting individuals of all races and ethnicities. The most common mutation involves a substitution of serine for asparagine at residue 370 (N370S) which accounts for about three-quarters of the cases in the Ashkenazi Jewish population and about a third of the non-Jewish population. Interestingly, Asn 370 is not a catalytic residue. Type I Gaucher patients typically have a very low level (about 10-15% of normal) of b-glucosidase enzyme activity.

There are three strategies used to treat Gaucher disease, diagrammed in Figure 3. One strategy involves enzyme replacement therapy (ERT) in which patients are provided with a recombinant form of the acid b-glucosidase enzyme (CerezymeTM). A disadvantage of this therapy is that patients may develop an immune response to the exogenous enzyme, limiting its effectiveness. A second strategy aims to reduce the concentration of the substrate (SRT) by inhibiting the synthase enzyme that synthesizes glycosphingolipids. Reduction in substrate concentration is the outcome, due to the decreased synthesis of the substrate, reducing the amount required to be degraded by the b-glucosidase enzyme, which has the potential to be successful even with the low activity of the enzyme found in Gaucher patients. A third strategy involves the use of inhibitors that act as “pharmacological chaperones” which bind to the active site and stabilize the mutant form of the enzyme at neutral pH as it progresses through the secretory pathway diagrammed in Figure 1. The inhibitor dissociates when the enzyme reaches the low pH environment of the lysosome. This is termed chaperone-mediated therapy (CMT). Interestingly, there are compounds that are able to bind to both the glucosylceramide synthase as well as the acid b-glucosidase, meaning that a single drug has the potential to act in a way that employs both the SRT and CMT strategies.

**Figure 3**: Therapies to treat Gaucher disease, in which a low-functioning acid b-glucosidase enzyme results in the accumulation of glucosylceramide, which is responsible for the symptoms of the disease. (1) Enzyme replacement therapy (ERT) involves providing the missing acid b-glucosidase enzyme. (2) Substrate reduction therapy (SRT) involves using a drug that binds to and inhibits the glucosylceramide synthase enzyme (green), which results in a decrease in the amount of glucosylceramide. (3) Chaperone-mediated therapy (CMT) involves the use of a drug which binds to the mutant acid b-glucosidase at neutral pH (shown in blue) and stabilizes the mutant enzyme as it makes its way through the cellular trafficking pathway shown in Figure 2. Interestingly, there are compounds that can bind both to the synthase and to the b-glucosidase, using a single molecule that employs both SRT and CMT strategies.

The design and synthesis of drugs, small organic molecules that are able to bind to either the synthase or the b-glucosidase enzymes (or both), involves an understanding of the mechanisms of both enzymes. The mechanism of the b-glucosidase enzyme is shown in Figure 4. The role of the enzyme is to catalyze the hydrolysis of the substrate d-glucosyl-*N*-acylsphingosine to yield glucose and *N*-acyl sphingosine (ceramide). (Various mechanisms have been proposed, but the mechanism shown in Figure 4, which proceeds via an oxocarbenium ion, is supported with structural data.) When the newly synthesized b-glucosidase arrives in the acidic lysosome, the enzyme becomes tightly associated with the lysosomal membrane. The b-glucosidase enzyme has two Glu residues in its active site, Glu235 and Glu340 (shown in blue in the figure). The catalytic cycle begins when the *O*-glycosidic bond in the d-glucosyl-*N*-acylsphingosine substrate (shown as Step 1 in Fig. 1) is first protonated by the Glu235 residue, forming the oxocarbenium ion and liberating the ceramide, the first product. The oxocarbenium ion (with its oxygen shown in red) is nucleophilically attacked by Glu340. Glucose becomes covalently attached to the enzyme (Step 2). In Step 3, Glu235 removes a proton from a water molecule, and the resulting hydroxide ion nucleophilically attacks the glucose-enzyme complex, liberating b-glucose, the second product, in Step 4. Catalytic activity is enhanced when the enzyme is associated with the negatively charged phospholipids of the lysosomal membrane.

A structure of a chemical formula

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**Figure 4**: The catalytic mechanism of acid b-glucosidase proposed by Brumshtein, et al. The ceramide moiety is designated as an R group (*inset,* shown in magenta). Active site Glu residues are shown in blue. The substrate is shown in black, with oxygens participating in the mechanism shown in red.

Compounds that have shown promise in treating Gaucher disease are imino- and azosugars. These compounds resemble glucose but have a nitrogen instead of an oxygen in the six-membered ring and the hydroxyl group on C1 is missing, which increases the stability of the drug. The iminosugar compounds mimic the oxocarbenium intermediate formed in the reaction mechanism as shown in Figure 4. There are hundreds of naturally occurring iminosugars and synthetic organic chemists can add to this collection by synthesizing derivatives based on the naturally occurring sugars. An example of a “lead” compound is 1-deoxynojirimycin (DNJ) which can be alkylated to form *N*-butyl-deoxynojirimycin, abbreviated NB-DNJ. NB-DNJ was the first drug approved to treat Gaucher patients; its generic name is miglustat and its trade name ZavescaTM. Attachment of a longer alkyl chain results in *N*-nonyl-deoxynojirimycin (NN-DNJ). The structures and properties of these compounds are shown in Table 1.

**Table 1:** Acid b-glucosidase inhibitors

|  |  |  |
| --- | --- | --- |
| **Compound name** | **Structure** | **Generic and trade names** |
| 1-deoxy-nojirimycin (DNJ) |  |  |
| *N*-butyl-deoxy-nojirimycin (NB-DNJ) |  | Miglustat, ZavescaTM |
| *N*-nonyl-deoxy-nojirimycin (NN-DNJ) |  |  |

Questions

1. Patients with Gaucher disease express an acid b-glucosidase enzyme with impaired catalytic activity. Consult Figure 2 and read the caption carefully. Brainstorm with your team and make a list of about four or five various steps in either the processing of the enzyme or the enzyme structure itself that could potentially result in a patient’s inability to degrade d-glucosyl-*N*-acylsphingosine.
2. The acid b-glucosidase enzyme catalyzes the hydrolysis of d-glucosyl-*N*-acylsphingosine. Draw the structures of the products of the reaction, using the structure provided in Figure 1 as the substrate.
3. We can use the [Protein Data Bank](https://www.rcsb.org/search/browse/diseases) to obtain information about the acid b-glucosidase enzyme that is the focus of this case study. Access the Protein Data Bank and enter the code 2F61. You can explore various aspects of the structure of the enzyme by accessing the tabs at the top of the page.

* Is the acid b-glucosidase enzyme a monomer or an oligomer?
* How many amino acids in length is the enzyme?
* Click on the Sequence tab and look at the Active Site entry. Hover your mouse over the pink dots corresponding to this entry. Identify the amino acids in the enzyme’s active site.

1. The enzyme mechanism is described in the Background and shown in Figure 4. A pH-rate profile, in which the activity of the enzyme is measured over a pH range, is shown in Figure 5. From the pH-rate profile, the following can be discerned:

* The pH optimum
* The ascending inflection point corresponding to the initial *pK*R for one active site Glu residues
* The descending inflection point corresponding to the initial *pK*R for the other active site Glu residue

Determine the pH optimum and the p*K*R values for both Glu residues and be sure to assign the correct p*K*R value to each Glu residue. Are these residues protonated or unprotonated? Consult the mechanism of the enzyme in Figure 4 and explain why you assigned the p*K*R values the way you did.

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**Figure 5**: pH-rate profile for acid b-glucosidase (from Karatas, et al., *Heliyon* **6** e05191, 2020. ©All rights reserved.)

1. The Disease Ontology feature of the Protein Data Bank can be used to identify molecular entities associated with diseases identified by Mondo Disease Ontology identification number. Using the search function, these molecular entities are retrieved as a group, which can be viewed to see if there are any common features to the structures that will provide new insights into the disease or could possibly be used to identify drug targets.

Access the [Disease Ontology feature](https://www.rcsb.org/search/browse/diseases) at the Protein Data Bank and type “Gaucher disease type I” into the search bar. What is the MONDO number for this disease? How many polymer entities are associated with the disease? In general, what do these molecular entities have in common?

1. The scientific research team constructed two acid β-glucosidase mutants: K79N and R120Q. [Note: “K79N” means that a lysine (K) in the wild-type enzyme was replaced with an asparagine (N). “R120Q” means that an arginine (R) in the wild-type enzyme was replaced with a glutamine (Q).]

Use the program PyMOL to visualize the acid b-glucosidase. The PDB code is 2F61. Note that the crystal structure is presented in the Protein Data Bank as a dimer, but if you look at the Biological Assembly box at the left, you’ll see that the biologically active protein is a monomer. We can load the biologically active monomer into PyMOL by entering **fetch 2F61, type=pdb1** to load the monomer (and not the dimer).

* + Begin by hiding the waters.
* Display the different domains in different colors as described below. It will be easiest to do this if you create and rename the domains as selections Domain I, Domain II, and Domain III.
  + - Domain I (green): Residues 1-27 and 383-414 (this domain contains two disulfide bonds at 4-16 and 18-23 which are important for maintaining stability)
    - Domain II (cyan): Residues 30-75 and 431-497
    - Domain III (magenta): Residues 76-381 and 416-430 (this domain contains the catalytic site)
  + Display the two active site Glu residues as sticks, as well as the Lys79 and the Arg 120 residues, which are also located in the active site and are able to impact catalytic activity, as we will see in Question 5. Use the **set cartoon\_side\_chain\_helper, on command to display just the side chains. Displaying the sticks in a different color (perhaps coloring by element) will allow these side chains to be distinguished from the main chain cartoon.**
  + Are there noncovalent contacts between the active site Glu and the Lys 79 and/or Arg 120 residues, which also reside in the active site? Use the measurement tool to investigate this question, keeping the following in mind:
    - Hydrogen bonds are typically 2.8-3.4 Å in length.
    - Ionic bonds are typically shorter than hydrogen bonds.
    - London dispersion forces (or van der Waals—VDW—forces) are typically 3.8-4.2 Å in length.

In your case study, provide a minimum of two images (saved as .png files and imported into your document) in which you display the work as directed in this question. Be sure to provide figure captions to orient the reader.

1. A graph of activity and activity

   Description automatically generatedThe activities of the K79N and R120Q mutants were measured and are shown in Figure 6. Additional kinetic data is shown in Table 2.

**Table 2**: *K*M values for glucosidase enzymes

|  |  |
| --- | --- |
|  | *K*M (mM) |
| Wild type | 1.9 ± 0.5 |
| K79N | 2.4 ± 0.6 |
| R120Q | 2 ± 1 |

**Figure 6**: Glucosidase activity of two mutants, K79N and R120Q (at right), compared to the wild-type enzyme (figure constructed from data presented in Liou, et al.).

Write a short paragraph in which you compare the activities of the mutants with the wild-type enzyme, describing the results as shown in Figure 6. Then propose hypotheses in which you explain how the amino acid substitutions in each of the mutants results in a non-functional protein, using the information in Figure 4 and Question 3.

1. Next, we will investigate how the inhibitor NB-DNJ binds to the glucosidase. The compound NB-DNJ has been approved for treatment of Gaucher’s disease; its trade name is ZavescaTM, and it is the drug prescribed by Lila’s physician to treat her symptoms. The glucosidase enzyme crystal structure, with the NB-DNJ inhibitor co-crystallized, has been determined. The PDB code is 2V3D. We will visualize the active site using the procedure described by “Dr. Molecule” in her video “Active Site in Minutes” which can be found here: <https://www.youtube.com/watch?v=mBlMI82JRfI&t=1399s>

In your case study, be sure to display several images in which you demonstrate how you completed the following exercises.

* Load the biologically active monomer by typing **fetch 2V3D, type=pdb1** in the command line.
* Hide the waters.
* Hide all of the ligands except for the NB-DNJ bound to the A chain (NB-DNJ is denoted as **NBV** in PyMOL). Create selection **NBV** so that you can refer to it as you build your image.
* Show the active site Glu resides (Glu235 and Glu340) as sticks, in a contrasting color from Chain A, displayed as a cartoon. Use the **set cartoon\_side\_chain\_helper, on command to show just the Glu side chains.**
* **Show all amino acid residues within 5 Å of the active site by using the command show sticks, byres all within 5 of NBV** as described in the video.
* **Show polar contacts between the NB-DNJ and amino acid side chains. Are there any contacts with either of the active site Glu residues?**
* **Show any contacts between NB-DNJ and water molecules, as demonstrated in the video.**
* Measure the lengths of the interactions between NB-DNJ and water and the amino acid side chains (and classify these contacts as hydrogen bonds, van der Waals forces). **Are there any contacts with either of the active site Glu residues?**
* Export at least one image as a .png file in which you display the NB-DNJ with its polar contacts.
  + Display the NB-DNJ in a contrasting color.
  + Show the amino acids within 5 Å of the NB-DNJ.
  + Hide the amino acid side chains within 5 **Å** that do not have any contacts to the NB-DNJ.
  + Show the active site Glu residues (in a contrasting color), whether or not the NB-DNJ makes contacts with these residues.
  + Show any water molecules making contact with the NB-DNJ as red spheres.
* Construct a table in which you identify the residues making contacts with the NB-DNJ and note the measured distance between them.

1. Smith, et al., identified the following residues as important in the active site of the enzyme: Arg120, Asp127, Phe128, Trp179, Asn234, Tyr244, Phe246, Tyr313, Ser345, Trp381, Asn396, Phe397 and Val398. How many of these residues were you able to identify when you constructed your active site? Some of these residues are further away than 5 Å from the NB-DNJ, so you may not have captured all of them.
2. Repeat the above exercise with b-glucosidase bound to NN-DNJ (PDB code 2V3E). This compound was synthesized by pharmaceutical scientists but is not yet an approved drug to treat Gaucher’s disease. In your case study, display several images in which you demonstrate how you completed the following exercises.

* Load the biologically active monomer by typing **fetch 2V3E, type=pdb1** in the command line.
* Hide the waters.
* Hide all of the ligands except for the NN-DNJ bound to the A chain. (NN-DNJ is denoted as **NND** in PyMOL). Create selection **NND** so that you can refer to it as you build your image.
* Show the active site Glu resides (Glu235 and Glu340) as sticks, in a contrasting color from Chain A, displayed as a cartoon. Use the **set cartoon\_side\_chain\_helper, on command to show just the Glu side chains.**
* **Show polar contacts between the NN-DNJ and amino acid side chains.**
* **Show any contacts between NN-DNJ and water molecules.**
* Measure the lengths of the interactions between NN-DNJ and water and the amino acid side chains (and classify these contacts as hydrogen bonds, van der Waals interactions, or ionic interactions).
* Export at least one image as a .png file in which you display the NN-DNJ with its polar contacts.
  + Display the NN-DNJ in a contrasting color.
  + Show the amino acids within 5 Å of the NN-DNJ.
  + Hide the amino acid side chains within 5 **Å** that do not have any contacts to the NN-DNJ.
  + Show the active site Glu residues (in a contrasting color), whether or not the NN-DNJ makes contacts with these residues.
  + Show any water molecules making contact with the NN-DNJ as red spheres.
* Construct a table in which you identify the residues making contacts with the NN-DNJ and note the measured distance between them.

1. The image in Figure 7 shows NN-DNJ bound to the glucosidase enzyme. The enzyme is shown as a hydrophobicity map, with dark red being the most nonpolar, white the most polar and pink being in-between.

A close-up of a red and white molecule

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**Figure 7**: PyMOL image of the acid b-glucosidase enzyme with the ligand NN-DNJ (shown in magenta) bound. The enzyme is shown as a surface with the most nonpolar portions of the enzyme shown in red and the most polar in white, with pink being intermediate.

The IC50 is defined as the amount of inhibitor required to inhibit 50% of the enzyme. The IC50 value for NB-DNJ is 520 μM and the IC50 value for NN-DNJ is 660 nM. Use the structures of the compounds in Table 1 and the image in Figure 7 to explain the significance of the differences of these values.

1. Genetic testing reveals that Lila’s glucosidase enzyme has an N370S mutation, which is the most common mutation found in patients with Gaucher’s disease. Propose a hypothesis in which you explain why an amino acid change in this position could result in an enzyme with impaired catalytic activity.
2. Let’s return to the Research Question posed at the beginning of the case. How can we use what we know about the molecular structure of the acid b-glucosidase enzyme to design drugs to inhibit this enzyme, with the goal of treating patients like Lila with Gaucher’s disease? Use your answers to previous questions in this case study and write a short paragraph in which you address this question.

Lila’s story: Epilogue

It’s now May, and the school year is ending. Lila has been taking Zavesca since her diagnosis the previous September. She’s just returned from seeing her doctor and Cristela is anxious to hear about Lila’s visit.

Lila shows some documents provided to her by her doctor to Cristela. “Look at these results!” she exclaims. “My doctor explained to me what these values mean. After nine months on Zavesca, my spleen volume is lower, my liver health has improved, and my bone scans are nearly normal!”

Cristela was happy to see her friend in such good health, after all she had been through. “My doctor told me that she had a patient on ERT and didn’t respond well,” Lila continued. “He developed allergies and had to stop ERT because he developed severe skin allergies, and he really didn’t want to try another type of treatment. But he eventually tried Zavesca and improved, so my doctor thought that this treatment regimen could work for me as well.”

“So, tell me all about your summer internship!” said Cristela.

“I’m going to be working with human rights organization in Ecuador that works with vulnerable populations of women. I’ll be organizing workshops, alongside community leaders, in which we empower women by teaching them how to access a variety of social services.”

“Aren’t you nervous?” asked Cristela.

“A year ago, I would have been, not because of the project—which will be admittedly challenging—but because I would have been worried about my health. But I don’t think that I need to worry about health issues this summer the way I have in the past. What about you? What are your plans for this summer?”

“I’ve accepted a position in one of the laboratories on campus,” said Cristela. “My biochemistry professor recommended me because I had done well in the class. And guess what? I’ll be researching new drugs to treat Gaucher’s disease!”

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