Chapter 6

The Growth and Structure of Hair

Key Terms

Amino acids
Arrector pili muscle
Cortex
Cuticle
Cysteine
Cystine
Dermal papilla
Disulfide bonds
End bonds
Follicle
Helix
Hydrogen bonds
Keratin
Medulla
Peptide bonds
Polypeptides
Proteins
Salt bonds
Side bonds
Stem cells

Learning Objectives

After completing this chapter, you should be able to:

- Understand how a hair follicle forms and grows.
- Describe the structure of hair.
- Describe hair's subfiber structure.
- Account for the physical properties of hair.
- Explain why keratin is cross-linked.

WHY DO WE NEED HAIR?

Our primitive ancestors depended on hair for warmth and protection, and although hair is no longer needed for survival, it still has an enormous impact on our psychology.

The social importance of hair is astounding. In the 1960s, hair length was not just a fashion statement but a political one as well. Some religions insist on complete removal of the hair, while others forbid cutting it. In some ancient civilizations, hair was a symbol of power, while in others it was considered a sign of wisdom.

According to the Bible, Samson's hair made him the strongest man on Earth, and cutting it was his downfall. In Japanese history, the importance of a woman's hair was second only to her life! A woman's immortal spirit was thought to be located in her hair. Even in modern times, the significance of hair and its styling is still deeply rooted in every culture.

The earliest records of hair growth studies come from the ancient Greeks. Aristotle noticed that eunuchs (men or boys deprived of the testes or external genitals) never lost their hair. Centuries later, Julius Caesar demanded that the Roman senate allow him to wear his laurel wreath at all times to hide his baldness. He also carefully groomed his hair to shield his bald spot from Cleopatra's view.

STRUCTURES OF THE SCALP

There are approximately 100,000 hair follicles in the scalp. Each of these follicles was created by a special relationship between the dermis and epidermis. As the scalp develops, certain changes take place. Look at Figure 6-1 and use your imagination to visualize the creation of a hair **follicle** (FOL-i-kel).

Follicle Formation

Before a hair follicle can develop, tissue cells must undergo a dramatic change (Fig. 6-2). First, a portion of the epidermis grows downward into dermal tissue creating a deep canal called the follicle. Deep in the dermis (just above the subcutaneous layer) this newly formed follicle canal wraps itself tightly around a small piece of dermis tissue. The epidermis almost completely surrounds this piece of dermis. This process of follicle formation happens about five million times on the average body.

Dermal Papilla

The small, cone-shaped piece of dermis tissue that bulges up into this new follicle canal is called the **dermal papilla** (pa-PIL-uh). Since the epidermal tissue that lines the follicle canal has no blood supply of its own, oxygen and nutrients are supplied by tiny capillaries located in the dermal papilla. Eventually, the epidermis tissue completely surrounds the papilla and forms a *hair bulb*. Capillaries remain attached to the bottom of the bulb. If you pull a hair from its follicle, you can see this bulb of dermis tissue (Figs. 6-3 through 6-7).

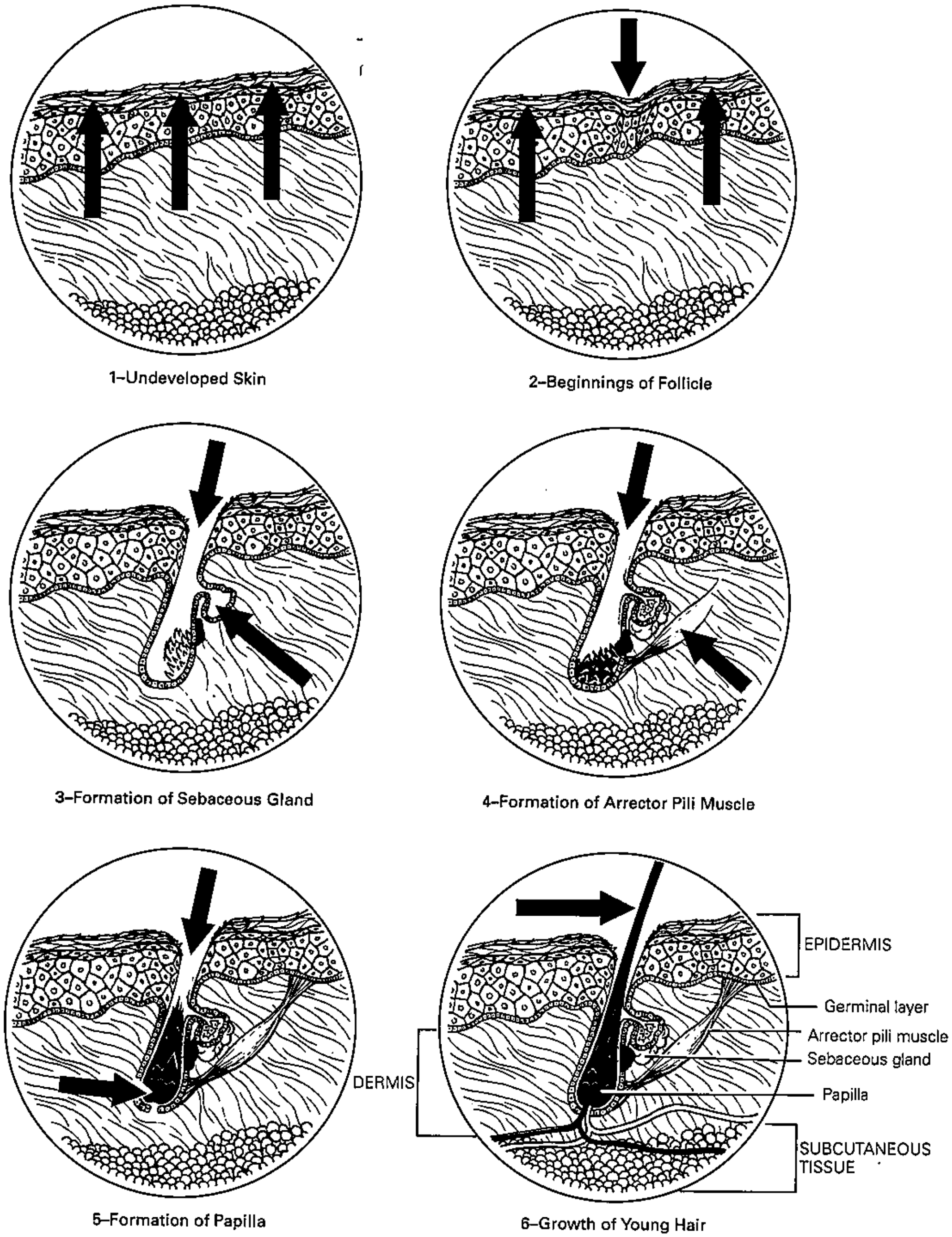

Figure 6-1 *Origin of follicle and hair.*

Figure 6-2 *Formation of follicle. Three stages in the development of hair follicles in the scalp approximately six months before birth.*
(Courtesy: Structure & Functions of Skin—*Academic Press*)

Figure 6-3 *Single hair growing from follicle, magnified 600 times. This is an excellent view of the follicle opening and the sheath around the base of the hair.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Figure 6-4 *Multiple hairs growing from what appears to be a single follicle, magnified 630 times. Notice follicle architecture, which is clearly shown in the center.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Figure 6-5 *Photo of human skin, magnified 360 times, showing two hairs emerging from what appears to be a single follicle. Also notice two fine hairs emerging from follicle in lower left corner.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Figure 6-6 *Photo of two hairs just emerging from the surface of the skin, magnified 630 times. These represent two newly growing fibers.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Hair Shaft

Hair grows from special types of cells called **stem cells.** Until late 1990, it was believed that the stem cells were found in the epidermis cells surrounding the bulb and that the hair shaft grew upward from this "root." Scientific evidence now shows that this belief is incorrect.

Researchers at the University of Pennsylvania have found that stem cells come from a small bulge directly under the sebaceous (oil) glands. This bulge sits beside the follicle. This is where the hair shaft begins. These newly formed cells become quickly "keratinized." This means the cytoplasm of the cell is completely replaced by a special protein called **keratin.** As more and more keratinized cells are made, they are pushed into the follicle canal. After the entire canal becomes packed, a column of keratinized cells emerges from the follicle.

In chapter 4, we learned that newly formed epidermis cells in the skin are filled with cytoplasm and that each cell contains a nucleus. As a cell moves toward the skin's surface, the nucleus disappears and the cell becomes filled with keratin. The dead cells then flake off the skin's surface and are continually replaced by cells from below. A similar process occurs in the follicle. The keratinized cells

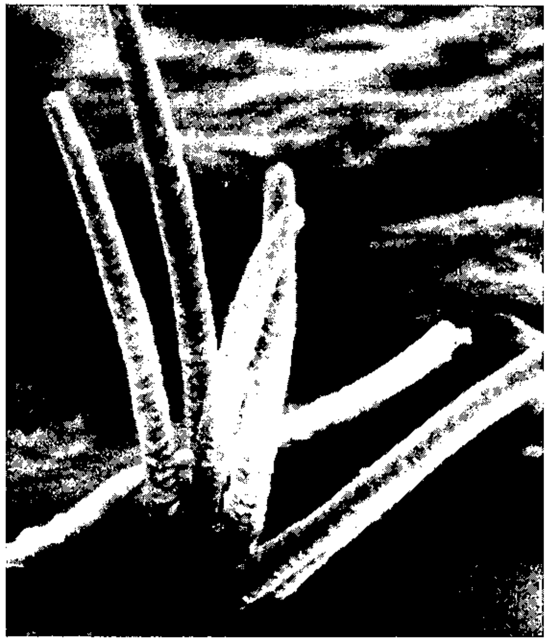

Figure 6-7 *Multiple hairs growing from what appears to be a single follicle, magnified 780 times, obtained from the forehead of a young male.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

of the hair shaft also contain no cytoplasm or nucleus. Hair cells die before the shaft of the hair ever pushes above the skin.

Other Special Structures

As the follicle canal is growing toward the dermis, other important changes are taking place. Several small, saclike bulges appear on the upper part of the follicle. One of the bulges becomes a sebaceous gland.

These glands make sebum. Sebum is secreted into the hair follicle and lubricates and conditions both the hair and skin. On the average, the body makes only one ounce of sebum every one hundred days. A little sebum goes a long way!

A second bulge on the follicle attaches to the **arrector pili muscle** (a-REK-tohr **PIGH**-ligh). This muscle can pull the hair shaft into an upright position. It also causes "goose bumps" or "goose flesh" on the skin. In primitive times, these muscles were important to survival. They could raise hair to an upright position allowing air to flow more freely across the skin to cool it and prevent over-heating. Goose bumps help control the flow of blood near the skin's surface and also cool the body (Fig. 6-8).

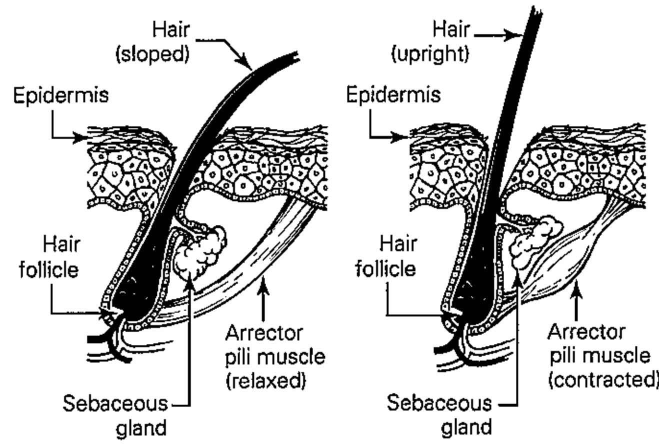

Figure 6-8 *Action of arrector pili muscle.*

STRUCTURE OF HAIR

From the outward appearance, hair is misleading. There is more to a strand of hair than meets the eye. Underneath the outer surface, there are many different layers. Each of these layers is important to healthy, beautiful hair. There are dozens of sub-layers: but only three separate and distinct main layers (Figs. 6-9 through 6-11).

1. Medulla
2. Cortex
3. Cuticle

Medulla

The **medulla** (me-DUL-uh) is the innermost portion of the hair shaft (Fig. 6-12). This section has between two and five rows of cells across. Usually, only thicker, coarse hair shafts contain a medulla.

All male beard hair contains a medulla. It is quite common for fine and naturally blond hair to lack a medulla. As far as cosmetology is concerned, the medulla is an "empty" air space and is not involved in any salon services.

Cortex

As much as 90 percent of the total weight of hair comes from the **cortex** (KOR-teks). The cortex gives the hair its strength, flexibility, elasticity, and color. The cortex is made of rectangular-shaped cells that are tightly bonded together. These cells are filled with keratin. The natural color of the hair is due to the pigment in

Figure 6-9 *Normal hair magnified 2,500 times.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Figure 6-10 *Normal hair magnified 5,000 times.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

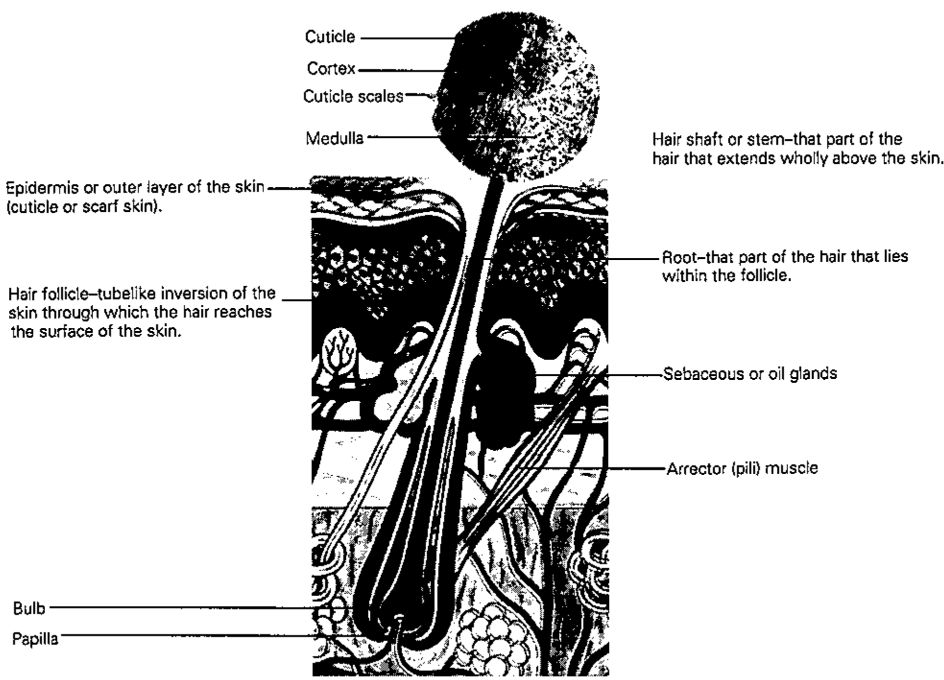

Figure 6-11 *Cross section of skin and hair.*
(Courtesy: CEM and Gillette Company Research Institute, Rockville, Maryland)

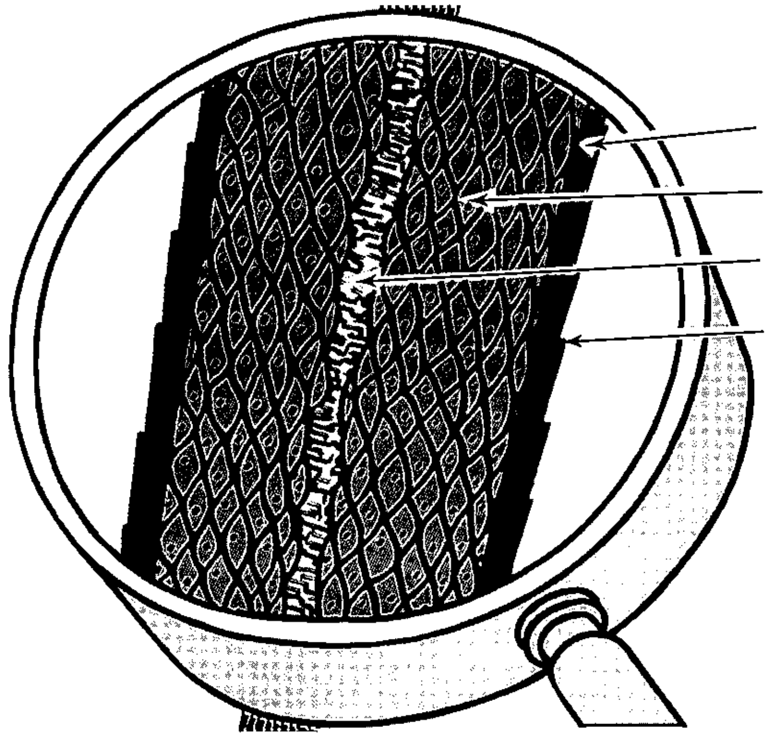

Figure 6–12 *Magnification of a cross section of hair.*

the cortex. For a natural-looking hair color it is necessary to get cosmetic coloring into this layer (Figs. 6-13 and 6-14).

Temporary and semi-permanent haircolor primarily coat the cuticle of the hair, which is transparent. Permanent haircolor can both lighten the natural color and deposit color within the cortex.

The elasticity of the hair is the result of the unique protein structure within the cortex. Wet setting, thermal styling, permanent waving, and chemical hair relaxing all take place within the cortex and would not be possible otherwise.

Cuticle

The cortex is surrounded by a single layer of overlapping transparent, scalelike cells of the **cuticle** (KEW-ti-kul). These scales overlap like shingles on a roof. A longitudinal section of hair shows that although the cuticle scales overlap, each individual cuticle scale is attached to the cortex (Fig. 6-15). This single layer of cuticle scales makes up the cuticle layer. Although when viewed on end, the scales can be seen to overlap, hair has only one overlapping, cuticle layer. A cross

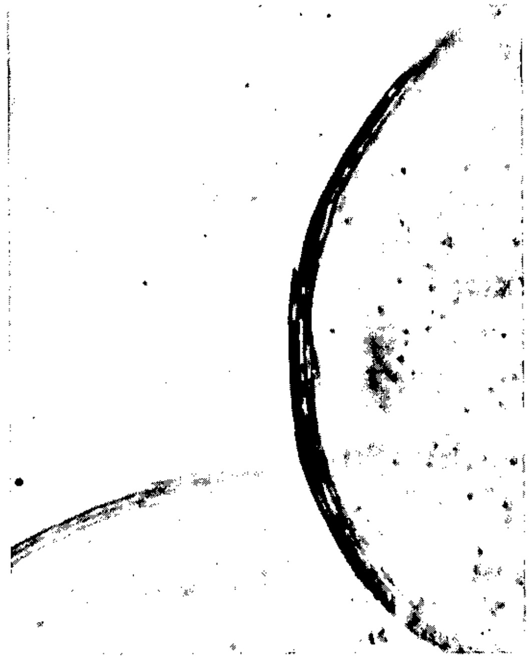

Figure 6-13 *Cross section of human hairs (magnified 500 times showing cortex with overlapping scales of cuticle).*
(Courtesy: Wool Industries Research Council)

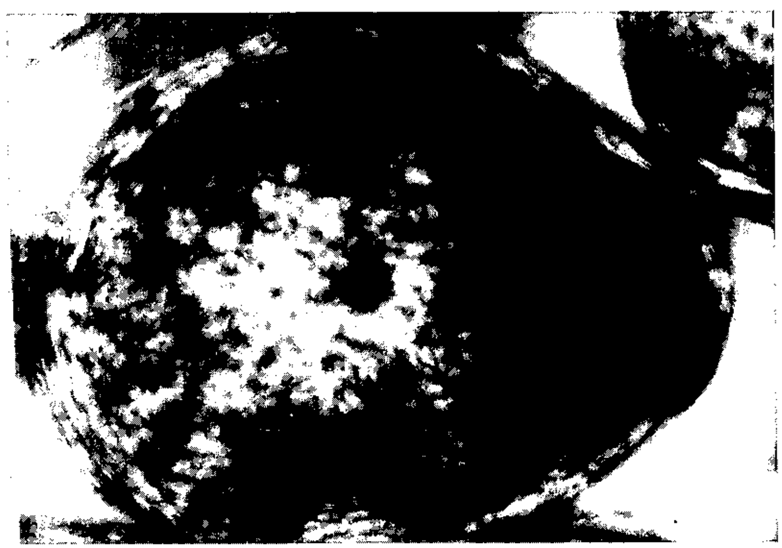

Figure 6-14 *Cross section of a straight hair. Note pigment in cortex and medulla (magnified 300 times).*
(Courtesy: Wool Industries Research Council)

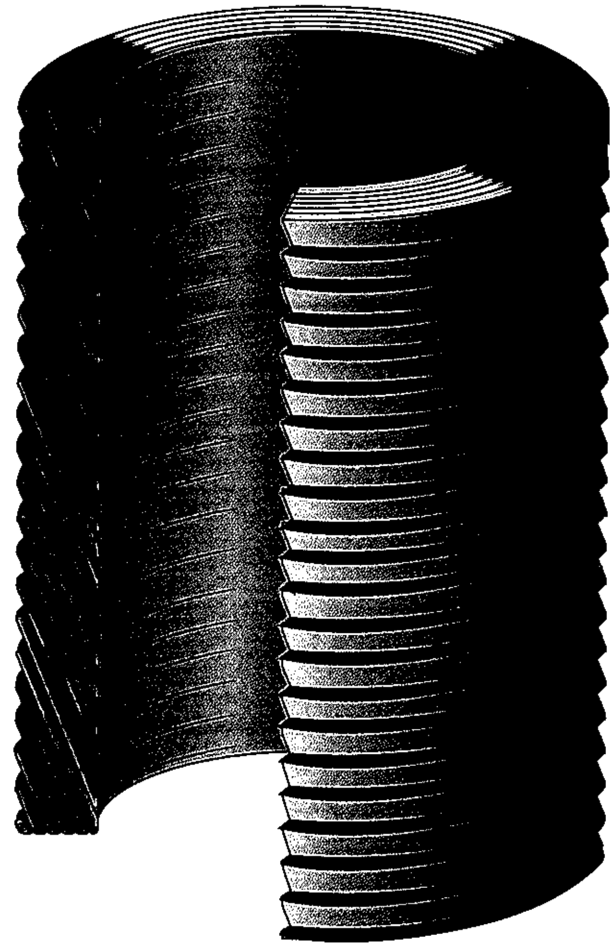

Figure 6-15 *Cross section of hair showing that, although you can count six distinct layers of overlapping cuticle, each individual scale is attached to the cortex in one cuticle layer.*

section of hair shows that when viewed on end, six distinct layers of overlapping cuticle scales can be seen (Fig. 6-15). The number of overlapping layers varies depending on the length of the cuticle scales. The hard cuticle protects the more delicate cortex and medulla. Without the cuticle layer, the cortex would become frayed and fall apart. The cuticle also acts as a barrier to chemicals such as tints and permanent wave lotions. This barrier is not impenetrable. Factors such as high pH and temperature can loosen the barrier. Since this layer is transparent, it is the pigment in the cortex which determines hair color (Figs. 6-16 through 6-19).

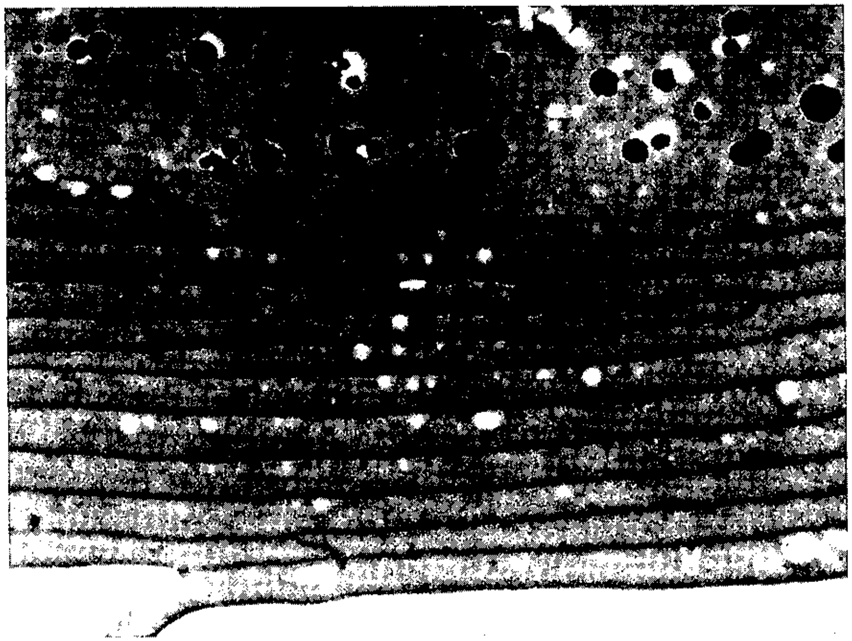

Figure 6–16 *A photo of cuticle scales around the cortex, magnified 14,800 times. Eleven of cuticle scales layers can actually be counted overlaying the cortex. The dark black spots represent melanin granules in the fibers of the cortex.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

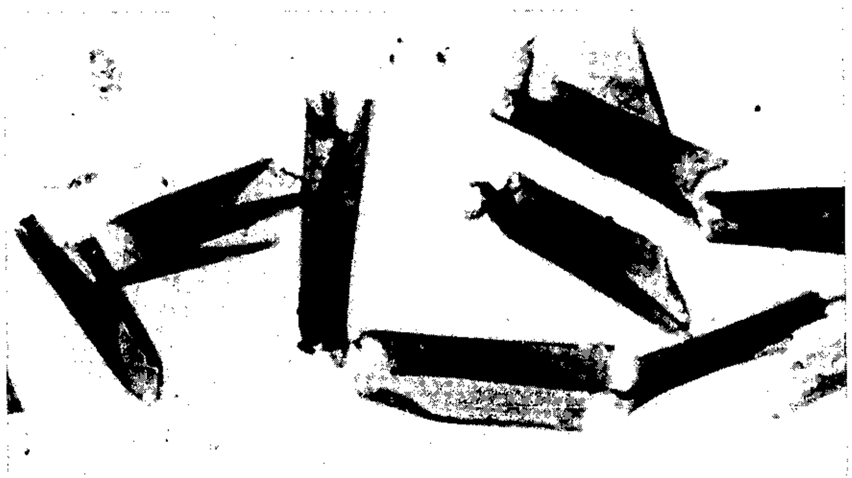

Figure 6–17 *Cuticle scales after removal from hair shaft.*
(Courtesy: Unilever Limited)

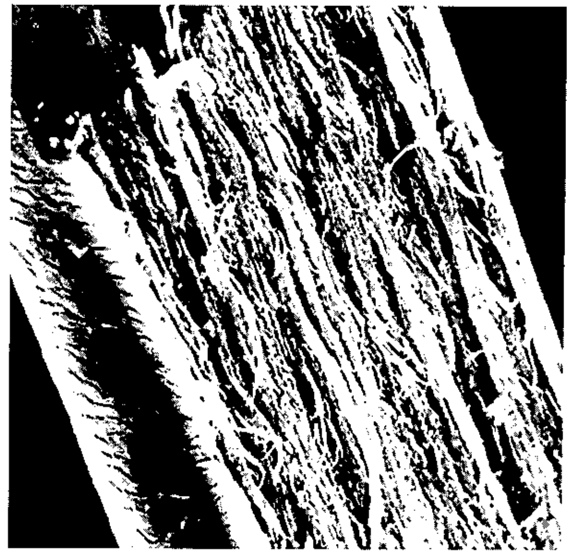

Figure 6-18 *Hair fiber with part of the cuticle stripped off exposing the cortex, magnified 1,470 times. Cortical fibrils can be clearly seen. Notice the vast difference in architecture of the interior of a fiber as compared to the surface.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Figure 6-19 *This photo of the same hair structure in Fig. 6.18, magnified 4,200 times. This gives a closer view of the cortical fibers.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

SUBFIBERS AND PHYSICAL PROPERTIES OF HAIR

The combination of the medulla, cortex, and cuticle makes a fiber of hair, but it is the many subfibers which give the hair its physical properties.

Hair is a unique substance. Wet healthy hair can be stretched 40 to 50 percent and still return to its original length. Hair can withstand extreme temperatures and years of repeated stresses. The extraordinary properties of hair come from the complexities of its substructure. To understand these important properties fully, we must explore the basic foundation of each fiber.

The Protein Structure of Hair

Hair is approximately 91 percent **protein** (PROH-teen). Proteins are made of long chains of **amino acids** (uh-MEE-noh AS-udz) that are linked together end to end like pop beads. The chemical bond that links amino acids together is called a **peptide** (PEP-tyd) **bond** or **end bond**. A long chain of amino acids linked by peptide bonds is called a **polypeptide** (pahl-ee-PEP-tyd). Proteins are long, coiled, complex polypeptides made of amino acids. The shape of a coiled protein is called a **helix** (HEE-licks).

The Amino Acid Content of Hair

All the protein structures of hair are made from these eighteen amino acids.

Cysteic acid	Aspartic acid	Threonine
Arginine	Serine	Glutamic acid
Proline	Glycine	Alanine
Valine	Cystine	Methionine
Isoleucine	Leucine	Tyrosine
Phenylalanine	Lysine	Histidine

SIDE BONDS

The cortex is made of millions of polypeptide chains, which are cross-linked together by three types of **side bonds**: hydrogen bonds, salt bonds and disulfide bonds. These side bonds are essential to wet sets, thermal styling and permanent waving (Chapter 13, Permanent Waving).

A **hydrogen bond** is a special type of ionic bond. Within the structure of hair, a hydrogen bond occurs when a hydrogen atom, from the acid portion of an amino acid, is attracted to an oxygen atom, in the acid portion of another amino acid. Hydrogen bonds are easily broken by water or heat and are responsible for wet sets and thermal styling. Although individual hydrogen bonds are weak, there are so many of them is the hair that they account for about one third of the hair's total strength.

A **salt bond** is also an ionic bond. Within the structure of hair, a salt bond occurs when the negative charge of one amino acid is attracted to the positive charge of another amino acid. Salt bonds depend on pH and account for about one third of the hair's total strength. Salt bonds are easily broken by strong alkaline or acidic solutions.

A **disulfide** (dy-**SUL**-fyd) *bond* is a covalent bond, which is different from the ionic bonding of a hydrogen or salt bond. A disulfide bond joins the sulfur atoms of two neighboring cysteine amino acids to create cystine. Although there are fewer disulfide bonds than hydrogen or salt bonds, disulfide bonds are stronger and account for about one-third of the hair's total strength. Disulfide bonds are not broken by heat or water. Permanent waves and chemical hair relaxers work by creating chemical and physical changes in the hair's disulfide bonds.

Individual protein chains are cross-linked by side bonds to create tiny, invisible, threadlike fibers. At least nine of these fibers twist around each other to make larger bundles called *micro fibrils*. Dozens of micro fibrils, in turn, twist together to create larger *macro fibrils*. Finally, six macro fibrils intertwine to form *fibrils*, the cells of the cortex (Figs. 6-22 and 6-23).

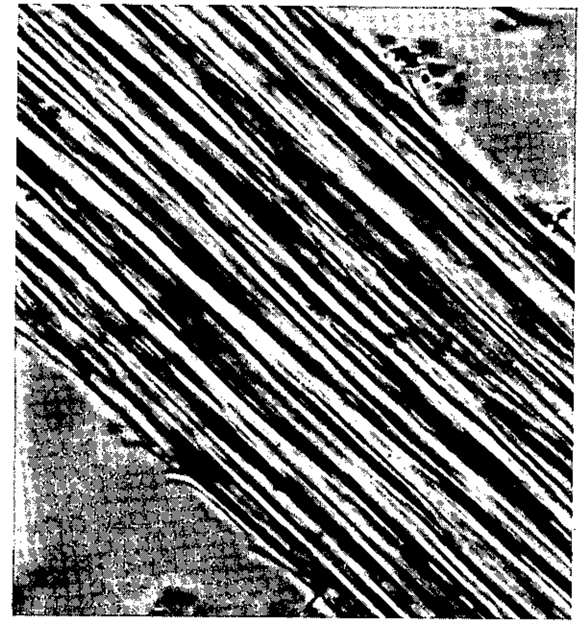

Figure 6-20 *Longitudinal section of cortex illustrating long keratin chain structure.*
(Courtesy: Wool Industries Research Council)

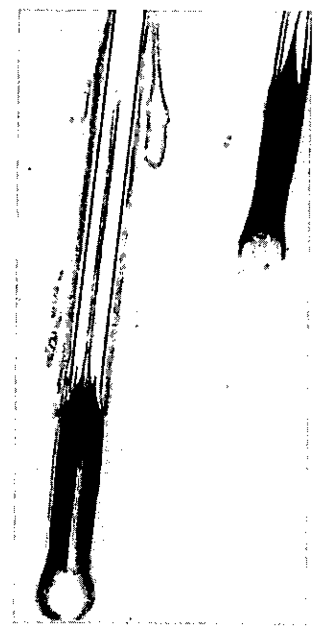

Figure 6-21 *Hair follicles showing soft keratin of hair (dark) and hard keratin (white).*
(Courtesy: Wool Industries Research Council)

KERATIN

Keratin is an important example of an insoluble, complex protein (Figs. 6–20 through 6–21). Hair is made almost entirely of this important substance. Keratin is made from eighteen different amino acids, including cystine and **cysteine** (**SIS**-ti-een) (uncross-linked cystine).

Cystine is the most abundant amino acid in hair. Cystine makes up nearly 18 percent of hair. With so many possibilities for making cross-linked disulfide (sulfur) bonds, cystine gives hair much of its strength. It is also responsible for causing hair to hold a permanent curl or relaxer.

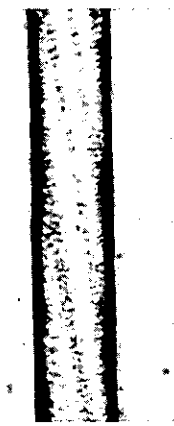

Figure 6–22 *Arrangement of twisted chains of hard keratin subfibers in hair cortex.*

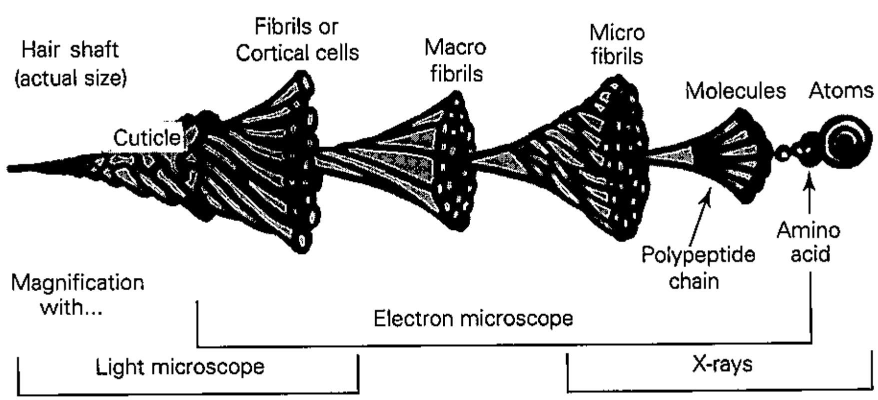

Figure 6–23 *Magnification of subfibers.*

This highly organized structure is designed much like the high-strength cables used to support suspension bridges. The polypeptide chains in keratin are both physically and chemically bound together. Millions of these keratinized cells are securely bonded together in the cortex and covered with a protective cuticle shield. This is how nature has created hair, a superstrength structure with amazing physical characteristics and chemical resistance!

Review Questions

1. What type of cells line the walls of a hair follicle?
2. What are stem cells and why are they important?
3. Which of the three main layers of hair is most important to natural hair color? Why?
4. How do amino acids get to the dermal papilla?
5. Explain how, once amino acids reach the follicle, they become fibrils.

Discussion Questions

1. Hairstylists and the hair styles they create have helped mold society and may influence future Americans for generations to come. How and why do you think this is possible?
2. Based on your understanding of the complex, subfiber structure of the cortex, does it seem reasonable that damaged hair can be "rebuilt" or "repaired" by using products that contain amino acids? (Hint: The answer is no; can you explain why?)