Chapter 7 The Properties of Hair

Key Terms

Anagen phase
Catagen phase
CHONS elements
Complimentary foods
Dihydrotestosterone
Essential amino acids
Eumelanin
Finasteride
Melanin
Melanocytes
Minoxidil
Nonessential amino acids
Phaeomelanin
Telogen phase
Terminal hairs
Vellus hairs

Learning Objectives

After completing this chapter, you should be able to:

- Understand the three phases of the hair growth cycle.
- Describe the different types of hair and where they are found.
- Explain normal daily hair loss.
- Describe the factors that influence hair color.
- Define hair density and its importance.
- Describe the chemical composition of hair.
- Understand the factors that influence hair growth.

GROWTH CYCLES

Like events in nature, hair growth also occurs in rhythms or cycles. Each complete cycle has three phases which are repeated again and again throughout life. The three cycles are called the **anagen phase,** the **catagen phase,** and the **telogen phase** (Fig. 7-1).

Anagen Phase

This is the growth part of the cycle. When hair is in the anagen phase, the stem cells actively manufacture new keratinized cells in the hair follicle. During this part of the cycle, hair cells are produced at staggering rates. It is believed that while in the anagen phase, hair cells are created faster than any other normal cell in the body. This part of the cycle generally lasts three to five years, but in extreme cases can last as long as ten years. Then it enters the next phase of the cycle.

Catagen Phase

This is the transition phase. During this phase, the follicle undergoes many striking changes. The follicle canal shrinks to about one-third of its length, leaving the dermal papilla far below. The lowermost part of the follicle is now located just below the sebaceous gland. The hair bulb disappears and the shrunken root end forms a rounded, brushlike *club*. The cells also stop making color pigments and the root takes on a milky white appearance. The dermal papilla shrinks and becomes a small compacted ball.

Not all activity in this phase is destructive. During the catagen phase, the follicle is also preparing for new growth by making *germ cells*. Germ cells can be thought of as the "seeds" for new growth. The germ cells surround the club and await the signal to renew the anagen phase. The length of the catagen phase is only two to three weeks.

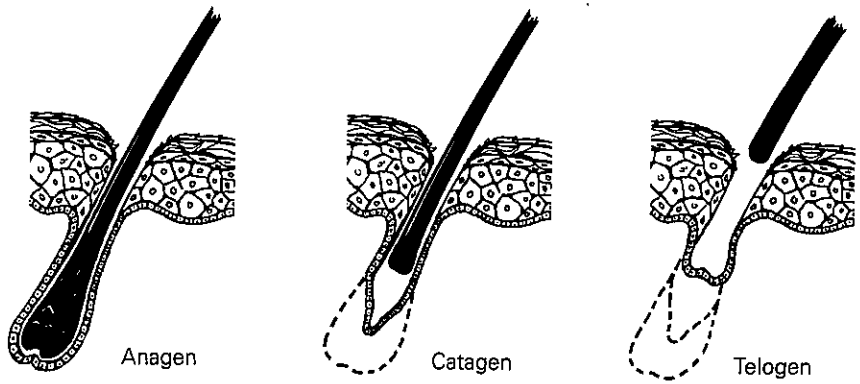

Figure 7-1 *The anagen, catagen, and telogen phases of hair growth.*

Telogen Phase

Next, the follicle enters a resting stage called the telogen phase. Normally the old hair shaft is shed during this part of the cycle. Since the hair club may be anchored to the follicle walls, the hair may remain in place until the next anagen phase. Then it is pushed out by the new growth. The anagen phase lasts for about three to five years; consequently, the average lifetime of a hair shaft is four years.

The follicle will remain resting in the telogen phase for approximately three to six months. Then the entire cycle repeats itself on an average of once every four to five years.

HAIR TYPES

Two types of hair are found on the body: vellus and terminal. **Vellus hairs** (also called *lanugo hairs*) are short, fine, and silky soft. They almost never have a medulla or contain color pigments. On adults, they are usually found in places that are normally considered "hairless," i.e., forehead, eyelids, and bald scalp. The bodies of children and infants are covered with vellus hair, but it disappears after puberty. The vellus hair is replaced by thicker **terminal hair.** Women, however, retain 55 percent more vellus hairs than men.

Terminal (*tertiary*) **hair** is coarse and pigmented. It usually has a medulla and is easily distinguished from vellus hair.

The short, thick hairs that grow on the eyebrows and lashes are *primary terminal hairs*. After puberty, the fine vellus hairs are replaced by thicker, *secondary terminal hairs*. The same follicle is capable of producing both types of hair. Secondary terminal hair is mostly found on the scalp, beard, chest, back, legs, and pubic area. Frequently, when scalps begin to bald, the follicles stop making terminal hair and revert back to the vellus type (Fig. 7-2).

NORMAL HAIR LOSS AND GROWTH RATE

Normal Hair Loss

At any one time, 88 percent of scalp hair is in the anagen phase, one percent is in the catagen phase, and 11 percent is in the telogen phase. The scalp contains about 100,000 hairs on average, with slightly more for blonds and less for redheads. Although estimates of the rate of hair loss have long been quoted at 100 to 150 hairs per day, recent measurements indicate that the average rate of hair loss is closer to 35 to 40 hairs per day.

Growth Rate

In general, scalp hair grows faster on women than men. The average rate of growth is 0.36 mm/day (0.01417 inches/day) for women and 0.34 mm/day

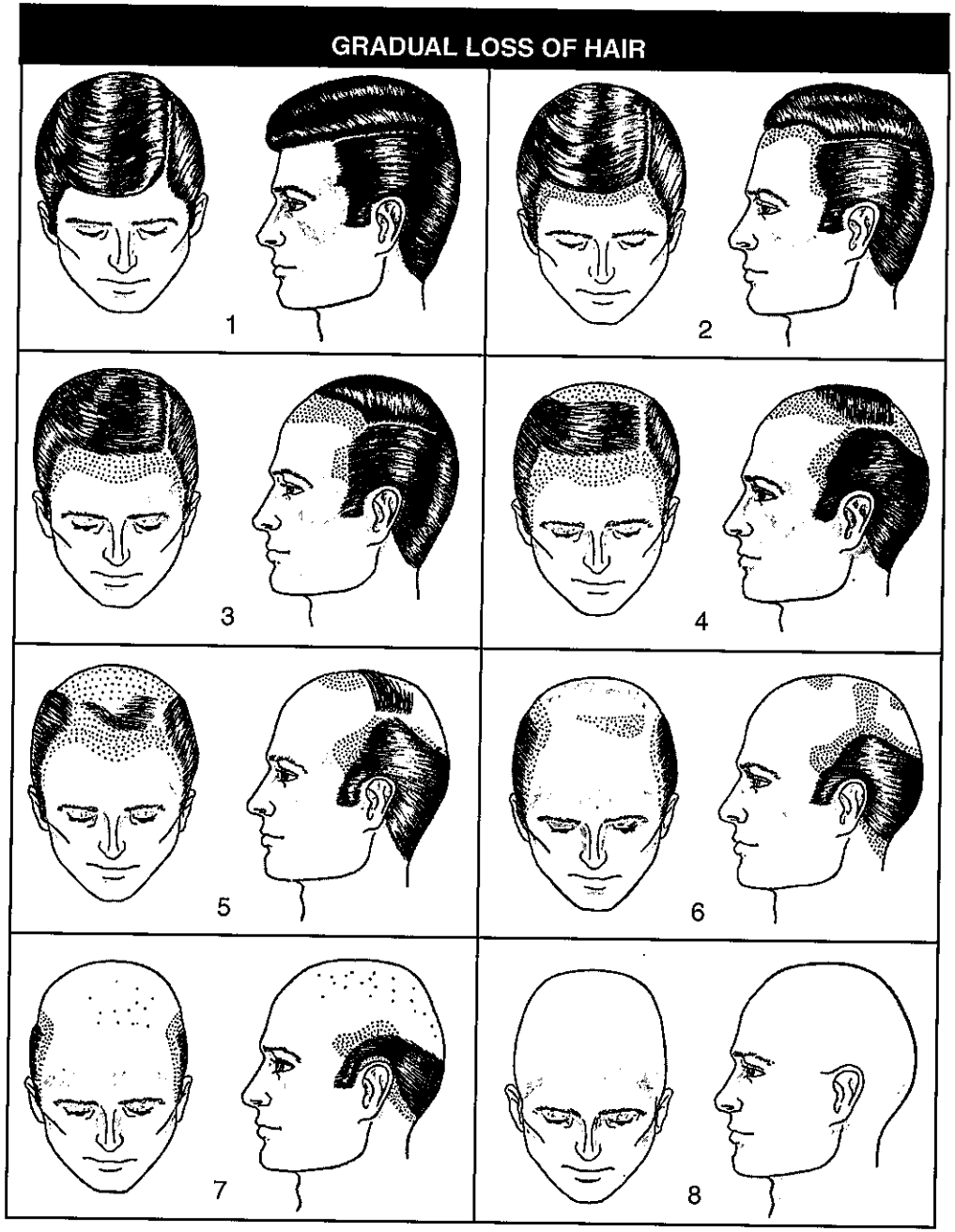

Figure 7-2 *Unless it is caused by some severe illness or unusual phenomenon, scalp baldness does not occur overnight. It is rather a gradual process, usually caused by some form of alopecia, during which the hair growth cycle is slowed down, interrupted, or discontinued entirely. This illustration shows the gradual loss of hair that occurs in the usual case of progressive baldness.*

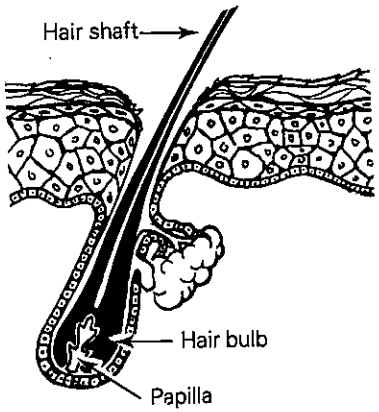

Figure 7-3 At *an early stage of shedding, the hair shows its separation from the papilla.*

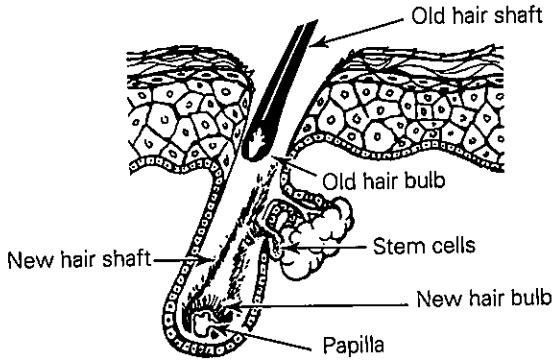

Figure 7-4 At *a later stage of the hair shedding, a new hair is seen growing from the stem cells below the sebaceous gland.*

(0.01339 inches/day) for men. Time-lapse photography shows that individual hairs grow at a constant rate day or night.

It has also been proven that shaving and cutting hair has absolutely no effect on the rate of growth. Likewise, menstrual cycles have no effect on how rapidly hair grows, but during pregnancy the growth rate slows slightly. Controlled studies show that scalp hair growth rates reach a maximum in the summer, while more hair shedding occurs in November.

If a follicle is pulled from the scalp, it takes about 130 days before a new hair emerges (Figs. 7-3 and 7-4).

The shedding of hair is not exactly regular; it is more noticeable in the morning and at certain other periods. No sensation of pain is felt when these hairs are pulled away from the scalp. The reason is that these hairs are not tightly bound and pull away easily. You may have noticed that when the scalp is brushed or combed a number of loose hairs are invariably found. These have detached themselves from the scalp and may be seen on the brush, comb, coat, or pillow.

Each follicle has a definite age and when the hair reaches this natural limit, it falls out or is brushed or combed out. The follicle has a brief period of rest and then begins once more to produce a young new hair. On the scalp, this cycle of growth and replacement is from three to five years. The life span of the follicles of a woman's hair is about 25 percent longer than those of a man.

When the hair reaches its maximum age, an air space slowly develops between the medulla and the top of the papilla. Following this, the cuticle of the hair is no longer formed by the outer cells of the papilla and the cortex shrinks in thickness. A short period later the complete hair bulb loosens and separates from the papilla. At this stage, the hair is known as a *bed-hair* and it lies loosely in the

follicle. The papilla completely dies away and the follicle closes in over it. If the neck of the follicle is tight, it will continue to hold the bed-hair for a period of time.

The bed-hair may be pulled out by the daily brushing and combing, or it may be removed by shampooing or any other form of pulling or friction. Sometimes the bed-hair remains in the follicle until it is pushed out by the fresh, young hair.

Detached hair is known as *shed-hair*. Under the microscope the base of the shed-hair has a clublike, tattered appearance (Figs. 7-5 through 7-9).

Figure 7-5 A *normal hair and follicle also showing hardening of cortex and cuticle (lighter areas).*

Figure 7-6 A *young follicle just starting to produce a hair. Note bed-hairs of previous cycles which have not been brushed or combed out.*

Figure 7-7 A *typical shed-hair illustrating club end.*

Figure 7-8 A *bed-hair in an old follicle. The follicle has shortened past it sebaceous gland.*

Figure 7-9 An *old hair in a dying follicle.*

Cutting a cross section of a hair reveals that it is not circular, but is instead irregular and *elliptical* (forming an oval). African-American black, curly hair is the most elliptical of all hair types. Asian hair is the closest to being round. The natural curl of hair is closely related to the cross-section shape. The more elliptical (flatter) the cross section, the curlier the hair (Figs. 7-10 through 7-14).

The strength of hair is remarkable. Each individual strand is actually stronger than an aluminum fiber of the same thickness! The average healthy head

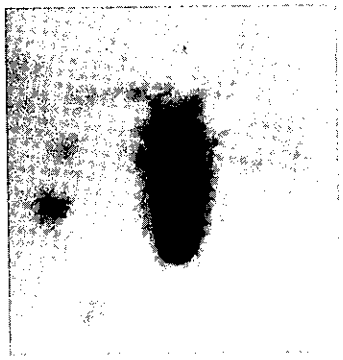

Figure 7-10 *Technology now provides microscopes that are so powerful that they can see inside a hair shaft. A single oval-shaped, blackish brown melanin molecule, such as the one shown, is the basis for all hair color.*
(Courtesy: Redken Laboratories, Inc.)

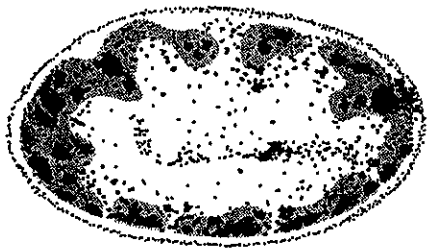

Figure 7-11 *A cross section of African-American black hair.*
(Courtesy: Redken Laboratories, Inc.)

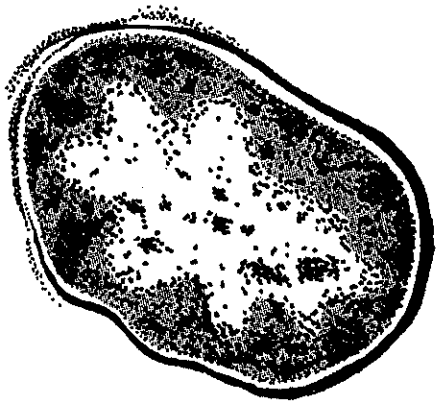

Figure 7-12 *A cross section of Caucasian hair.*
(Courtesy: Redken Laboratories, Inc.)

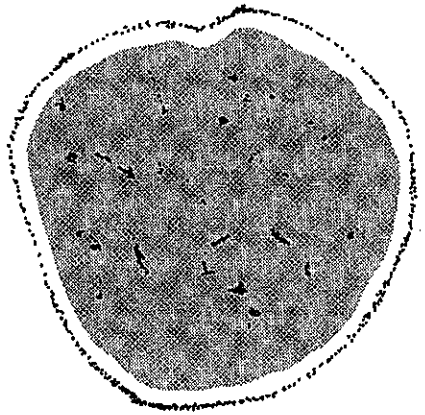

Figure 7-13 A *cross section of straight hair.*
(Courtesy: Redken Laboratories, Inc.)

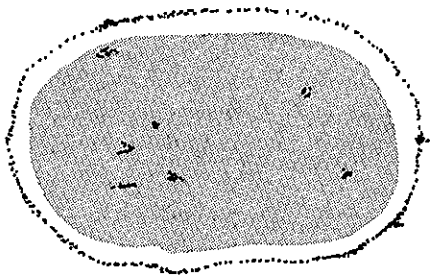

Figure 7-14 A *cross section of curly hair.*
(Courtesy: Redken Laboratories, Inc.)

of hair, with 100,000 strands of hair, could lift over twelve tons. Because of its subfiber structure and disulfide bond cross-links, hair behaves much like reinforced wire cable.

Hair is also elastic and can be stretched, 40 to 50 percent of its length, without damage. However, hair should never be extended to more than 25 percent of its original length (Figs. 7-15 through 7-18).

Wetting the hair before stretching it greatly reduces the chance of damage. Compared to skin, hair is less resistant to water penetration. Normally, four percent to nine percent of a hair's weight is made up of water. However, the hair can absorb up to 40 percent of its normal dry weight in water. It will even absorb 30 percent of its weight directly from moisture in the air. When hair absorbs large amounts of moisture, it softens the hydrogen bonds and allows curls to relax.

Added water causes the hair to swell as much as 20 percent in diameter. Strong alkaline solutions (such as chemical relaxers) can increase the swelling to 100 percent. Chemicals that cause the hair to swell are often added to products to assist penetration of molecules that normally are too large to pass the cuticle.

Hair Body

Hair body is a combination of several hair characteristics. Many physical properties contribute to the hair body, including shaft diameter, texture, degree of curliness, density, moisture content, stiffness, and weight. Body is defined as the structural strength, volume, and resiliency of the hair.

Figure 7–15 *Hair before stretching.*

Figure 7–16 *Slight stretching is loosening cuticle scales.*

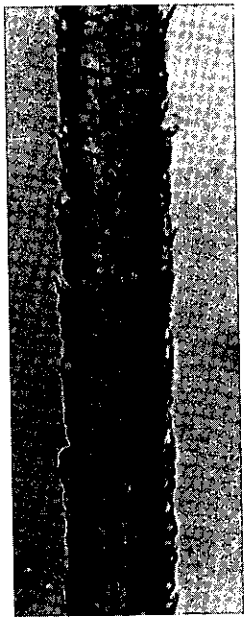

Figure 7–17 *Separation of cuticle from cortex has begun.*

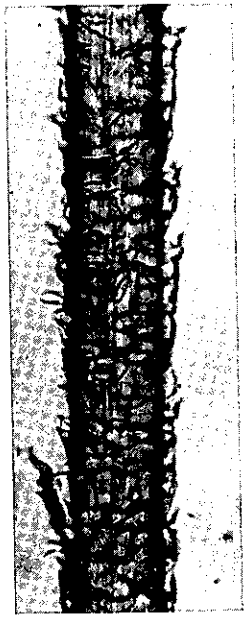

Figure 7–18 *Hair immediately prior to breakage; note the weakness due to excessive strain.*

Color

The pigment that gives natural color to hair and skin is called **melanin** (MEL-a-nin). The wide range of hair color is due to combinations of two types of melanin: **eumelanin** (yu-MEL-a-nin) and **phaeomelanin** (FE-o-mel-a-nin).

The type and amount of melanin in hair is an inherited, genetically controlled trait. Specialized cells called **melanocytes** (cytes = cells) produce all the melanin found in hair, skin, and eyes. Only completely white hair contains neither type of melanin. White is the actual color of keratin without the coloring influence of melanin.

Eumelanin is the most common type of melanin. This form gives hair shades from brown to black.

Phaeomelanin gives hair the yellowish-blond tones, ginger, and red colors.

Melanin pigments are found in the cortex. Both types of pigments are frequently present in the hair shaft. The ratio of eumelanin to phaeomelanin determines the hue seen in untreated hair. For example, red-blond tones such as copper-gold and medium chestnut brown result from mixtures of both pigments (Figs. 7-19 through 7-22).

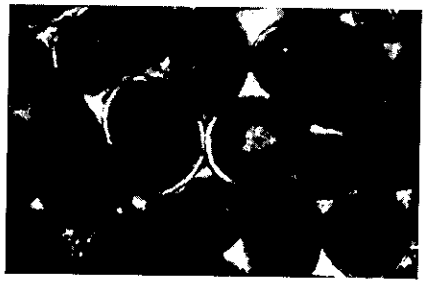

Figure 7-19 *Natural black straight hair (only black hairs). (These hairs absorb light intensely.)*

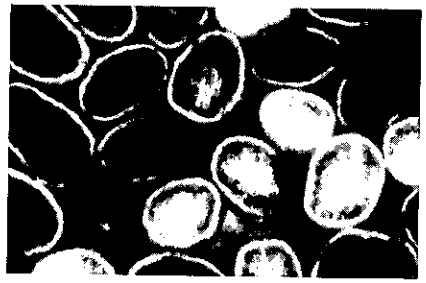

Figure 7-20 *Natural brown straight hair (contains black, brown, yellow hairs). (Note that there is no color in the cuticle.)*

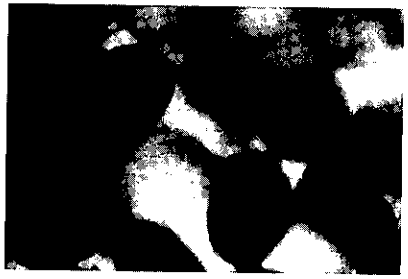

Figure 7-21 *Natural blond straight hair, golden shade (mostly dark hairs with lighter-colored hairs).*

Figure 7-22 *Natural red straight coarse hair (auburn shade — contains yellow, red, brown, black hairs). (This hair has a large cortex with a thin cuticle layer.)*

Three factors determine all natural hair colors from light blond to jet black:

1. The thickness of the hair
2. The total number and size of pigment granules
3. The ratio of eumelanin to phaeomelanin

The number of pigment granules (*density*) is important. Not only does it affect the color of hair, but it can make changing the color easier or more difficult. The ebony black hair associated with African-Americans has the same type of melanin as Caucasian brown hair. The difference is that the melanin granules are twice as large in black hair. This gives a higher pigment density.

Blond hair has fewer and smaller phaeomelanin granules which are widely spread through the cortex. It would be easier to mask the effects of these pigments (low density) than to cover densely packed eumelanin granules. Bleaching hair actually destroys the melanin granules and removes their coloring influence (Fig. 7-23).

When the number of pigment granules begins to decrease naturally, graying becomes noticeable. This usually begins between 28 and 42 years old. Graying indicates the melanocytes are slowing down and making less melanin. Research shows that melanin production stops completely during the catagen and telogen phases (Fig. 7-24 and 7-25).

Normal hair color sometimes changes noticeably between 13 and 20 years old. This change is especially noticeable in blond, red, and light brown hair. These colors often begin to darken. This is due to increased melanin production. Higher pigment density causes darkening. Apparently, melanocytes vary the amount of pigment they produce according to age.

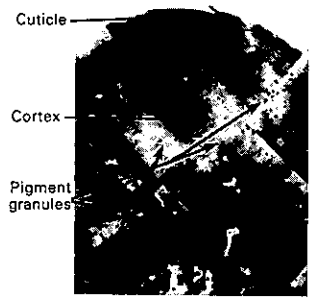

Figure 7-23 *Pigment granules.*

Figure 7-24 *Aging hair bulb with gray hair. Granules are formed but lack pigment.*
(Courtesy: Biology of Hair Growth—Academic Press)

Figure 7-25 *Albino hair showing no granules of pigment in bulb.*
(Courtesy: Biology of Hair Growth—Academic Press)

Density

Hair density measures how many hairs are growing in a square inch of scalp. It tells how thick or full the hair is growing. Hair density varies widely among individuals, as well as races. The average hair density is about 2,200 hairs per square inch. Hair density is also influenced by cosmetic hair procedures, daily care, and disease/health.

- Hair density remains the same during pregnancy.
- Hair density is lower in women.
- Hair density decreases in both sexes after age fifty.
- Hair density is highest in young adults.
- Hair density decreases in chemically overprocessed hair.
- Hair density decreases with improper brushing techniques.

It is not practical to count hair on a client's head, but paying attention to the general, overall density can provide valuable information about the condition and health of the scalp. Blonds generally have the highest density and redheads have the lowest.

Diameter

Hair thickness is the diameter of each hair strand and can be classified as fine, medium, or coarse. Hair thickness is dependent on genetics and is known to vary based on racial background. Hair thickness not only varies from person to person, but also from strand to strand, on the same person's head.

It should be obvious that fine hair is fragile and the most susceptible to damage from salon services. As a general rule, fine hair will process faster and with less difficulty than medium or coarse hair.

Coarse hair is stronger than fine hair, for the same reason that a thick rope is stronger than a thin rope. Coarse hair has a larger diameter and will not only require more processing, but it may also be more resistant to that processing. It is usually more difficult for hair lighteners, haircolor, and permanent waving solutions to penetrate coarse hair (Figs 7-26 through 7-28).

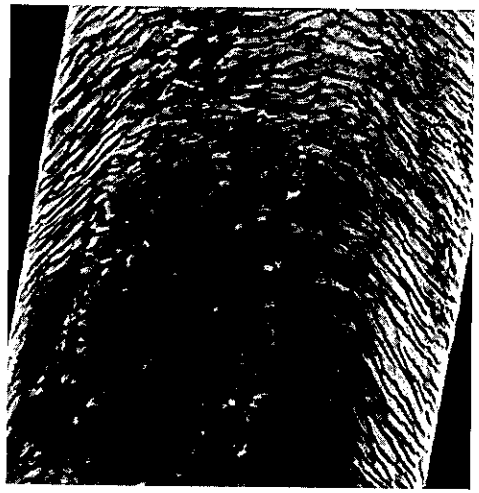

Figure 7-26 *Coarse hair magnified 1,200 times.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

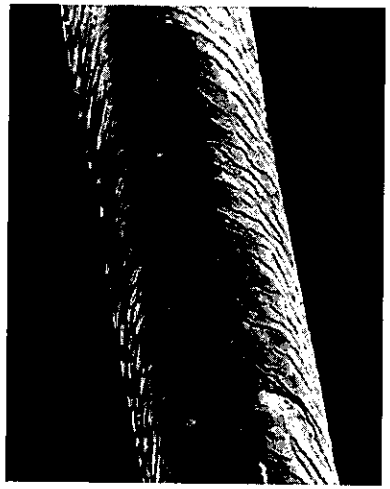

Figure 7-27 *Medium hair magnified 1,200 times.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Figure 7-28 *Fine hair magnified 1,200 times.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Chemical Composition

The protein in human hair is made of amino acids and those amino acids are made of elements. Human hair is composed of carbon, hydrogen, oxygen, nitrogen, and sulfur. These five elements are the major elements in skin and hair and are often referred to as the CHONS elements. Table 7-1 shows the relative ratios of each element in normal hair.

Factors That Influence Growth

Hair growth is not completely understood. For example, no one is sure what signal tells the follicle to leave the telogen phase and resume growth in the anagen phase. Still, several factors have been shown to influence hair growth on the scalp. Some of these are race, age, sex, season of the year, location on the body, nutrition, and hormones.

Pregnancy seems to disrupt the normal growth cycle of hair. Women usually have little hair loss during their pregnancy, but experience sudden and excessive shedding from three to nine months after delivery. Although this is can be traumatic to the new mother, the growth cycle quickly returns to normal.

Hair Loss Treatments

There are currently two drugs that have been proven to stimulate the growth of hair and are approved by the Food and Drug Administration (FDA).

1. **Topical Medication**
   Minoxidil is a topical medication that lowers blood pressure. This topical solution is applied to the scalp twice a day, and although it's greasy and inconvenient, it has been proven to stimulate hair growth. It's sold over the counter (OTC), as a non-prescription drug under the brand name *Rogaine*. Minoxidil is available for both men and women and comes in two different strengths: 2 percent regular and 5 percent extra strength. It is not known to have any adverse side effects. Although there are many advertisements to the contrary, there is no evidence that massage, physical stimulation, or any other topical treatment encourages hair growth.

TABLE 7-1 Average Elemental Composition of Hair

Carbon	51%
Hydrogen	6%
Oxygen	21%
Nitrogen	17%
Sulfur	5% (from cystine)

2. Oral Medication

Hair growth is controlled by androgens that are converted to testosterone. Testosterone is converted to **dihydrotestosterone** (DHT) by the enzyme 5-alpha-reductase. At sexual maturity, DHT causes the vellus pubic hair in males and females to be converted to longer, thicker terminal hair. DHT also causes the facial hair of males to be converted to the longer, thicker, terminal hair we know as a beard.

Paradoxically, in male pattern baldness (androgenic hair loss) that occurs later in life, the same DHT causes the miniaturization of the terminal hair of the scalp to vellus hair. At the same time, DHT stimulates the vellus hair on the rest of the male body to become terminal hair. Men with male pattern baldness lose their scalp hair and grow thicker, longer, darker hair on the rest of the body, especially the upper arms and back.

Finasteride is an oral, prescription medication for men only. Finasteride is sold under the brand name *Propeca*. Finasteride inhibits the production of 5-alpha-reductase, the enzyme that reacts with (DHT) to cause male pattern baldness. Although Finasteride is more effective and convenient than Minoxidil, possible side effects include weight gain and loss of sexual function. These drugs are available for men only and only by prescription. Women may not use this treatment, and pregnant women or those who might become pregnant are cautioned not to touch the drug because of the strong potential for birth defects.

Amino Acids and Nutrition

Although more than 100 **amino acids** naturally occur, the proteins of all plants and animals are made from just 20 "common" amino acids. Eleven of the 20 common amino acids are called the **nonessential amino acids** because they can be synthesized by the body and don't have to be in our diet. The remaining nine are the **essential amino acids** that must be in our daily diet because they cannot be synthesized by the human body.

There is some confusion concerning histidine, which has long been considered an essential amino acid for infants but recently has also been shown to be essential for adults. Cystine and tyrosine may also be essential to some infants who may not be able to synthesize them due to liver damage.

11 NON-ESSENTIAL AMINO ACIDS

Alanine	Arginine	Asparagine
Aspartic acid	Glutamic Acid	Glutamine
Glycine	Serine	Proline
Cystine*	Tyrosine*	

*Cystine and tyrosine may be essential in some infants.

9 ESSENTIAL AMINO ACIDS

Histidine	Isoleucine	Leucine
Lysine	Methionine	Phenylalanine
Threonine	Tryptophan	Valine

Although meat, fish, poultry, eggs, and dairy products are complete proteins that provide all of the essential amino acids, they should be limited in the diet because they are also high in fat. Many plant sources are low in fat and also a good source of fiber, but they are not complete proteins because they all lack at least one of the essential amino acids. **Complimentary foods** are combinations of two incomplete proteins that provide all the essential amino acids and make a complete protein. Some complimentary proteins are peanut butter and bread, rice and beans, beans and corn, and black-eyed peas and cornbread.

If you eat an adequate amount of complete protein each day, there is no need to take amino acid or protein supplements. Remember that protein supplements in large amounts can be harmful, particularly to the kidneys (Fig. 7-29).

Other Nutritional Factors

It is tempting to believe that certain foods influence the growth of longer, stronger, or more beautiful hair. As nice as this sounds, there is no evidence that any specific food can improve hair or speed its growth. Unfortunately, what you eat (or don't eat) can have many negative effects.

Both skin and hair require vitamins for healthy development, but vitamin supplements can do more harm than good! Excessive amounts of Vitamin A, for instance, appear to cause hair loss and can be toxic.[2]

The solution is proper nutrition. Eating correctly is the most important thing you can do to keep healthy. Vitamin supplements are not necessary if you eat properly. Vitamins don't correct problems that are caused by improper eating habits.

No vitamin supplement can substitute for eating wisely. In fact, vitamins can harm you if taken excessively. If you suspect you need a dietary supplement, get advice from a qualified medical doctor.

Eat a wide range of foods in moderation, from each of the basic food groups.

1. C. Zviak, *The Science of Hair Care* (New York: Marcel Dekker, Inc., 1986).
2. Masusle, R. and Zaun, H., *Fortschr. Med.*, 1972, 90:687.

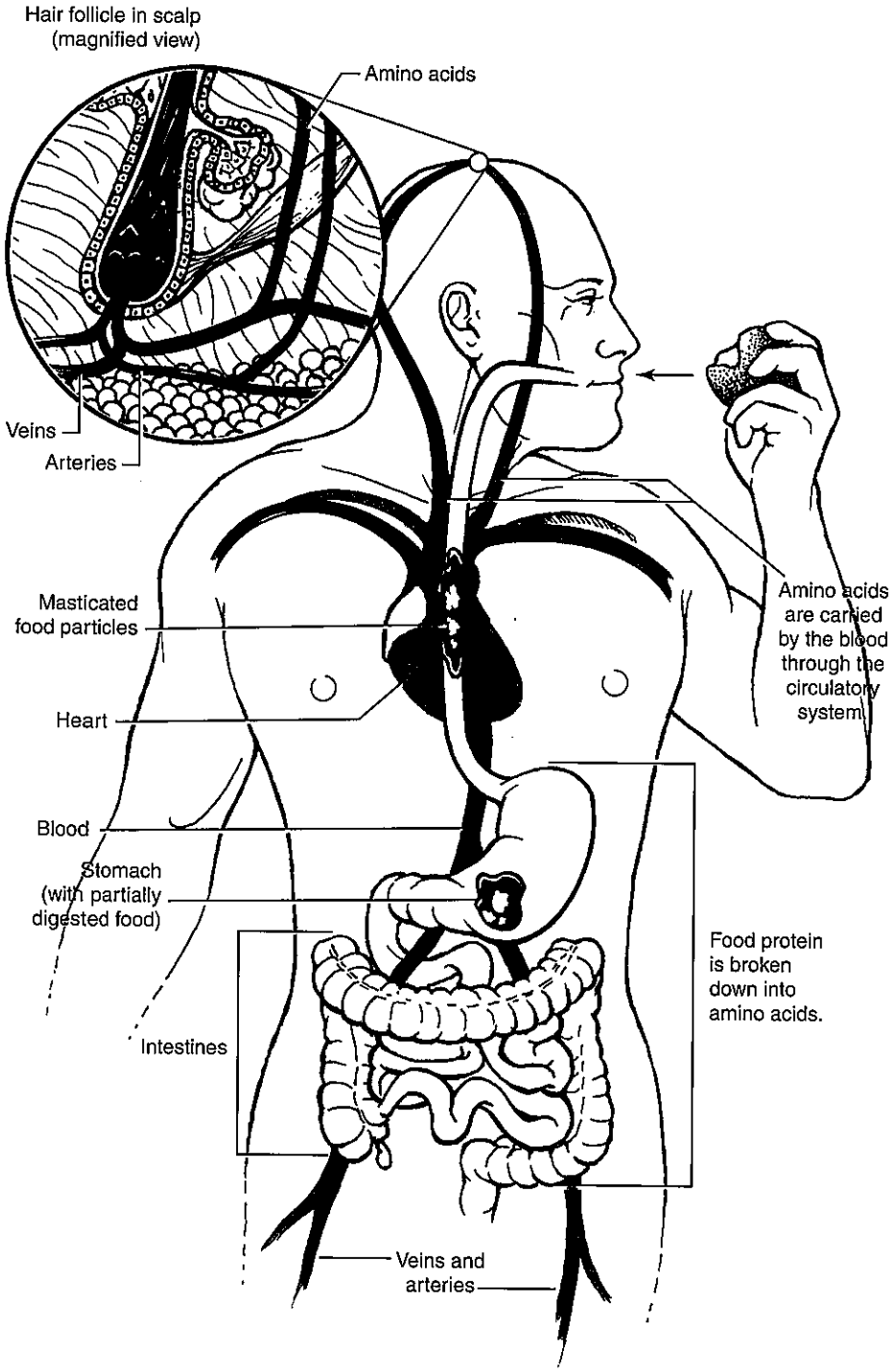

Figure 7-29 *Digestion converts the food we eat into a form that can supply nourishment to the skin and hair.*

Review Questions

1. What are the three phases of hair growth, and how long does each phase last?
2. Which grows faster, men's hair or women's?
3. On the average, how long will most hairs remain in the scalp?
4. Which type of hair is found on the head and legs of both sexes?
5. Using the information found in this chapter, estimate how long the average hair would grow on a woman in one year. Then do the same for an average male. How do they compare?
6. What combination of pigments causes light chestnut brown hair?
7. What effect do chemical relaxer applications have on hair diameter?
8. Why would light blond hair be easier to color than dark blond hair?
9. If a client's scalp contains 100,000 hairs, use the average density of hair (given in this chapter) to figure out how many square inches are in the entire scalp.

Discussion Questions

1. Hair comes in a variety of diameters. What factors (there are several) do you think influence the diameter of the hair? For example, could a hair shaft be wider than its follicle canal?
2. What do you suppose would happen if the length of a client's anagen phase was cut in half and his or her telogen phase lasted for one year?
3. If shaving or cutting hair has no effect on the rate of hair growth, why does hair seem to grow so fast after a shave, but so slowly when a man is growing a beard?