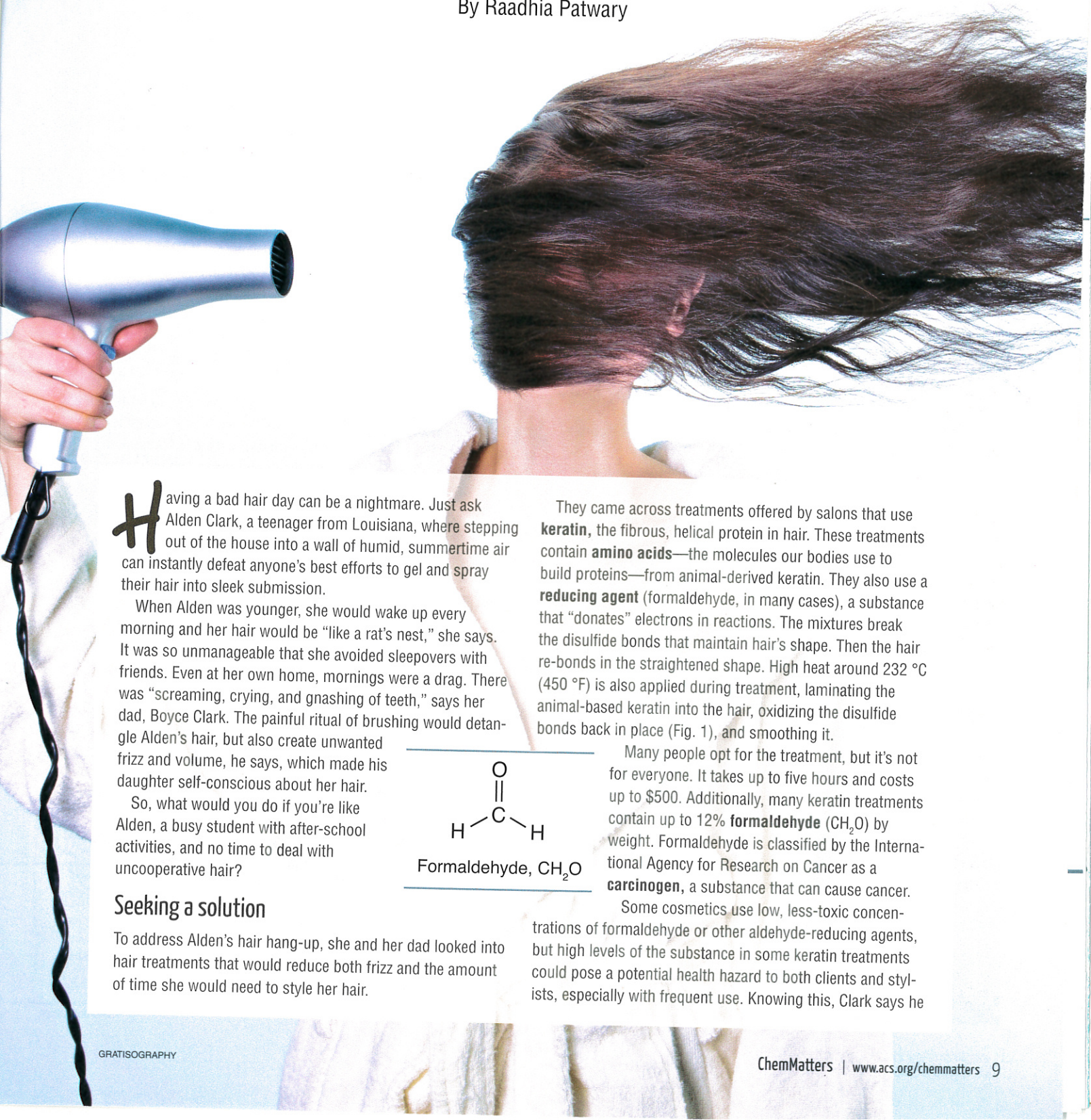
Fighting Frizz

How Chemistry Solved a Bad Hair Day

By Raadhia Patwary



Having a bad hair day can be a nightmare. Just ask Alden Clark, a teenager from Louisiana, where stepping out of the house into a wall of humid, summertime air can instantly defeat anyone's best efforts to gel and spray their hair into sleek submission.

When Alden was younger, she would wake up every morning and her hair would be "like a rat's nest," she says. It was so unmanageable that she avoided sleepovers with friends. Even at her own home, mornings were a drag. There was "screaming, crying, and gnashing of teeth," says her dad, Boyce Clark. The painful ritual of brushing would detangle Alden's hair, but also create unwanted frizz and volume, he says, which made his daughter self-conscious about her hair.

So, what would you do if you're like Alden, a busy student with after-school activities, and no time to deal with uncooperative hair?

Formaldehyde, CH_2O

Seeking a solution

To address Alden's hair hang-up, she and her dad looked into hair treatments that would reduce both frizz and the amount of time she would need to style her hair.

They came across treatments offered by salons that use **keratin,** the fibrous, helical protein in hair. These treatments contain **amino acids**—the molecules our bodies use to build proteins—from animal-derived keratin. They also use a **reducing agent** (formaldehyde, in many cases), a substance that "donates" electrons in reactions. The mixtures break the disulfide bonds that maintain hair's shape. Then the hair re-bonds in the straightened shape. High heat around 232 °C (450 °F) is also applied during treatment, laminating the animal-based keratin into the hair, oxidizing the disulfide bonds back in place (Fig. 1), and smoothing it.

Many people opt for the treatment, but it's not for everyone. It takes up to five hours and costs up to $500. Additionally, many keratin treatments contain up to 12% **formaldehyde** (CH_2O) by weight. Formaldehyde is classified by the International Agency for Research on Cancer as a **carcinogen,** a substance that can cause cancer.

Some cosmetics use low, less-toxic concentrations of formaldehyde or other aldehyde-reducing agents, but high levels of the substance in some keratin treatments could pose a potential health hazard to both clients and stylists, especially with frequent use. Knowing this, Clark says he

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wouldn't let his teenage daughter get a commercial keratin straightening treatment.

Instead, Clark, who has a Ph.D. in geochemistry, set out to come up with a safer solution to help his daughter get a handle on her hair. Although his field is quite different from cosmetics chemistry, he recalls thinking, "How hard can shampoo chemistry be?"

Hairy beginnings

Clark started experimenting with **surfactants** and other ingredients. Surfactants are molecules that, when added to a liquid, reduce its surface tension. In shampoos, they act as the cleansing ingredient. Creating effective, stable hair products turned out to be a lot harder than he anticipated.

To better understand hair science, Clark headed to his local university library for textbooks on the chemical and physical characteristics of hair. He learned that a strand of hair is made of three different layers (Fig. 2).

The outer layer is called the **cuticle,** which is like a roof with shingles. It provides a **hydrophobic** ("water-fearing"), protective layer to the hair, and is the layer associated most with aesthetic traits of hair such as shine and smoothness. The next layer is the **cortex,** which is composed of dead cells packed with **hydrophilic** ("water-loving") keratin proteins that give hair strands strength and structure. The cortex is also the layer that holds the hair's pigment. Inside the cortex is the **medulla,** a sponge-like layer.

Clark says that frizz occurs when the cuticle is damaged, which happens as your hair is exposed to the sun's ultraviolet rays, heat, air pollutants, or hair products such as dyes. This damage lifts the cuticle, allowing moisture in. A lifted cuticle reflects light poorly, giving hair a dull appearance, and allows strands to catch on each other. This causes static buildup and tangles.

As moisture gets in between keratin proteins, the hair shaft swells. Because the defects in the cuticle are not uniform, a wave or kink forms along the hair strand. Frizz results when thousands of hairs are swelling and waving in different locations.

To tackle this problem, Clark set out to create a product to clean hair and protect it from damage at the same time. Starting in a makeshift kitchen lab, he experimented with various surfactants to make a conditioning shampoo that would clean hair without stripping away its natural oils. Clark also tried adding positively charged polymers or proteins to balance out the negative charge of defects in the hair cuticle. Mixing stable emulsions using cationic polymers and anionic surfactants was a challenge.

To add to the complexity of the problem, Clark wanted the product to be

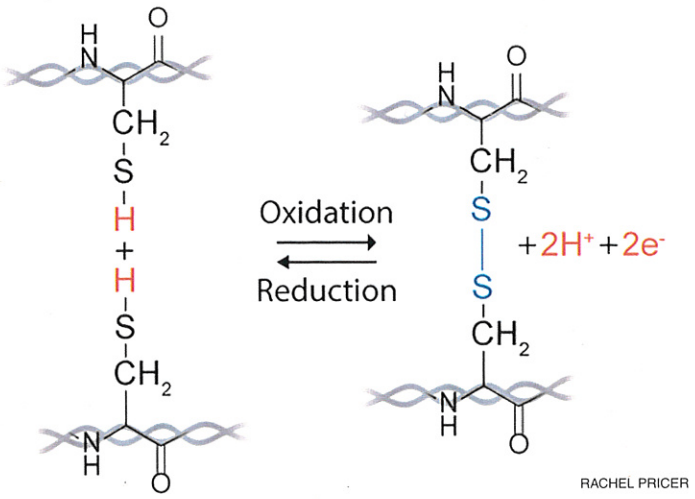

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FIGURE 1. Breaking and re-forming disulfide bonds in hair are key steps in curling or straightening hair. The disulfide bonds form between the cysteine amino acids in keratin.

« Since she was little, Alden Clark has struggled with tangles and unruly hair.

BOYCE CLARK

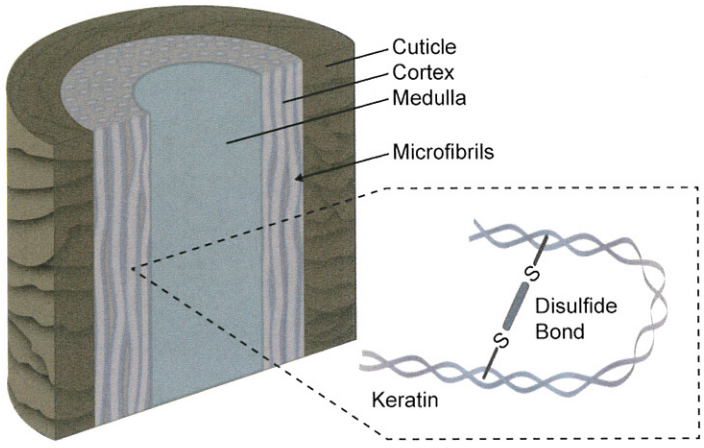

FIGURE 2. Hair strands consist of three layers: the cuticle, the cortex, and the medulla. The cortex is primarily made of keratin.

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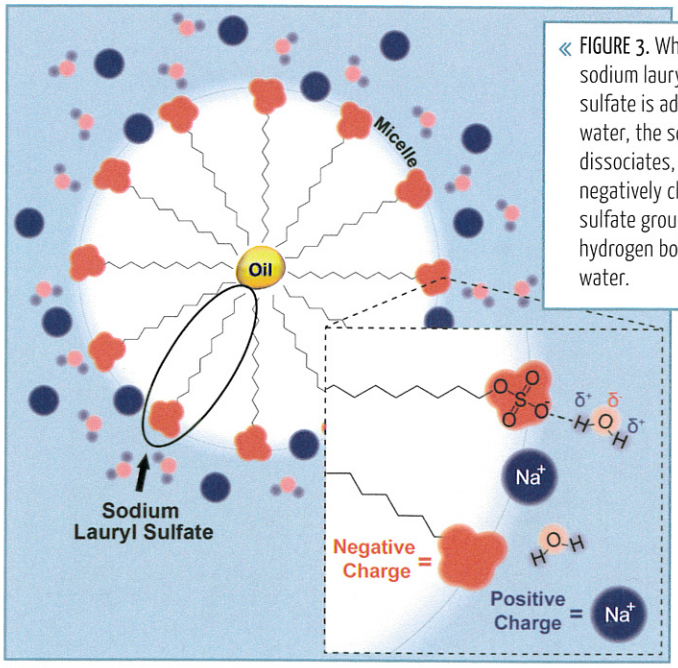

« FIGURE 3. When sodium lauryl sulfate is added to water, the sodium ion dissociates, and the negatively charged sulfate group can hydrogen bond with water.

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How Shampoo Cleans Your Hair

The cleansing ingredients in shampoos are surfactant molecules, which have a **hydrophilic** head group and a **hydrophobic** tail.

This structure allows surfactant molecules to form spheres, or **micelles,** with the head groups facing outward toward the water. The hydrophobic tails and oil get tucked inside the micelles, away from the water. Packaged in these micelles, the oil can be washed away.

Surfactants come in different varieties, but one of the most common surfactants in shampoos is sodium lauryl sulfate (SLS), an anionic surfactant (Fig. 3). SLS has 12 carbons in its tail [$CH_3(CH_2)_{11}SO_4$ Na], and a sulfate group and sodium ion in the hydrophilic head group. In water, the sodium ion dissociates from the SLS molecule. The sulfate group's negative charge forms hydrogen bonds with the positive sides of H_2O molecules, which are **polar** and have an uneven distribution of charge.

safe. Research has shown that many naturally occurring compounds such as aloe vera (a great film-former) and surfactants made from coconut and palm fatty acids meet the requirement for safety, and would likely be effective at smoothing hair. So, Clark and Alden spent their evenings testing different formulations on Alden's hair. After 17 trials over several months, they finally had a formula that worked.

One of the main ingredients Clark settled on is **glycolic acid** ($C_2H_4O_3$), which acts as the principal frizz-fighting substance in the Lubricity Labs System, the product line he developed. Glycolic acid, which can be derived from sugarcane, is an alpha-hydroxy acid (AHA) typically used in skincare products to remove layers of dead skin cells.

Clark found from past studies that glycolic acid is small enough to penetrate hair through the cuticle and bind to the keratin proteins in the cortex. Although the mechanism is not completely understood, it appears that the glycolic acid binds to keratin and makes it more hydrophobic, thus reducing moisture-induced swelling. Additionally, glycolic acid products cause lifted cuticles to lie flat and thus reflect more light, making hair shinier.

What you won't find in Clark's products are sulfates, specifically sodium lauryl sulfate (SLS) or sodium laureth sulfate (SLES). Sulfates are commonly used in other hair products as surfactant agents. Although not harmful, they can strip natural oils from hair. If you want to de-frizz your hair, you definitely want to keep your hair's natural oils, which guard against humidity and frizz.

Happy endings

Ultimately, the many months of experimentation paid off. Clark says he is overjoyed that he found a formulation that works. Now, he has moved on from working in geochemistry to continue developing hair products that help people who want more control over their locks.

As for Alden, she says that throughout the experience, she felt confident they would succeed and was happy to finally wake up in the mornings without having to battle with her hair. As a busy teenager, she has bigger fish to fry.

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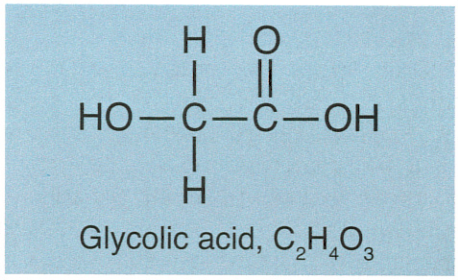

Glycolic acid, $C_2H_4O_3$

BOYCE CLARK

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