Hair Biology
Growth and Pigmentation

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KEYWORDS

• Hair growth cycle • Hair pigmentation • Gray hair • Hair biology • Minoxidil • Finasteride • Dutasteride • PRP

KEY POINTS

- The 3 phases of the hair growth cycle are anagen, catagen, and telogen.
- Topical minoxidil opens potassium channels and increases the diameter of existing hairs.
- Oral finasteride is a Food and Drug Administration–approved type 2 5α-reductase inhibitor that affects the follicle, size, and amount of hair.
- Dutasteride is a type 1 and type 2 5α-reductase inhibitor used off-label to treat hair loss.

INTRODUCTION

For both men and women, having healthy hair denotes health, youth, and vitality. In mammals, hair serves a protective and evolutionary function. Although hair in humans may not be important for skin barrier protection from a biologic perspective, hair and pigment, or lack thereof, can have a significant impact on perceived social relevance as well emotional and psychological health. According to the American Hair Loss Association, more than $3.5 billion are spent each year by both men and women in the United States to treat hair loss. The practice of hair coloring has been documented since 1500 BC, and interest in hair restoration has not waned. The development of synthetic dyes for hair can be traced to the 1860s with the discovery of reactivity of paraphenylenediamine with air. Today, even with the advent of follicular unit extraction and various synthetic hair pigmentation regimens available to rejuvenate scalp hair, there remains a great demand for a product that could potentially halt, slow, or even reverse hair senescence. This article reviews the anatomy and physiology of hair growth and pigmentation as well as briefly reviewing the various biologic modifiers most commonly used.

ANATOMY OF THE HAIR FOLLICLE

Hair can grow individually, in groups of 2 to 3, or even at times in groups of 4 to 5. These groups are known as *follicular units*. Each individual hair shaft in the growth phase is composed of 3 main concentric regions: the medulla, cortex, and cuticle. The medulla comprises the innermost layer and is formed from transparent cells and air spaces that vary among different hair types. It is often difficult to identify on light microscopy and at times may be entirely absent. The cells comprising the medulla contain glycogen-rich vacuoles and medullary granules, which contain citrulline. The middle layer is called the cortex and is the business center of the hair shaft. The cortex is what comprises the bulk and lends the mechanical strength to the hair shaft; it is comprised of a highly structured protein, keratin, which is organized filaments made up of long,

Disclosure: None.
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Facial Plast Surg Clin N Am ■ (2018) ■–■
https://doi.org/10.1016/j.fsc.2018.06.003

helical strands. The cells keratinize without forming granules through a process known as *trichilemmal keratinization*, as they move gradually upward from the hair matrix. The filamentous structure allows a single hair shaft to resist strain of up to 100 g, whereas the helical structure lends it elasticity. Therefore, the average full head of hair can hold more than 10 tons of weight. The groups of filaments form the cortex and are held together with disulfide, hydrogen, and salt bonds. This layer also has many important roles, such as storing the majority of the hair's moisture and housing the cells that lend pigment to the hair shaft. The number, distribution, and types of melanin granules contained in the cortex are what gives the hair fiber its pigment. Finally, the outer layer is known as the cuticle. This layer is composed of overlapping layers of 8 to 10 flat cells pointed outward and upward that interlock with the inner root sheath (IRS). When viewed under light electron microscopy, it has the appearance of roof shingles and is approximately 3 μm to 4 μm in thickness. When this layer is intact, it can last up to 6 years; it also reflects light and gives hair its shine and the appearance of good health.[1,2]

The hair follicle can be divided into 3 segments: lower, middle, and upper (**Figs. 1** and **2**). The lower segment is the area from the base of the follicle to the insertion of the arrector pili muscle and consists of the bulb and suprabulb regions. The bulb

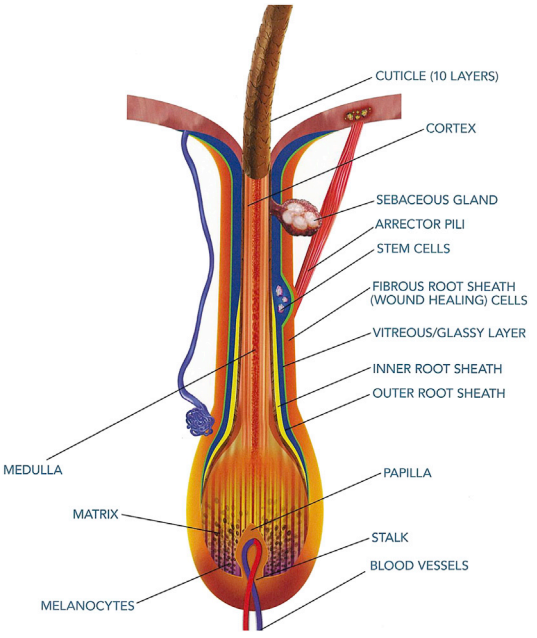

Fig. 1. Anatomy of a hair follicle. This is an illustration of the anatomy of a hair follicle and its associated adnexal structures. (*Courtesy of* Sajjad Khan, MD, Dubai, United Arab Emirates.)

is comprised of the dermal papilla and the surrounding matrix. The papilla protrudes into the hair bulb and consists of an accumulation of egg-shaped mesenchymal cells, which direct hair growth. An abundance of melanin can be found within the melanophages that reside within the dermal papilla. The lower aspect of the papilla merges with the fibrous root sheath (FRS), which surrounds the hair follicle. It is the size of the papilla and the bulb that determines a hair's diameter. The matrix contains the hair's germination cells; this collection of peridermal cells divides rapidly and migrates upward to give rise to the hair shaft and internal root sheath. Melanin is transferred from the melanocytes found between the basal cells of the hair matrix to the cells, which make up the hair shaft. Hair pigmentation is determined by the quantity of melanin deposited to the growing hair shaft. The hair matrix cells give rise to 6 different types of cells that make up the different layers of the hair shaft and the IRS.[1,2]

The suprabulb region is the area between the hair bulb and the isthmus. It consists of the hair shaft, the IRS, the outer root sheath (ORS), vitreous layer (VR), and the FRS (see **Fig. 2**). The IRS serves to coat and support the hair shaft until it reaches the level of the isthmus, at which point it degenerates and exfoliates in the infundibular space. The IRS is composed of 3 concentric cell layers, which keratinize by forming trichohyalin granules (soft keratin): outer, middle, and inner. The outermost layer, also known as the Henle layer, keratinizes first. The middle layer, also referred to as the Huxley layer, keratinizes last. The cells of the innermost layer, also known as the IRS cuticle layer, keratinizes after the Henle layer. The cells of this innermost layer point downward and inward to interdigitate with the cells of the hair cuticle. Although these 3 layers are distinct, they keratinize relatively low in the hair follicle and become indistinguishable at higher levels, thereby enabling it to function as a single unit to cover the hair shaft. The ORS covers the IRS as it extends up from the matrix cells at the lower end of the hair bulb to the meatus of the sebaceous gland duct. It is thinnest at the bulb and thickest in the middle portion of the hair follicle. Only once the IRS disintegrates at the level of the isthmus does the ORS keratinize without forming granules. The ORS cells have a clear, vacuolated appearance due to the large amounts of glycogen. When the ORS reaches the level of the infundibulum, the keratinization changes to normal epidermal keratinization with formation of the granular cell layer and the stratum corneum. The vitreous (glossy) layer is an acellular, eosinophilic zone the surrounds the ORS. It is continuous