

The Biochemistry of Curly and Straight Hair

by

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Part I – Introduction

It was a busy weekend for Felicia who had to get her family ready for Easter Sunday. Felicia was the primary caretaker of her three granddaughters. Madison was the middle child at 10 years of age and she hated when it was time for her grandmother to do her hair. She disliked having to sit still because there were so many other things she could do such as playing on her iPad or talking on the phone with friends.

“Ouch, Grandma! That hurts,” exclaimed Madison.

“I’m just combing your hair, Madison. Please keep still! You’ve got it so much easier than when I was your age. You have a chemical relaxer that can change your curls into straight hair. When I was coming up, my mother had to use a straightening comb. She first used this heavy pressing grease to oil my scalp and then she would lay the straightening comb on the stove until it got piping hot. My hair would look good after she finished, but it was painful going through the process. Every now and then she would burn the tips of my ears or my forehead by accident. Madison, be grateful that you have this relaxer that makes your hair straight without having to add heat. Madam C.J. Walker was a genius for inventing a line of hair care products for girls with curly hair and Annie Malone for patenting the straightening comb, but I am glad for the creation of the chemical relaxer.”

“Grandma, that was a long time ago. And besides, I think I want to stop getting chemical relaxers to straighten my hair. You don’t know the effects these chemicals have on your body. Is it healthy? And besides, all of the girls in my school are rocking the natural curly looks. How can I get my curls back? You know I don’t like waiting for anything. How long do you think it will take for this relaxer to grow out?”

“Madison, you have to be patient. Everything doesn’t happen right away when you want it to. Maybe you should decide on a career in chemistry where you can create your own formula that can cause your hair to be curly or straight in 10 minutes or less—some magic in a jar? Anything is possible when you believe and work hard toward your goal.”

“You know what, Grandma, that’s a great idea! I think I do want to become a chemist so I can learn about the science behind relaxers, shampoos and other hair care products.”

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Credit: Photo of Madam C.J. Walker., entrepreneur, philanthropist, and activist who made her fortune by developing and marketing a line of beauty and hair products. PD, <https://commons.wikimedia.org/wiki/File:Madam_CJ_Walker_face_circa_1914.jpg>.

Part III – The Molecules of Life

Madison could hardly contain herself. She was giddy that maybe today was the day that Mr. Thompson would explain why the chemical relaxers she used when she was younger could straighten the curly coils of her hair and how one could go the other way from straight to curly. Could this be the day that her questions would be answered?

Mr. Thompson cleared his throat. “I know everyone has read the section on the major molecules of life. You now know that the four major macromolecules are carbohydrates, lipids, nucleic acids and proteins. Each of these macromolecules is formed from basic building blocks that are assembled through various chemical reactions. Dehydration reactions build macromolecules from their basic building blocks while hydrolysis reactions break down the macromolecules into their building blocks.”

Madison was eager for Mr. Thompson to continue; this was all very interesting, but she really wanted him to talk about hair. Then she recalled her grandmother saying, *Madison, you have to be patient.*

“Class, remember that I was going to talk about the macromolecules in terms of your hair, so keeping to my promise, I’ll do just that. The type of hair that you have—curly, wavy, or straight—is dictated by your DNA. Your DNA is the genetic material that you obtain or inherit from your parents. The information stored in your DNA, which contains your genes, directs the production or synthesis of the second macromolecule, which is protein. Proteins are responsible for most of the cellular functions within a cell. The building blocks of proteins are called amino acids, which join each other in a dehydration reaction through the formation of peptide bonds. One of the major types of protein in hair is called keratin. You may have heard about keratin in some of the hair care products you use. This protein is important in making your hair stronger and resistant to breakage.”

“The third type of macromolecule is carbohydrate. Carbohydrates consist of the elements carbon, hydrogen, and oxygen. Their building blocks are called monosaccharides, such as glucose, and these monosaccharides chemically bond together through dehydration reactions to form a polysaccharide, such as starch. Carbohydrates are essential for storing energy in a cell. When a cell needs energy to do cellular work, the energy stored within the chemical bonds are broken to release the energy to the cell. All cells need energy, including your hair cells.

“The final type of macromolecule is lipid. Lipids are hydrophobic molecules that have high energy chemical bonds. In the scalp, there are oil glands that release a lipid substance called sebum, which helps to lubricate the hair. So as you can see, class, each of the major macromolecules plays a role in the development or maintenance of your hair.”

Madison raised her hand. “Mr. Thompson, so how can chemical relaxers, a hot comb, or perms change the texture of your hair from curly to straight or from straight to curly?”

“Madison, I’m so glad you asked that question. We are out of time, but I promise that will be the subject of our discussion tomorrow.”

Madison was nearly exasperated. She had to wait yet again, but she hoped that her patience would soon be rewarded.

Questions

1. What are the building blocks of the four major macromolecules? Draw and describe an example of a reaction that shows how a dipeptide is formed and broken down.
2. Explain how each of the macromolecules contributes to the development and maintenance of hair.
3. What do you predict is the answer to the question that Madison asked at the end of class?

Part IV – The Chemical Process of Chemical Relaxers, Hot Combs and Perms

Mr. Thompson entered the classroom and stood before his desk. “Hello class. I promised you that today I would discuss the topic that Madison raised about how chemical relaxers, hot combs and perms can modify the texture of your hair. Recall our previous discussion of the four major macromolecules of life. One of those, namely protein, plays an especially important role in this chemical process in virtue of its structure. We stated that the building blocks of proteins are amino acids. The first structure of a protein is its amino acid sequence. The secondary structure of a protein consists of folds and twists stabilized by hydrogen bonds that result in an alpha helix shape or a beta pleated sheet. The tertiary structure is where the protein becomes functional and assumes a three dimensional shape that consists of a single polypeptide chain and one or more of the secondary structures. In aqueous environments, the main driving force of stabilization of tertiary structures are hydrophobic interactions between nonpolar side chains of amino acids, which brings other amino acids closer together forming ionic bonds, disulfide bonds and hydrogen bonds. Disulfide bonds are a type of covalent bond where the two sulfur atoms from cysteine amino acids will cross-link with each other. The final shape some proteins may have is the quaternary structure where proteins have two or more polypeptide chains that are stabilized by mainly noncovalent bonds, such as hydrophobic interactions, hydrogen bonds and ionic bonds.”

Madison, annoyed, interjected. “Mr. Thompson, this is good information and everything, but what does this have to do with the question I asked? I don’t see the connection.”

“If you let me continue I’ll answer your question and you will see how everything fits together. Alpha keratin, a major component of hair, is a fibrous protein having a quaternary structure with many alpha helix structures. This protein contains many cysteine amino acids that are capable of forming disulfide bonds that can stabilize the structure of the protein. When certain chemicals are added to hair such as the ones found in chemical relaxers, or when heat is applied to hair with flat irons or hot combs, it disrupts the shape of the alpha helix or beta pleated structures in the alpha keratin by unfolding it. This process of unfolding these structures in alpha keratin is called denaturation. When a protein becomes denatured or unfolded, it changes the shape of the protein and the function of the protein may also be lost as a result. Thus, chemical relaxers and hot combs can change curly hair to straight hair by the denaturation of alpha keratin.”

Mr. Thompson continued. “Perms work by creating a permanent wave in your hair. The chemicals in perms, such as ammonium thioglycolate, a reducing agent and a perm salt, work by breaking disulfide bonds within the cysteine amino acids in the keratin protein in hair. The hair is then wrapped in curlers that help to create a new shape by holding the polypeptide chains in new positions. A neutralizing reagent, which is also known as an oxidizing reagent, is then added to allow new sulfide bonds to lock the hair in place.”

Another student was slightly confused and asked, “Mr. Thompson, what’s the difference between a reducing reagent and an oxidizing reagent?”

Mr. Thompson smiled. “Great question, Ms. Shepard. I’d like you and the rest of the class to do some research to find out what reducing agents and oxidizing reagents are and the role they play in breaking and forming chemical bonds.”

Questions

1. What chemical bonds stabilize the different structures in primary, secondary, tertiary and quaternary structures?
2. Draw and model simple primary, secondary, tertiary and quaternary structures of proteins using clay or a model kit.
3. Compare and contrast a reducing and oxidizing reagent and the role that they play in building chemical bonds.
4. Demonstrate through chemical modeling what happens to the protein structure (keratin) of curly hair after a chemical relaxer and heat are applied and what happens to straight hair after a chemical perm or relaxer is applied.