hair root characteristics of the human scalp hair in health and disease

PROEFSCHRIFT

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WOENSDAG 24 FEBRUARI 1982, DES NAMIDDAGS
TE 2.00 UUR

DOOR

johanna dora renske peereboom-wynia,

GEBOREN TE 's-GRAVENHAGE.

PALLAS-OFFSET N.V. - DEN HAAG

PROMOTOR : PROF.DR.E.STOLZ
CO-REFERENTEN: PROF.DR.F.J.EBLING
PROF.DR.G.L.KALSBEEK

ERRATA

p. 15	text to fig. 12	the hair follicle in catagen (high magnification) .... the hair follicle in catagen.
p. 39	2nd paragraph, last line	a progressive .... a progressive atrophy during the next ten days.
p. 44	3rd paragraph, last line	page 37 .... page 36
p. 58	nr. 7	>20° angulation .... >20° angulation, hair root sheaths firmly encasing the hair shaft and hair root.
p. 73	table 21 - 1st paragraph	TAA patients .... AA patients (T-region)
	2nd paragraph	MAA patients .... AA patients (M-region)
p. 74	table 22 - 5th paragraph	TAA patients .... AA patients (T-region)
	6th paragraph	MAA patients .... AA patients (M-region)
p. 77	Reference 7.5, 1st line	table 6 .... table 16
p. 79	last paragraph - 3rd line	processes
p. 84	2nd paragraph, last line	page 82 .... page 83.
p. 93	4th paragraph, 1st line	hours of .... hours after
	Reference 10.1 - 1), 2nd line	lentil- to penny-sized hairless .... lenticular- to nummular-sized hairless
p. 96	4th paragraph, last line	5 and 2 .... 4 and 3

CONTENTS

INTRODUCTION

Morphological data on hair follicles have been available for over a hundred years, but only in recent years has a substantial advance been made in our knowledge of types and distribution of hair, its structure, metabolism, biochemistry and clinical patterns, and hormonal influences on hair growth.

Hair plucking followed by microscopic examination has been used as a diagnostic procedure in the past two decades. Van Scott et al. (1957) were first to standardize the technique of human hair plucking (epilation) and to design criteria for assessment of the morphology of the various phases of the hair growth cycle and of aberrant hair roots.

Subsequent authors, however, have used modifications of this technique and applied varying and conflicting criteria in assessing the morphology of the various phases of the hair growth cycle and of aberrant hair roots.

General acceptance of a reliable uniform technique, and equally strict criteria for different morphological hair root structures, can ensure that comparable data are obtained.

The findings presented in this thesis are confined to human scalp hair roots. The preparation of a hair root status involves a simple, atraumatic technique of obtaining material, and the study of the physiology and pathology of hair growth in a manner which could be very useful in evaluating hair diseases and determining appropriate therapy (Peereboom-Wynia 1975; Peereboom-Wynia and Beek 1977).

We attempted to achieve standardization of the terms 'anagen', 'catagen', 'telogen', 'dysplastic' and 'dystrophic' in a comparative study which included the following efforts:

- assessment of the importance of various hair plucking techniques
- registration of morphological hair root characteristics in a diagram
- determination of the incidence of various hair root types, root sheath features, angulation and deformities in healthy subjects and patients
- determination of morphological hair root characteristics in the various phases of hair growth cycle and in aberrant hair roots
- registration of the limits of normal values of various hair root characteristics in healthy subjects.

Finally, clinical research with the newly designed hair plucking technique demonstrates the value of the new scheme of the hair root status in examining patients in the first two stages of infectious syphilis, and its significance for the prognosis of alopecia areata.

CHAPTER 1

THE HUMAN HAIR

1.1 *Introduction*

Hairs are solid structures composed of compactly cemented keratinized cells, produced by sac-like epidermal follicles which grow into the dermis to varying depths. Hair follicles, together with the sebaceous glands attached to their upper parts, form pilosebaceous units (Montagna 1976).

Anatomical details of hair follicles have been known for over a hundred years (Montagna 1956), but "in spite of this, most observations on hair growth have suffered from the investigators' ignorance of the most fundamental principles of the biology of hair growth" (Montagna, Ellis 1958, p.IX). In recent years, however, there has been "a considerable advance in our knowledge of the types and distribution of hair, of its structure and cyclical pattern of growth, of its metabolism and biochemistry, and how they are affected by genetic, hormonal and environmental factors" (Montagna, Parakkal, Moretti et al 1974, p.172).

1.2 *Embryology*

1.2.1 *Early formation of the hair follicle*

The human skin arises from the juxtaposition of two major embryological elements: the prospective epidermis and the mesoderm (fig.1a).
The first hair primordia develop towards the end of the second or early in the course of the third month in the areas of the eyebrows, upper lip and chin. The sign heralding a future hair follicle is a crowding of nuclei in the basal layer of the epidermis, the so-called "pre-germ" (Pinkus 1910; Serri and Huber 1963).

The pre-germ rapidly passes into the "hair germ" stage: basal cells become very high, nuclei are elongated and begin to protude down into the dermis.
A group of mesenchymal cells - the presumptive dermal papilla - gathers at the bottom of the hair germ (fig.1b).

The characteristic asymmetry of early germs is demonstrable in longitudinally cut hair follicle sections: the steep anterior side lies perpendicular to the epidermis, while the slanting posterior side gradually merges with the basal layer: hair peg stage (fig.1c).
As the germ develops further, the crowding mesenchymal cells form an anteroposteriorly slanted column (or peg) which grows into the dermis (Pinkus, 1958).

The free end of the peg becomes progressively indented and bulb-like, growing around a gradually more differentiating presumptive dermal papilla. Next, two solid epithelial swellings start to grow on the posterior side of the follicle. The upper is the primordium of the

sebaceous gland, while the lower gives rise to the arrector pili muscle (fig.1d).

In this stage the follicle is still a solid epithelial structure surrounded by a mesenchymal sheath. Its expanded distal part - the bulb - enclosed the dermal papilla, which remains attached to a basal plate of dermal cells by a narrow stalk.

Pigment cells are initially seen throughout the bulb, but subsequently they are almost entirely restricted to the upper two-thirds.

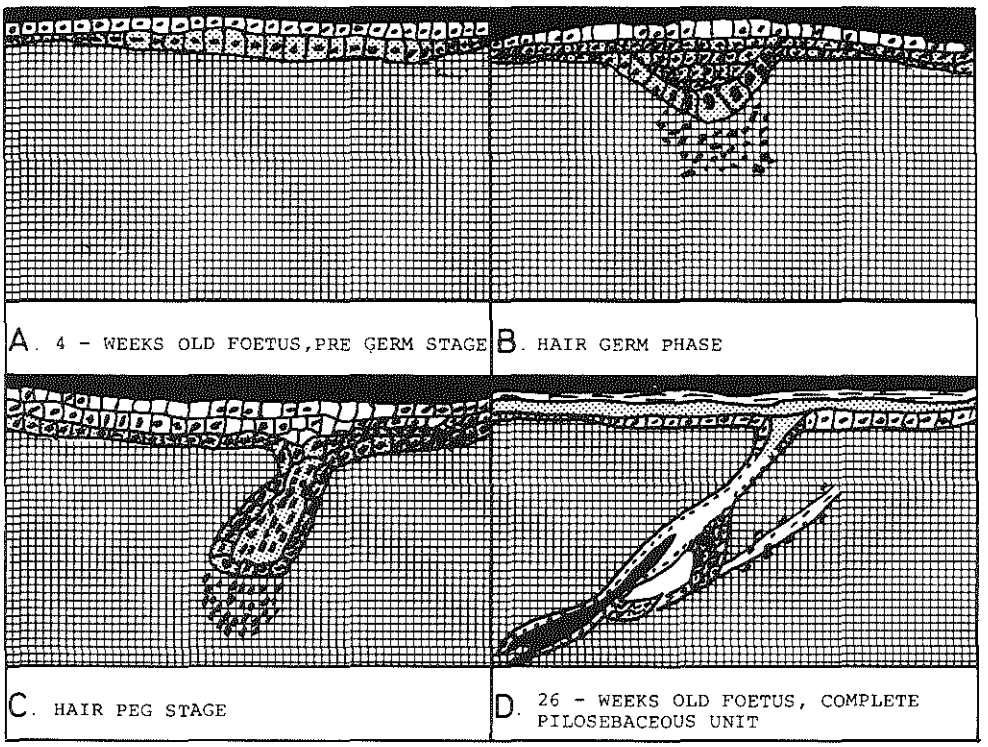


FIG. 1. EMBRYOLOGY OF THE HUMAN HAIR FOLLICLE.

1.2.2 *Further development of the hair follicle*

Cells which give rise to the inner root sheath in the fourth foetal month, are the first to differentiate. They originate from bulb cells bordering the dermal papilla, which align themselves longitudinally and around the lower half of the papilla by frequent mitotic division. The resulting cells ascend higher and, through mechanisms so far unknown, differentiate

into five dissimilar end-products: the outer root sheath, the inner root sheath (composed of the layers of Henle and Huxley), the cuticle of the inner root sheath, the cuticle of the hair and the cortex. The medulla is still absent before birth.

During the fourth and fifth human foetal months, primordial hair follicles develop throughout the body in cephalocaudal direction.
After the seventh foetal month, concomitantly with the development of the dermis, connective tissue sheaths can be seen around the hair follicles: the entire hair follicle is surrounded by a hyaline membrane and two or three layers of connective tissue made up of collagen fibres and fibrocytes, in full accordance with the development of the dermis. Figure 2 shows a section through the lower one-third of a developed hair follicle.

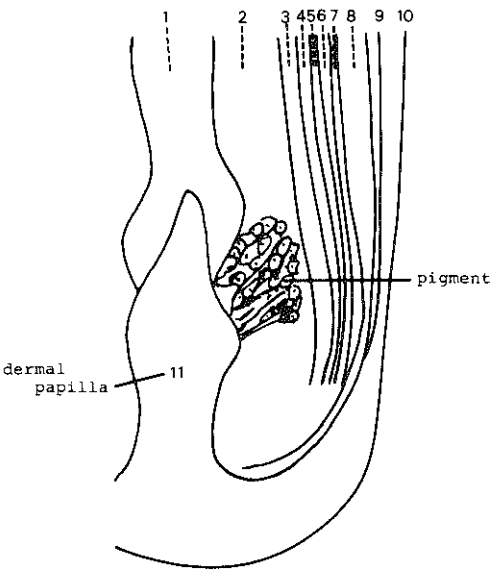


FIG. 2 SCHEMATIC REPRESENTATION OF THE LOWER PART OF THE DEVELOPED HAIR FOLLICLE . (FROM H.RABLE: HANDBUCH DER HAUTKRANKHEITEN, 1902.)

1. medulla
2. cortex
3. hair cuticle
4. inner root sheath cuticle
5. Huxley's layer
6. Henle's layer
7. outer root sheath
8. basal cells of outer root sheath
9. basal layer of epidermis (hyaline membrane)
10. connective tissue

The first elastic fibres appear in the dermis much later than the collagen fibres. Very few elastic fibres can therefore be found in the connective tissue sheaths of hair follicles in a 9-month foetus. Subsequently their numbers increase, especially after birth and the finest elastic fibres are finally formed during puberty (Arao, 1976).
The absolute number of hair follicles developed in utero, however, does not increase after birth (Szabo, 1958).

1.3 *Hair types and hair coat*

All hair follicles formed in utero produce delicate, slender, slightly pigmented woolly structures which have no medulla: the so-called lanugo hairs. These hair follicles contain functional melanocytes in small, irregularly distributed clusters, not only in the matrix but also in the inner root sheath.

Complete shedding of these hairs takes place shortly before or immediately after birth, and all of them are replaced by shorter, more delicate hairs without either pigment or medulla: the vellus or down hair (fig.3). (In exceptional cases, i.e. in the rare hereditary syndrome known as hypertrichosis lanuginosa congenita, the lanugo hairs may persist throughout life).

Only the hairs of the eyelashes, eyebrows and scalp are replaced, not by vellus but by a coarser hair type which shows more vigorous growth and represents the ultimate stage of hair development. These hairs are called terminal hairs (fig.3) and ultimately differ in diameter, length and pigmentation. As a rule they have a well-developed medulla over most of their length, and they have flattened scales (McCarty 1940).

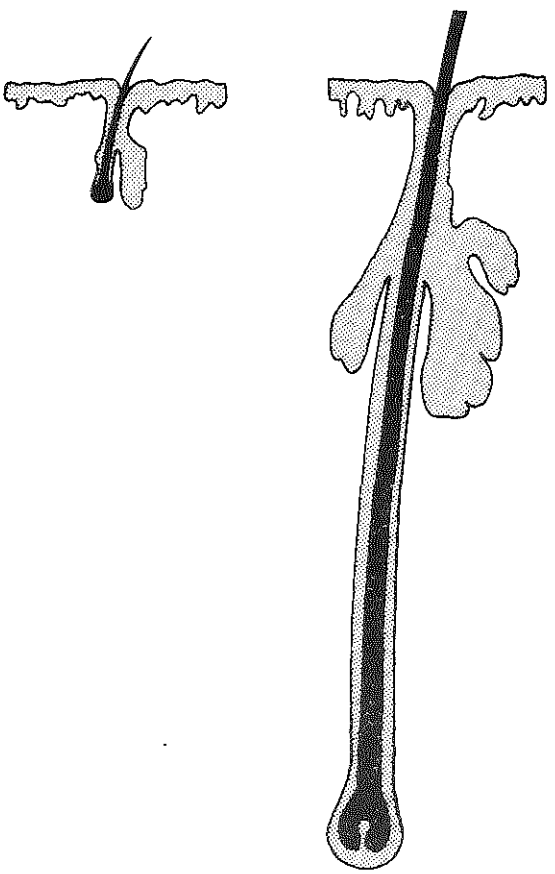


FIG. 3 VELLUS HAIR TERMINAL HAIR

1.4 *Hair patterns*

The development of different hair patterns after birth is influenced by:
1) sex and age
2) race and heredity
3) hormonal factors.

1.4.1 *Influence of sex and age*

Apart from the terminal hairs of the eyelashes, eyebrows and scalp, all hairs on the human body are vellus hairs until puberty. These vellus hairs are the same in both sexes. In early puberty these vellus hairs are gradually replaced by terminal hairs in a smooth conversion.

The chronological order of terminal hair growth is: pubic region, axillae, lower legs, upper legs, forearms, gluteal region, chest and back, upper arms and shoulders. In the face, replacement is seen first on the lateral side of the upper lip, followed by the chin, cheeks and finally the remaining beard region.

Males show much more pronounced development of beard and body hairs than females. Figures 4 through 6 show body patterns of extreme terminal hair growth in the male, normal terminal hair growth in males and hirsute females, and normal terminal hair growth in the female, respectively.

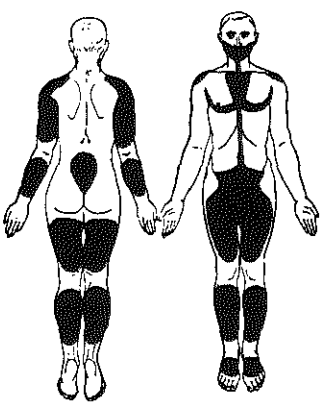


FIG. 4 EXTREME BODY PATTERN OF HAIR GROWTH IN MALES

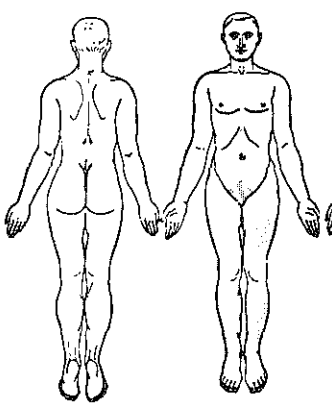


FIG. 5 NORMAL BODY PATTERN OF HAIR GROWTH IN MALES AND HIRSUTE FEMALES

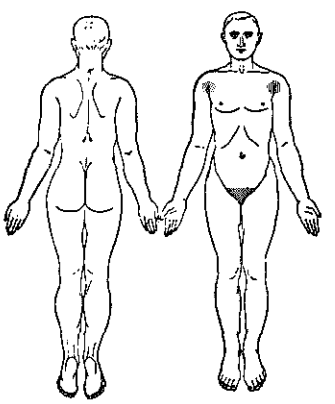


FIG . 6 NORMAL BODY PATTERN OF HAIR GROWTH IN FEMALES.

Moreover, there is considerable individual variation in physiological human hair distribution, while the two sexes show only relative differences in hair coat. A study of the extension and distribution of human body hair was published by Beek in 1950.

The male is generally much more hairy than the female. Terminal hair on the extremities and the chest is found three times as frequently in men as in women. Hair growth in the areas of the beard, moustache, sternum, sacrum and buttocks is five to six times as frequent in men as in women, and the same applies to baldness and frontal recession. Hair growth on the external ear is sixty times as frequently seen in men as in women.

Another important feature is the cranial border of the pubic hair, which can be horizontal, sagittal, acuminate (tapering) or disperse (fig.7).

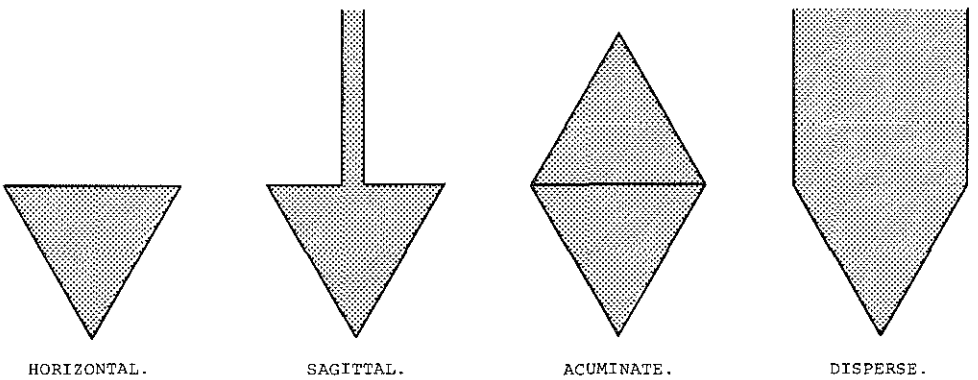


FIG. 7. CRANIAL BORDER OF PUBIC HAIR.

A graphic representation of the distribution of pubic hair growth patterns as observed in 1000 normal women and men is presented in fig.8. Horizontal and sagittal cranial borders of pubic hair are found in most women and a relatively large number of men. An acuminate cranial border is found in a small percentage of women but a large percentage of man. There is one absolute difference in body hair growth pattern between males and females: a disperse cranial border of the pubic hair is found only in males, not in females.

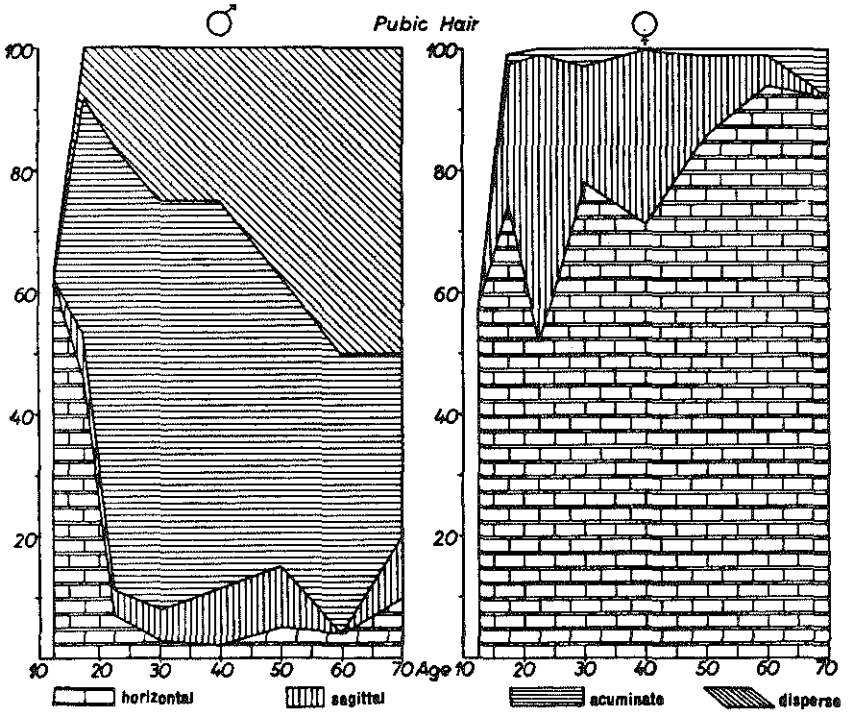


Fig. 8 Graphic representation of the distribution of cranial pubic border
(From C.H. Beek: A study of the extension and distribution of human body hair. Dermatologica 101 322,1950)

Male pattern baldness gradually increases during ageing. The process commences with recession, first in the frontal and then in the cranial region. When baldness in these two regions becomes confluent we have the clinical picture of "calvities frontalis et cranialis" or androgenetic alopecia. This kind of regressive conversion of terminal to vellus hair in males starts after puberty. Females may develop comparable baldness after the onset of the climacteric (Beek 1950), and the stages of this balding process are similar to those observed in males.

Ludwig (1977), however, stated that the female balding process generally differs in course from male balding (fig.9). It starts with uniform rarefaction of hair on the crown. The resulting oval area of rarefied hair growth, which encompasses inconspicuous hairs of normal length and a variable percentage of thinner, shorter and sometimes less pigmented hairs, is surrounded by a circular band of variable width in which hair growth is of normal density. A usually well-preserved fringe of hair along the frontal border is quite characteristic.

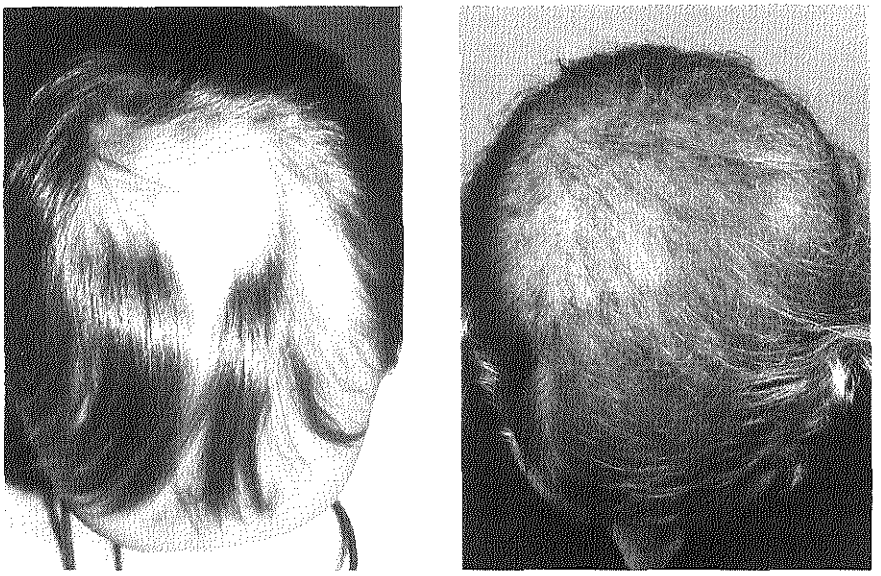


FIG. 9 COMMON BALDNESS A. MALE B. FEMALE

The rarefaction on the crown within the abovementioned area becomes more pronounced with increasing age, and the thinner and shorter hairs become more numerous.

Severe loss of body hairs can occur during the female climacteric, and is sometimes accompanied by increased hair growth in the region of beard and moustache. The male climacteric, on the other hand, is accompanied by less abrupt hair loss (Beek 1950). In both sexes, terminal hairs are generally replaced by vellus hairs.

In conclusion: from early puberty on vellus hairs are progressively replaced by terminal hairs, while more advanced age is characterized by regressive conversion of the terminal hair coat to a vellus hair coat.

1.4.2 Influence of race and heredity

Wide, genetically determined variations in pattern and extent of hair growth can be observed both between ethnic groups and between individuals. A comparison of ethnic groups shows that mongoloids, both male and female, show less pubic, axillary, beard, coarse body and external ear hair growth, and less baldness of the scalp, than do caucasoids.

No instance of facial hirsutism was found in a large series of Japanese women, but a high incidence has been reported in caucasian women (Hamilton 1958). Studies of twins and members of large families as well as comparisons between caucasians and Japanese, moreover, demonstrate and emphasize the significant influence of genetic factors on hair growth. Environmental factors would seem to exert no influence: for example, males of Japanese origin who lived in New York City and ate American food, had

beard and axillary hair growth values similar to those of Japanese of comparable age living in Tokyo and eating Japanese food.

Geographical, climatic and dietary factors seem to be of no major importance in explaining the less marked beard and axillary hair growth in Japanese versus caucasians.

The most striking genetically and racially determined differences are seen in scalp hair. It is general knowledge that mongoloids tend to have coarse, straight hair, while negroids tend to have curly hair and caucasoids show a whole range of textures and curls. In cross-section, these hairs are solid, flattened and moderately elliptical, and slender, respectively.

Significant variations in medullation, amount of cuticular scales, kinking and average curvature are also observed between different populations (Hrdy 1973).

1.4.3 Hormonal factors

On the basis of hormonal factors, human hair can be classified as follows:

a. hair which is the same in both sexes and not dependent on steroid hormones, e.g. vellus hair and the hair of eyebrows and eyelashes;

   development of common baldness and sexual hair growth can be prevented by prepuberal castration, but castration of a bald adult does not promote re-growth of hair (Hamilton 1958);

b. ambosexual hair, which is present and similar but not necessarily identical in both sexes, e.g. axillary and pubic hair, and which shows conversion from vellus to terminal hair in puberty. This conversion coincides at least initially with a rise in levels of androgenic steroid hormones from testicular, adrenocortical and ovarian sources;

c. truly sexual hair, which develops as a secondary sex character during puberty; its development depends on the level of androgenic steroid hormones, and it comprises the terminal hairs of the beard, chest, abdomen (upper pubic triangle), shoulders, ears and nose.
   Common baldness also depends on these hormones (Flesh 1954).
   The abovementioned dependence has been clarified by findings obtained in a) eunuchs and b) agonadal women.

   A woman suffering from hypogonadotropic hypovaria was given substitution therapy. Cyclic oestrogen and progesterone induced regular menses and she developed breasts and a feminine habitus; but pubic and axillary hair failed to appear. Androgens were then added, and growth of pubic and axillary hair followed but disappeared again when the androgens were discontinued (Greenblatt, 1965).

   Further animal experiments and clinical studies have made it clear that also oestrogens, corticosteroids and thyroid hormones may influence and modify body patterns of hair growth, but that androgenic steroids are responsible for growth of sexual hair in man (Mohn 1958, Ebling and Johnson 1961, 1964, 1979; Hamilton 1958, Johnson 1977).

1.5 *Dynamics, histomorphology and ultrastructure of the human hair growth cycle*

Each hair follicle shows recurrent cycles of active growth, regression and rest, in contrast to the continuous production of sebum and keratin. In most wild mammals of temperate zones the cycles of follicle growth in each region of the body are synchronized: waves of growth activity flow from one or several centres so that all hairs are in the same phase of active growth, regression or rest (Ebling 1965, 1970).
In Merino sheep, however, follicular activity - although in actual fact also of the "wave type" - appears to be continuous because the growing period has been markedly prolonged by natural selection.

The situation in human adults and guinea-pigs is different: the cycle of each follicle is independent of that of the adjacent follicle, and follicular activity thus shows what is known as a mosaic pattern.

The various phases of the hair growth cycle (fig.10) are known as:

1) active growth phase (anagen)
2) regression phase (catagen)
3) rest phase (telogen)

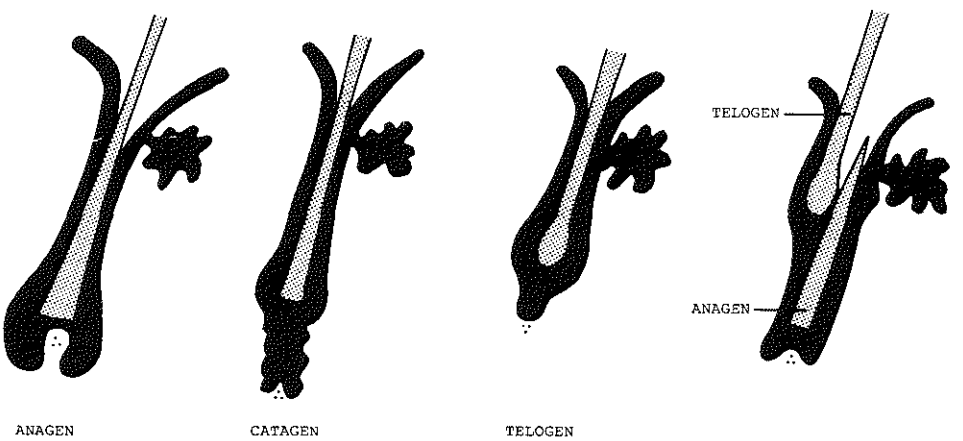


FIG. 10 PHASES OF THE HAIR GROWTH CYCLE

The first sign of the anagen is increased mitotic activity in the nipple-like protrusion beneath the hair bulb. The strand extends down and envelops the papilla through continued cell division, while the base of the entire follicle extends down until the hair root is deeply embedded in the dermis. The hair becomes thick, although there is some resistance of the adjacent connective tissue (Sato 1976).

The first sign of the catagen is an upward movement of the hair root, which assumes the shape of a club in the telogen. At the end of the telogen, a new hair in its early anagen grows up beside this club hair as a thin keratinized dome, which pushes its way past the club hair.

In humans the club hair is as a rule not immediately extruded from the

follicle but remains in situ for a while, next to the new hair. For a while, therefore (rarely more than a week), two hairs emerge from the same follicle: the old club hair and its successor.

In some animal species', including man club hairs remain in the follicle through several subsequent hair generations, and this explains the occurrence of one kind of multiple hairs (Pinkus 1951; Flesh 1954).

During each new cycle of hair growth the follicle region between the bulb and the upper limit of the inner root sheath is completely replaced.

The upper permanent portion of the follicle contains: the follicular canal surrounding the hair, the aperture of the sebaceous gland duct, and sometimes the aperture of the apocrine sweat gland duct. The follicular canal normally consists of a capillary space between the hair cuticle and the horny layer of the epidermis lining the follicle, which is continuous with the surface epidermis.

These relationships are not static, however, because the follicle shows adaptive growth and can provide space for more than one hair fibre, a capillary space being re-formed around each single hair.

This facilitates the escape of sebaceous and possibly apocrine fluid from the follicular aperture and also, through continuous lubrication, the upward movement of the hair. At the bottom of the follicular canal in the growing hair follicle, the inner root sheath shows a region of desquamation demarcated on one side by the hair and on the other side by the epidermal horny layer (fig.11).

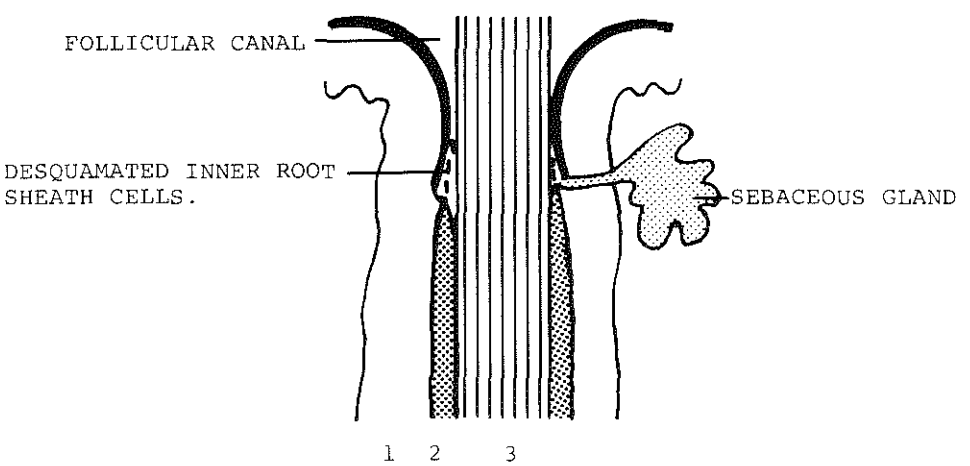


FIG. 11 THE UPPER PART OF THE HAIR FOLLICLE IN ANAGEN

1. OUTER ROOT SHEATH
2. INNER ROOT SHEATH
3. HAIR

When a hair is retained, it is attached by its "brush" fibrils to the sac of the outer root sheath in a permanent portion of the follicle.

Because the hair is pushed up while the perifollicular horny layer grows inward to the follicle, the desquamated horny cells are carried up by the hair cuticle movement and suspended in sebaceous secretion, together with other cells desquamated from the inner and outer root sheaths.

The emerging hair is consequently covered by a film of sebum which contains fragments of various follicular cells. Inner root sheath formation ceases at the end of anagen, and old cells are lost. Next, the hair become contiguous with the outer root sheath and the horny layer of the follicular canal. In most species, including man, cuticle cells and follicular horny layer cells - although in close apposition - are not physically attached and the hair and horny layer cells are desquamated separately (Spearman 1977).

1.5.1 *Ultrastructure of human terminal hair*

Early anagen, late anagen, catagen and telogen are described below according to publications by Hashimoto and Shibazaki (1976), Spearman (1977), Forslind (1979) and Parakkal (1979).

a) Early anagen:

Hair matrix cells form the lateral wall of the hair papilla, and all layers of the hair follicle originate from these cells (fig.2).

The outer root sheath surrounding the hair bulb consists of one or two layers of keratinocytes. These cells do not show true keratinization but possess so-called cementsomes. Together with these cementsomes, membrane-coated granules keep the keratinized Henle cells closely linked with outer root cells.

Matrix cells of the outer root are interconnected by means of desmosomes, but free upward movement of these cells is made possible by a paucity in these junctional structures.

In a follicle above the bulb, the outer root sheath is three layers thick and gradually increases in thickness to several layers in the direction of the sebaceous gland. At this side the most peripheral cells of the outer root sheath are columnar cells, joined to the basal lamina by hemidesmosomes, while individual cells are interconnected by multiple desmosomes and gap junctions similar to those seen in the epidermis. An abundance of hemidesmosomes, desmosomes and gap junctions may stabilise a coordinated cell movement at this level, as observed in the epidermis (MacKenzie 1972).

Non-keratinized outer root sheath cells, joined to keratinized Henle cells produce a number of cementsomes (Hashimoto 1971), which are eventually discharged into intercellular spaces and form an intercellular substance which could play a role in ensuring adherence between keratinized Henle cells and non-keratinized outer root sheath cells, since desmosomes and gap junctions presumably do not function properly in keratinized cells.

Between the insertion of the arrector pili muscle and the aperture of the sebaceous duct, i.e. in the isthmus, keratinization of the outer root

sheath takes place. The most peripheral cells are columnar, while toward the centre cells become flattened and keratinize at the level of the isthmus. Above the isthmus the structure of the outer root sheath gradually becomes identical to that of the epidermis. An increase in the thickness of the keratinized layer of the outer root sheath is presumably necessary to resist pressure from outside.

The inner root sheath inside the outer root sheath consists of three layers which, from the outside inward, are: Henle's layer, Huxley's layer and the cuticle (fig.2). Henle's layer is the first to keratinize in the entire hair follicle, followed by the cuticle of the inner root sheath and finally by Huxley's layer.

The junction between the Henle layer and the outer root sheath in the lower part of the follicle is effected by desmosomes and gap junctions, but when the Henle layer becomes keratinized (whereas the outer root sheath is not) the junction is maintained by a number of discharged cementsomes and some interdigitations of apposed cells.

The interconnections between the Henle cells and between the Henle and the Huxley cells (below) is ensured by desmosomes and gap junctions before these cells become keratinized. After keratinization, the connection between the Henle layer and the Huxley layer is effected by deep invaginations of the cell border which interlock the cells; these are commonly observed in keratinizing cells, not only in Henle's layer but also in other layers, e.g. those of the cortex and medulla. Desmosomes and gap junctions become microscopically inconspicuous and probably cease to function.

Cell shrinkage resulting from degeneration of organelles and from dehydration produces redundant cytomembranes, which either fold in or bulge out. This process also takes place in Huxley's layer and in the cuticle cells of the inner root.

The cuticle of the cortex is visible only in scalp hair of the 16-week-old foetus. In more advanced stages of keratinization the serrated edges of the cuticle cells of the inner root sheath become wedged between those of the keratinized cuticle of the cortex. Between these cells, large knob-like invaginations and small thumbtack projections occur.

The cortex consists of cortical cells which originate from the matrix cells and are localized on or near the vertex of the dome of the papilla. In this region (fig.2) many intermingling melanocytes occur, which transfer melanosomes, in particular to young cortical cells and to a lesser extent also to some cuticular cells. Young premature cortical cells are interconnected by desmosomes and gap junctions.

Cortical cells migrate up through the centre of the follicle, assuming a more and more elongated shape and developing more tonofibrils. No trichohyalin is produced.

During the upward movement, the cells shrink due to degeneration and dehydration, and cell peripheries begin to interdigitate at three-dimensional levels so that it is difficult to define cell contours. Remnants of desmosomes and gap junctions, however, remain clearly visible.

In completely keratinized cortical cells a criss-cross pattern of bundles of keratin filaments produces a fingerprint-like "keratin pattern", separated by melanosomes and cytoplasmic debris.

Cells of the medulla originate from a group of non-descript matrix cells interconnected by desmosomes and ring-like intracellular gap junctions, which surround the upper portion of the hair papilla.
Vacuoles appear within their cytoplasm in the region just above the bulb, and the cells also contain glycogen and may include melanosomes (Breatnach 1971). Above the epidermis, medulla cells appear to dehydrate and their vacuoles become air-filled.

The medulla is formed only in terminal hairs, but remains absent in vellus hairs. It is strand-like and broad in pubic, axillary and beard hair, while in scalp hair it is only one cell layer thick and in places discontinuous. Its presence is variable during the growth of human hair follicles, however, and subsequent hair generations often show alterations.

b) Late anagen:

The growth of follicular down-growth gradually diminishes in late anagen. Melanocytes of the dermal papilla absorb their dendrites, and melanogenesis and mitotic activity of matrix cells cease.

The inner root sheath is a strong, keratinized, funnel-shaped structure which consists of a tube whose widest part is localized just below the aperture of the sebaceous gland. It plays a vital role in the hair growth process.

Due to its early keratinization in comparison with other hair layers, the inner root sheath forms a rigid structure along which growing hair can move upwards. The loss of support at the bottom - due to disappearance of the bulb - causes rapid upward movement of the hair root as the first sign of catagen. Mitotic activity of matrix and inner root sheath as well as melanogenesis have ceased completely by now.

c) Catagen:

Several theories have been advanced on the formation of the resting follicle. Most investigators regard the changes during catagen as degenerative (Chase 1955; Ellis and Moretti 1959; Montagna 1962).
Straile et al. (1961), however, contend that "degeneration and dedifferentiation play little or no part at all during catagen", and "catagen is an orderly and logical sequence of events in the differentiation of the cells of the hair bulb that remain after cessation of mitosis".

Kligman (1959) suggests that both degenerative loss and dedifferentiation of cells take place in human hair follicles during catagen.

Although many authors maintain that degeneration of the lower part of the follicle takes place during catagen, the mechanism of this process has remained obscure (Montagna 1962).

On the basis of histological studies in rats, Braun-Falco and Kint (1965) reached the following conclusions.

- In catagen, the outer root sheath diminishes to one layer of thin cells while the inner root sheath disappears.
- The hair root - defined as "presumptive club" - moves up, surrounded by active cells of the outer root sheath.
- The keratogenous zone distal-to-proximal shortening until definitive keratinization of the club is achieved.

Parakkal (1970) studied rats and mice and described the histomorphology and ultrastructure of the hair follicle in catagen as follows:

"Many structures of the growing follicles are eliminated and new structures of the resting follicles are formed. Cells that are already partly differentiated continue to differentiate and migrate upwards to form the penultimate part of the hair shaft. Where the production of medullary and cuticular cells ceases, i.e. in the last part of the hair, cortical cells are found. A Layer of cells surrounding this last part differentiates into club hair, which is tightly attached to the cortical cells and resembles them in development and structure except that the filaments of the club do not exhibit the "keratin pattern" seen in the cortex.

During early differentiation of club cells, bundles of filaments are formed in their cytoplasm. But whereas the cortical filaments are all arranged parallel to the long axis of the hair, those of the club show a random arrangement. They increase in number and eventually fill the cytoplasm (the "ghost" of a nucleus is occasionally visible).

The club cells are firmly anchored into the surrounding germ cells by extensive interdigitating areas of modified desmosomal attachments (fig.12).

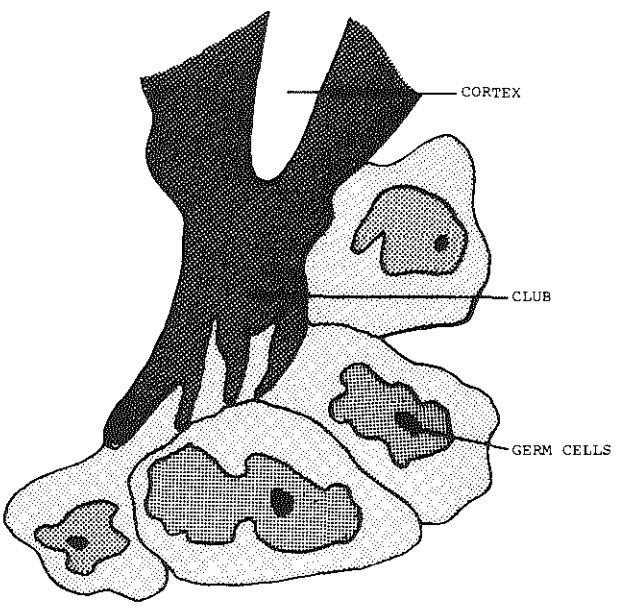


FIG. 12 SCHEMATIC REPRESENTATION OF THE LAST PART OF THE HAIR FOLLICLE IN CATAGEN (HIGH MAGNIFICATION)

Since the germ cells surrounding the club are formed by transformation

of the outer root sheath cells halfway the growing follicle, additional detailed knowledge of the structure of these sheath cells is important. All the cells have large accumulations of glycogen, which is one of the identifying characteristics of outer root sheath cells (the inner root sheath cells at the same level contain hardly any glycogen).

The outer root sheath cells have free ribosomes, a few profiles of rough-surfaced endoplasmic reticulum distributed throughout the cytoplasm, and a compact Golgi zone. The cell membranes are often convoluted and have only a few desmosomes.

When outer root sheath cells begin to transform into germ cells, numerous autophagic vacuoles of varying size and shape are formed, which contain an assortment of mitochondriae, ribosomes, endoplasmic reticulum and glycogen. These sequestered organelles undergo progressive degeneration mediated by acid hydrolases. Histochemical techniques have demonstrated that both acid phosphatases and esterases are localized in these vacuoles.

Simultaneously, the first cytoplasmic filaments are formed which eventually occupy a large part of the cells. Cell membranes have developed numerous desmosomal attachments by this time, which are hemidesmosomes where they face the dermis. These germ cells contain no glycogen and their most characteristic structures are individual and bundled filaments scattered throughout the cytoplasm.

Some of the fully formed germ cells resemble basal epidermal cells, the germ consisting of two or three layers which surround the club like a capsule, while the basal layer folds extensively (fig.13).

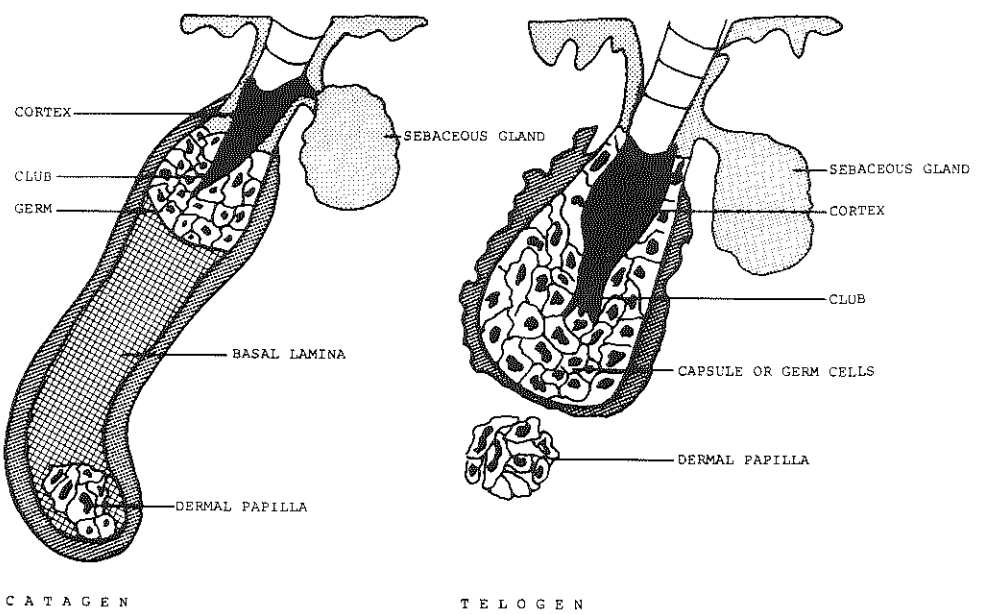


FIG.13. SCHEMATIC REPRESENTATION OF THE HAIR FOLLICLE IN CATAGEN AND TELOGEN

Since they are the cradle for the next hair generation, germ cells are the most important feature of the resting follicle. After formation of the club and the surrounding capsule of germ cells, cells below them are eventually resorbed. In the early stages of resorption, autophagic vacuoles containing phosphatases and esterases appear in all cells. In more advanced stages of resorption the cells undergo complete disintegration. The dermal papilla forms a ball of cells just underneath the hair.

Large areas of the lower part of the hair follicle are now occupied by cellular debris, myelin figures and dense bodies and vacuoles which contain assorted amorphous material. As such cells are resorbed, the follicle loses its integrity and buckles. Concomitantly, connective tissue elements around the lower part of the follicle develop gross changes: the highly plicated basal layer encloses the atrophying cells and - at the end of catagen - is completely resorbed."

The above description by Parakkal (1970) demonstrates unequivocally that the catagen is a phase of physiological regression: cellular disintegration and autolysis are brought about by acid hydrolysis.

d) Telogen:

In telogen, fibroblasts derived from the dermal papilla assume a spherical shape and migrate upwards, coming to rest just underneath the capsule. This phase is characterized by the presence of a formed "club" in the upper part of the hair follicle, which contains germ cells formed in catagen. The club initially consists of a "brush" of incompletely keratinized cells. Subsequently it ascends by virtue of multiplication of matrix cells, which form an epithelial cord and become fully keratinized. The solid cellular cord extends up to the level of the sebaceous gland, and the club is firmly fixed in this column by fusiform keratinized processes.

Next, cellular degeneration causes marked reduction in the size of the epithelial column, which shortens to a nipple-like protrusion found beneath the epithelial sac in which the club is inserted. The hair club finds its final resting position in the upper portion of the hair follicle, at the level of the attachment of the arrector pili muscle. At this time the visible hair shaft attains its final length. All these events are schematically represented in fig.14.

Although the club hair is a dead structure - a foreign body inserted in the skin - it would be arroneous to assume that its attachment in the follicle is loose. The club constitutes a firm, hard anchor which keeps the hair shaft in its resting position.

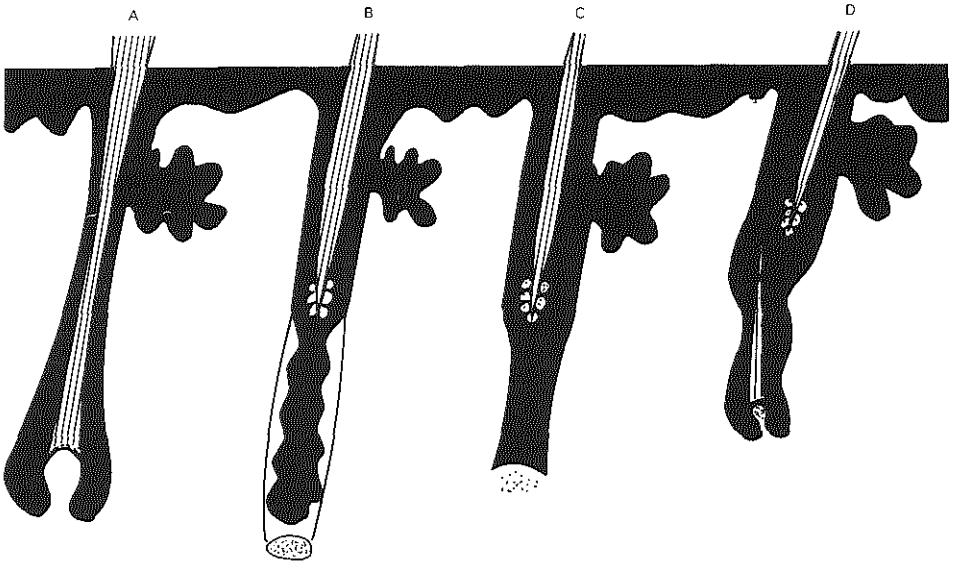


FIG. 14. A = ANAGEN
B = CATAGEN WITH IN INCIPIENT CLUB FORMATION
C = GRADUAL ASCENT OF DERMAL PAPILLA AND SHORTENING OF EPITHELIAL COLUMN
D = FORMATION OF THE NEW HAIR IN EARLY ANAGEN

1.6 *Mechanisms controlling the hair growth cycle and the hair root status*

The time relations of the various hair follicle stages depend on:

a. hair plucking,
b. hormonal influences,
c. sex and age, and especially
d. the body regions.

Mechanisms controlling the hair growth cycle have been studied in detail mainly in laboratory animals.

a) Hair plucking

In test animals with an undulant growth-pattern, plucking of telogen follicles and application of depilatory cream were shown to stimulate new anagen growth. (Chase and Montagna 1951, Ebling and Johnson 1964). These observations could not be reproduced in human subjects. (Johnson 1965, Peereboom-Wynia 1972).

b) Hormonal influences

In laboratory animals, Johnson (1977), Ebling and Johnson (1961, 1964), demonstrated the following changes in the hair growth cycle in response to hormonal influences:

- hypophysectomy accelerated the initiation of anagen in resting follicles;
- ACTH inhibited this acceleration, but not in adrenalectomized animals;
- adrenalectomy accelerated the initiation of anagen in resting follicles;
- thyroidectomy delayed this initiation;
- gonadectomy advanced the initiation of hair growth in resting follicles, while oestradiol and testosterone delayed it.

Hair growth cycles in wild mammals are linked to sexual cycles which, in temperate climates, are determined by the photoperiod. In mammals in which domestication has modified seasonal and sexual cycles, the normal essential features of the follicular cycle have been retained by adjustment (Ebling 1965). Even in human subjects, the possibility of seasonal fluctuations has been demonstrated by Orentreich (1969) and Saitoh (1970), who reported that in the northern temporate zone diffuse hair loss reaches a maximum in the month of November.

Although many observations on human subjects tend to resemble those made on test animals, there remain some inexplicable facts in man as well as in animals. Observations on animals can only suggest similar processes in man, but comparisons should be made with the greatest caution !

Unfortunately, many published accounts of disturbed hair growth in human disorders totally ignore the existence of a hair growth cycle, and interpretation is consequently difficult. It has been calculated that 25% of the hairs of the human scalp must be shed before hair loss becomes clinically apparent. This perhaps explains why very common but minor disturbances in the hair growth cycle are so often overlooked and have received little attention in research (Rook 1965).

c) Sex and age

The average daily growth rate of women's hair (0.34 mm/d) is less than that of men (0.37 mm/d), while the daily growth rate of the hair in subjects 50-69 years old is higher than that in either subjects 40-49 or 70-79 years old. (Pelfini et al. 1967).

The growth of human scalp hair passes through four cycles in the course of a lifetime. The duration of anagen is subject to marked individual variations, and ranges from one to six years. The proportion of anagen follicles is highest in childhood and lowest in old age.
Catagen takes two weeks or less, and the duration of telogen is three or four months.

d) Body regions

Relatively constant minor variations are seen in different regions of the scalp (Witzel and Braun-Falco, 1963). Time relations of the cycle in other body regions have been less widely studied, but many of the available data show a much higher proportion of telogen follicles than for the scalp. The anagen/telogen ratio for the normal scalp seems to be high, while that for other body regions is low.

The very different biological responsiveness of anagen, catagen and telogen follicles determines the diagnostic value of their ratio in clinical studies. Another important feature is the differentiation of normal hair roots in the anagen, catagen and telogen phases, from pathological hair roots.

Removed club hair can be grossly differentiated with the naked eye from hair in anagen: club hair has a solid, hard, dry, white node at its proximal end, the colourlessness being due to lack of pigment; roots of hair still growing in anagen are pliable and somewhat moist and sticky, and in pigmented hair have the same colour as the remaining part of the hair shaft.

Very useful clinical indications can therefore be obtained by low-magnification microscopic examination of the roots of plucked hairs.

The work presented in this thesis was done in an effort to evolve a reliable uniform technique of obtaining hair roots (chapters 2 and 3) and to outline the differentiation and interpretation of various types of hiar root structure (chapter 4 through 9).
In the last part of this thesis the findings are evaluated by means of clinical research (chapter 10 and 11).

CHAPTER 2

HAIR PLUCKING TECHNIQUES - A REVIEW OF THE LITERATURE

2.1 *Introduction*

Hair plucking (epilation) followed by microscopic examination of the extracted hair root under low magnification has for many years been used as a simple diagnostic procedure. As early as 1906, Williams observed changes induced in scalp hair roots by X-irradiation. His study is illustrated by sketches of extracted hair roots, but unfortunately the techniques of epilation are not specified.

Some fifty years later, Van Scott et al. (1957) standardized the technique of human hair epilation, stating in their paper (page 197): "Hair roots were obtained from sixteen healthy volunteers and nine patients hospitalized for neoplastic diseases. The hair roots were pulled from the parieto-occipital scalp region by means of a surgical needle-holding forceps, the jaws of which had been covered on the grasping surfaces with one to several layers of cellulose tape to ensure a tight closure and prevent slipping of hair shafts during the pulling procedure. Approximately fifty hairs were simultaneously grasped close to the surface of the scalp and extracted with a quick, forceful pull. The proximal ends of the extracted hairs were cut off and dropped into a 5.5 x 1.5 cm glass Petri dish, the bottom of which was covered with water. A grid pattern of 16 divisions had previously been scored on the underside of the Petri dish. The root ends of at least 100 hairs were thus obtained. Aggregates of hairs in the water were dispersed by means of a dissecting needle. In order to minimize movement of the hair roots on the grid, two 24 x 40 mm cover glasses were floated on the surface at right angles to each other, and the excess of water was removed with an eye dropper. The hair roots were examined with a dissecting microscope under 20x and 45x magnification, using transmitted light subdued by covering the sub-stage mirror with a sheet of lens tissue".

This technique of epilation and modifications of it were used in subsequent years by many authors, e.g. Kligman (1961), Braun-Falco and Zaun (1962), Bandmann and Bosse (1966), Witzel and Braun-Falco (1963), Braun-Falco and Rassner (1965), Braun-Falco and Fisher (1966), Bartosova (1967), Moll (1968), Steigleder and Mahrle (1973), Braun-Falco and Heilgemeir (1977), and Orfanos (1979).

2.2 *Review of the literature*

These slightly different techniques of epilation will be reviewed with special reference to:

1. Equipment used for epilation
2. Hair cutting before or after epilation
3. Speed of pulling hair roots
4. Interval between hair washing and epilation
5. Removal of all hairs from the sample site
6. Influence of the selected scalp area on results of hair root examination

7. Medium used and interval between epilation and hair root examination.

2.2.1 *Equipment used for epilation*

The equipment used by Van Scott et al. was employed also by Crounse et al. (1960), who coated one forceps jaw with solder, by Braun-Falco and Zaun (1962) and by Witzel and Braun-Falco (1963), who pulled 60-80 and 55 hair roots in one extraction, respectively.

Barman (1964), however, plucked the hairs with a Pean forceps whose jaws were wrapped in adhesive plaster; his study does not specify the number of hair roots pulled in one extraction.

Braun-Falco and Rassner (1965) used an arterial forceps whose jaws were covered with bicycle air-valve tubing, and pulled 80-100 hair roots in one extraction. The same technique was applied by Braun-Falco (1966), Heilgemeir (1975), Braun-Falco and Heilgemeir (1977) and Orfanos (1979), who all pulled 50-70 hair roots in one extraction.

Kligman (1961) advised the use of epilating forceps to ensure that all hairs are removed from the sample site, while Jacobi (1971) developed a mechanical epilator and discussed its advantages as compaired with manual plucking, without specifying his results.

2.2.2 *Hair cutting before or after epilation*

Like Van Scott et al. (1957), Braun-Falco and Zaun (1962), Witzel and Braun-Falco (1963) and Orfanos (1979) cut the proximal ends of the extracted hairs after epilation. Kligman (1961), however, held that hairs should be cut before extraction. None of these authors specifies reasons for cutting these hair ends before or after epilation.

2.2.3 *Speed of pulling hair roots*

The influence of fast and slow epilation on the quantitative composition of hair roots was studied by Maguire and Kligman (1964), who reported that the act of plucking a normal anagen hair frequently distorts its fragile root, as demonstrated in illustrations presented by various authors.

Braun-Falco and Rassner (1965) summarized the main effects of slow plucking as follows:
- decrease in the percentage of normal anagen hair roots containing root sheaths
- mostly increase in the percentage of normal anagen hair roots lacking root sheaths
- significant increase of dysplastic hair roots
- non-significant but occasionally appreciable increase in the percentage of dystrophic hair roots.

2.2.4 *Interval between hair washing and epilation*

The influence of the interval between hair washing and epilation was studied by Braun-Falco and Fisher (1966), who concluded that hair washing can cause a significant increase in the number of dysplastic hair roots

and a significant decrease in the number of telogen hair roots. The latter decrease, however, was only found in healthy males.

They recommended that, in order to avoid falsification of the true correlations in the hair root pattern, the hair root status should be determined no sooner than at least a week after the last hair washing. Orfanos (1979) in addition advised that the use of cosmetics be discontinued at least 2-3 weeks before hair plucking.

2.2.5 *Removal of all hairs from the sample site*

Removal of all hairs from the sample site is required in order to avoid skewness which might result from failure to remove the more firmly inserted anagen hair roots (Kligman 1961; Bartosova 1967).

2.2.6 *Influence of the selected scalp area on results of hair root examination*

This subject was studied by Witzel and Braun-Falco (1963), who found the following distribution:

in 70 females	% anagen	% telogen
cranial region	88	11
occipital region	88	11
temporal region	89	10
in 70 males		
cranial region	78	19
occipital region	83	15
temporal region	88	11

The author emphasize that not only sex and age but - particularly in males - the selected scalp area is of definite importance in hair root examination.

Pecoraro et al. (1964) studied the hair cycle in 20 children aged 3-9 years. Hair samples were obtained at random from five areas: mid-frontal, right and left parietal, coronal and occipital. They concluded that the proportion of telogen hairs appears to be higher in the frontal and parietal than in the coronal and occipital regions.

Bartosova (1967) took 50 hairs from each of the following regions: right and left parieto-occipital, parietal and temporal. An increased telogen percentage was seen only in the parietal region in 6 out of 26 males, the hair root status in the other regions being homogeneous.

2.2.7 *Medium used and interval between epilation and hair root examination*

a. A dry medium was used by Bartosova (1967), who kept hair roots in a Petri dish for a few weeks. Bosse (1967), however, states that within a few hours anagen hair roots change morphologically so as to become unrecognizable. Moll (1968) kept hair roots between two object slides, and Saadat et al. (1976) placed them on object slides and secured them with cover slips fixed to the slide with the aid of transparent adhesive tape.

b. Water was used as a medium by Van Scott et al. (1957), Smith et al. (1959), Crounse et al. (1960), Lynfield (1960) and Braun-Falco and Zaun (1962). They placed hair roots in a shallow layer of water in a glass Petri dish with a grid pattern on its underside, and floated cover slips on the water surface to minimize hair root movements. Witzel and Braun-Falco (1963) used a glass Petri dish lined with a layer of beeswax. Bartosova (1967) transferred hair roots from a Petri dish into a glass dish scored with a grid pattern, covered the roots with a large cover slip and removed excess water with filter paper. Braun-Falco and Rassner (1965) and Braun-Falco (1966) placed plucked hair roots immediately in a moist chamber and within a few hours placed them between two slides, one of which had transverse parallel ridges, to be examined at once. Bandmann and Bosse (1966) examined hair roots within a few hours of extraction, on slides with cover slips.

c. Glycerin was used as a medium by Rook (1965).

d. A 0.5% formalin solution was used by Archer and Luell (1960), who examined the hair root samples within a few hours of plucking.

e. Paraffin liquid was used by Zaun (1963) on covered 7.5 x 5.0 cm slides with a grid pattern, and with cover slips of the same size.

f. Canada balsam was used by Barman (1964, 1965) and Pecoraro et al. (1964), who cut the proximal ends of hair roots above a slide and then covered them with a cover slip on which a drop of Canada balsam and a cover slip.

g. Eukitt was dropped on a slide with the aid of a glass stick and the hair roots were placed in this medium by Steigleder and Mahrle (1973) and Rapprich (1969). The latter described the advantages of this medium as: rapid drying, near-colourlessness, favourable refraction index, and resistance to temperature and light.

h. Physiological saline was used as a medium for hair roots kept between two slided by Braun-Falco and Heilgemeir (1977).

The necessity of examining hair roots within a few hours of extraction has been emphasized by Bandmann and Bosse (1965), Bosse (1967), Rapprich (1969), Heilgemeir (1975) and Braun-Falco and Heilgemeir (1977).

2.3 *Conclusive comments*

The data supplied in this review of the literature show that equipment used for epilation can comprise a variety of instruments: 1) a surgical needle-holding forceps whose jaws are covered on the grasping surface with one to several layers of cellulose tape, adhesive plaster or a length of bicycle air-valve tubing, or with one jaw that is coated with solder; 2) epilating forceps, or 3) a mechanical epilator.

The number of hair roots grasped simultaneously and pulled out in one extraction ranges from 50 to 100 when a surgical needle-holding forceps is used. Using epilating forceps, only 7-10 hairs can be pulled out per extraction and several extractions are required to obtain a fair-sized

sample, but the advantage of this method is that one can be sure that all hairs are removed from the sample site and that none of the more firmly anchored anagen hairs is left in situ.

Most authors cut the proximal ends of the extracted hairs after epilation, but Kligman (1961) holds that hairs should be cut before, the advantage being that it is more easily ensured that all hairs are removed from the sample site.

The speed of pulling hair roots and the interval between hair washing and epilation are important because slow plucking, hair washing as well as application of cosmetics influence the quantitative composition of the hair root pattern (Braun-Falco and Fisher 1966; Orfanos 1979).

Unlike Bartosova (1967), Witzel and Braun-Falco (1973) and Pecoraro et al. (1964) maintain that the scalp area selected for examination may influence the results.

Several different media have been used in hair root examination. Most authors use water but the disadvantage of this medium and other liquid media is that hair roots must be examined within a few hours of plucking and cannot be kept indefinitely for comparison at a later date. Canada balsam and Eukitt (Rapprich 1969) do not have this disadvantage.

2.4 *Summary*

A review is presented of the literature on various techniques of hair root extraction, and instruments and media used. Other aspects discussed are hair cutting before or after epilation, fast or slow plucking, interval between hair washing/application of cosmetics and epilation, and the importance of: 1) removal of all hairs from the sample site, 2) selection of the proper scalp area, and 3) an adequate interval between epilation and hair root examination.

CHAPTER 3

PERSONAL TECHNIQUE OF OBTAINING HAIRS FOR HAIR ROOT EXAMINATION

3.1 *Introduction*

The review of the literature presented in chapter 2 shows that some aspects of the technique of obtaining hairs are of essential importance for a proper hair root status. They are:

1. equipment used for epilation
2. hair cutting before or after epilation
3. speed of pulling hair roots
4. interval between hair washing and epilation
5. the selected scalp area
6. removal of all hairs from the sample site
7. a. medium used
   b. interval between epilation and hair root examination
8. reproducibility of the method used.

Points 2 through 6 were not further studied because:

re 2: Hair cutting before epilation (down to 0.5 cm above the scalp surface) was simply accepted as necessary because this makes it easier to ensure that all hair roots are extracted from a given scalp area; moreover, epilation of short hairs is easier than that of long hairs.

re 3: The speed of pulling has been studied by Braun-Falco and Rassner (1965), whose advice in favour of fast pulling was followed.

re 4: The influence of hair washing on the hair root status was studied by Braun-Falco and Fisher (1966), who adhered to an interval of one week between the last hair washing and hair root examination. In our study, practical considerations dictated a 4-day interval between the last hair washing and hair root examination.

re 5: Witzel and Braun-Falco (1963) and Pecoraro et al. (1964) demonstrated regional differences in hair root pattern. This is why we used a fixed scalp area in our study: a skin area in the left temporal region, 5 cm above the cranial margin of the ear.

re 6: It was painstakingly ensured that all hair roots were removed from the sample site, as already emphasized by Kligman (1961).

In view of the fact that little research has so far been devoted to points 1, 7a, 7b and 8:

- equipment used for epilation
- medium used
- interval between epilation and hair root examination
- reproducibility of the method used,

these aspects were studied further in some detail.

3.2 *Material and methods*

3.2.1 *Equipment used for epilation*

A comparative study was made of a) the technique of Van Scott et al. (1957) as modified by Braun-Falco and Rassner (1965), with the aid of an artery forceps, and b) a personal technique using epilating forceps.

In four male and four female patients in age group 20-40 who presented with diffuse alopecia, about 50 hair roots were pulled from a skin area in the left temporal region, about 5 cm above the cranial margin of the ear, in a single extraction with the artery forceps (jaws covered with a length of bicycle air-valve tubing). At the same time, tightly closing epilating forceps (fig.15) were placed as close to the scalp skin as possible (fig.16) in an immediately adjacent scalp area and used to extract 4-7 hair roots at a time, up to a total of 50, until no further hairs were visible in this skin area. Use was made of a light-attached magnifying glass (magnification 5x).

FIG. 15 EPILATING FORCEPS

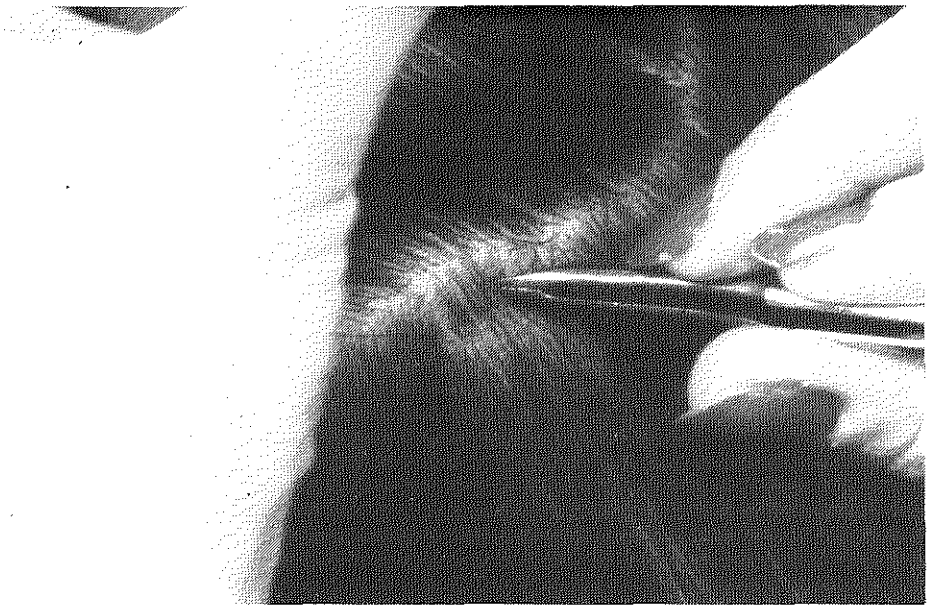


FIG. 16 EPILATION OF HAIRROOTS

3.2.2 Medium used

The hair root pattern was studied in several different media: water, cedar oil and Depex. Depex is a collecting medium that consists of knock-resistant polystyrene (pH 7), which assumes the hardness of glass within a few hours. (Pharbil B.V., Rotterdam).

In four healthy adult males aged about 25 years, 25 hair roots were epilated as already described from each of three immediately adjacent skin areas within the fixed sample site (left temporal region, about 5 cm above the cranial margin of the ear). The hair roots were then placed on three object slides (one for each of the three abovementioned media) and immediately covered with a cover slip (fig.17).

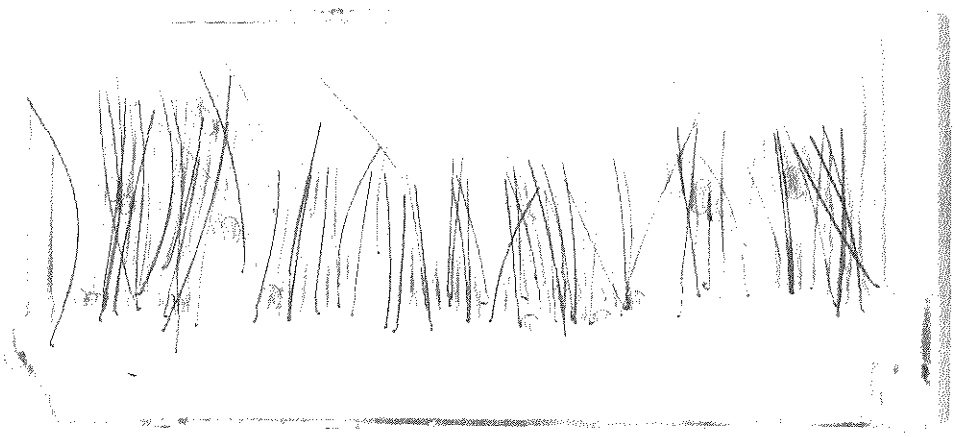


FIG. 17 HAIRROOTS READY FOR MICROSCOPIC EXAMINATION

3.2.3 *Interval between epilation and hair root examination*

The hair root status was evaluated immediately after epilation, and the influence of the interval between epilation and hair root examination was studied.

3.2.4 *Reproducibility of the method used*

The reproducibility of the method used was studied by having three members of the nursing staff of the Rotterdam Department of Dermatology and Venereology each epilate the fixed sample site on the scalp of one adult (one female and two males, respectively).

3.3 *Results*

Table 1 presents the results of epilation with the aid of the artery forceps lined with bicycle air-valve tubing in comparison with those obtained with epilating forceps.

Table 1 Hair root status after epilation with the aid of artery forceps lined with bicycle air-valve tubing (A) and epilation with the aid of epilating forceps (E) in four male and four female patients.

	male patients								female patients							
	1		2		3		4		1		2		3		4	
	A	E	A	E	A	E	A	E	A	E	A	E	A	E	A	E
% anagen	50	72	78	90	30	70	44	72	92	98	55	84	40	58	64	90
% catagen/telogen	25	24	6	6	12	8	4	5	8	2	30	8	35	18	24	10
% dysplastic/dystrophic hairs	15	4	10	4	38	20	40	23	0	0	5	8	10	24	12	0
% broken hairs	10	0	6	0	20	2	12	0	0	0	10	0	15	0	0	0
χ^2	20.3 p<0.001		12.2 p<0.01		37.2 p<0.001		23.5 p<0.001		3.8 p=0.10		29.4 p<0.001		29.5 p<0.001		22.1 p<0.001	

The data show that epilation with the aid of the artery forceps was characterized by:

a) a decreased anagen/telogen ratio in all patients
b) an increased number of dysplastic/dystrophic hair roots in 6 of the 8 patients
c) an increased number of broken-off hairs in 6 of the 8 patients.

Two female patients showed no broken-off hairs after epilation by both methods. There was no significant difference in hair root pattern between the two methods in 7 of the 8 patients. Statistical analysis was performed with the aid of the X^2-test.

Table 2 presents the results of hair root examination using the media water, cedar oil and Depex in four healthy adults.

Table 2 Hair root status in the media water, cedar oil and Depex in four healthy adults (a, b, c, d)

	WATER		CEDAR OIL		DEPEX	
% anagen	a 96 b 92 c 94 d 94	mean 94	a 87 b 89 c 91 d 89	mean 89	a 92 b 93 c 90 d 93	mean 92
% catagen/ telogen	a 0 b 6 c 4 d 6	mean 4	a 7 b 6 c 4 d 7	mean 6	a 5 b 4 c 6 d 1	mean 4
% dysplastic/ dystrophic	a 4 b 2 c 2 d 0	mean 2	a 6 b 5 c 5 d 4	mean 5	a 3 b 3 c 4 d 6	mean 4

The table reveals hardly any differences in hair root pattern between the three different media.
Concerning the interval between epilation and hair root examination we found, like Bosse (1967), that particularly anagen hair roots become unrecognizable in water by desiccation within a few hours. Hair roots collected in cedar oil and Depex, however, remained unchanged for months or even years.

The results of our study of the reproducibility of the method used are presented in table 3, which shows that evaluation of the hair status revealed no difference of any importance between the epilations performed by the three abovementioned nursing staff members on the three adults.

Table 3 Hair root status after epilation of two male adults and one female adult, performed by three nursing staff members (a, b, c) of the Department of Dermatology and Venereology.

Test subjects	Age		a	b	c		a	b	c		a	b	c
male	23		90	89	89		6	5	6		4	6	5
male	25	% anagen	97	98	96	% catagen/ telogen	2	2	3	% dystrophic/ dysplastic	1	0	1
female	26		80	80	81		7	8	9		13	12	10

3.4 Discussion

To obtain hairs for hair root examination we used epilating forceps after cutting the hairs down to about 0.5 cm above the scalp surface. The sample site on the scalp varied in size according to hair density. This makes it possible to gain an optimally accurate impression of the hair root status, and minimizes the risk of breaking hairs and artificial changes.

The results of epilation with the aid of the artery forceps may indicate that artificial lesions of the hair root may conceivably be confused with pathological lesions or iatrogenic lesions, thus leading to erroneous conclusions. This demonstrates the great importance of an optimal hair plucking technique for a reliable hair root status.

The abovementioned findings might be explained as follows:

- it proved to be nearly impossible in actual practice to epilate 50 hair roots simultaneously from a specified area with one pull; there is therefore a risk that hair roots - especially anagen hair roots firmly anchored in the dermis - are left in situ, with consequent errors in the evaluation of the hair root pattern; this important point was already made by Kligman (1961);
- it proved to be technically difficult to remove 50 hair roots simultaneously in the direction of the growth of the hairs; this increases the risk of breaking of hairs and of a higher incidence of dysplastic/dystrophic hair roots - probably due to artificial causes.

Epilation with the aid of the artery forceps, moreover, was experienced by most patients as more painful than extraction with the aid of epilating forceps. The technique with the artery forceps was therefore abandoned in favour of that with epilating forceps.

The advantages of pulling no more than 4-7 hair roots simultaneously with the epilating forceps are the following:

- the epilating force can be more accurately adjusted to needs
- epilation can be done exactly in the direction of hair growth
- using a light-attached magnifying glass (magnification 5x), it can be ensured that all hair roots are extracted from a given scalp area.

For standardization of hair root examination we selected a fixed sample site on the hairy scalp, so that:

a) comparative studies were possible, before and after treatment of the same patient as well as between different groups of persons;
b) in the case of a local abnormality of hair on the scalp, the influence of a systemic process on hair growth did not excape attention.

With regard to the interval between epilation and hair root examination, the medium used plays an important role. Using water as a medium, the hair roots must be examined immediately after epilation because the hair roots change quickly in water by desiccation.

The disadvantage of using cedar oil as a medium lies in the fact that this medium does not set, so that the specimens can be stored only horizontally and separately.

The collecting medium Eukitt, described by Rapprich (1969) and referred to in chapter 2 (page 24), was considered but found to be more expensive and more malodorous than Depex. Moreover, Eukitt can cause headaches and irritate the skin and mucosa, whereas Depex does not. Eukitt and Depex are both inflammable.

Specimens collected in Depex can be easily stored, if necessary in a vertical position in boxes, and yet remain usable for repeat inspections. The making of several hair root statuses in the course of time facilitates evaluation of the changes in the hair root pattern and of the effect of therapy. Using Depex, the use of a cover slip is recommendable but not absolutely necessary as long as it is ensured that the hair roots are embedded.

For these practical reasons we opted in favour of the collecting medium Depex.

A simple experiment showed that our technique of epilation yielded reproducible results in the hands of several different persons given proper instruction in advance.

3.5 Summary

A comparative study was made of the technique of epilation with the aid of artery forceps and with the aid of epilating forceps. We opted in favour of epilating forceps which, placed as close to the skin of the scalp as possible, can be used to extract 4-7 hair roots simultaneously (up to a total of 50 hair roots) from a fixed sample site on the hairy scalp - left temporal region, about 5 cm above the cranial margin of the ear - after cutting the hairs down to about 0.5 cm above the scalp surface.

The necessity of epilating all hairs from the sample site was emphasized.

Immediately after epilation the hair roots were placed on an object slide in the medium Depex, if required, covered with a cover slip.

The media water, cedar oil and Depex were all found to exert no influence on the hair root pattern as long as the hair roots in the medium water were examined immediately after epilation. The medium Depex was selected for practical reasons.

The reproducibility of this technique of epilation was tested by having three nursing staff members perform the epilation on three adults. No differences in the features of the hair root status were subsequently found.

CHAPTER 4

STRUCTURAL CHARACTERISTICS OF HAIR ROOTS - A REVIEW OF THE LITERATURE

4.1 Introduction

Hair growth is known to be a cyclic process with alternating phases of growth and quiescence.

During growth, follicles are said to be in anagen. When follicles arrive at a resting phase in which they contain club hairs, they are in telogen. Catagen is a period of transition in which follicles are reorganizing into an inactive (quasi-embryonal) state. When such a quiescent follicle starts to grow again it forms a new hair which dislodges the old club hair.

Hair root phases can be studied microscopically after plucking. In addition to the abovementioned normal phases, dysplastic and dystrophic hair roots can be distinguished under pathological conditions, but also in a small number of healthy persons. Normal and pathological hair growth phases merge smoothly, and this fact may explain some discrepancies in the literature on assessment of the hair root status.

In an effort to find a reliable key for proper determination of the hair root status, morphological criteria of hair root phases presented in the literature are systematically discussed in the following subsections, and are presented in summary in table 4.

Table 4 Descriptions of structural characteristics of hair roots in the literature

Authors	Year	Anagen	Telogen	Catagen	Dysplastic	Dystrophic
Van Scott et al.	1957 1958	- darkish keratogenous zone - melanin in matrix - internal and external root sheaths intact, partially present or absent	- no keratogenous zone - no melanin - no internal or external root sheaths - club-shaped keratinized tip surrounded by epithelial sac	- internal and external root sheaths - keratinized club - club-shaped keratinized tip	- decreased matrix diameter - marked hair shaft constrictions - broken hair shaft	
Archer & Luell	1960				- constrictions of bulb or shaft - constrictions in keratogenous zone - broken hairs - "hooked" hairs	
Braun-Falco & Zaun	1962	"	"	"		- no matrix - no club - no root sheaths - torn-off hairs
Witzel & Braun-Falco	1963	"	- typical club hair occasionally containing pigment	"		"
Moretti	1965			- hardly any keratinization		

Braun-Falco	1966	"	"	- early catagen I: dysplastic anagen root root diameter < shaft diameter - catagen II: presumptive club - catagen III: club-shaped thin hair root root sheath absent or only remnant		- matrix dystrophy I: reduced volume relatively big papilla cuticle and internal root sheath intact - matrix dystrophy II: markedly reduced matrix incomplete keratinization - matrix dystrophy III: parakeratotic shape
Bandmann & Bosse	1966	- widest at proximal end - sharply defined border perpendicular to longitudinal axis - distally tapering to same diameter as hair shaft - clear zone between keratogenous zone and matrix		see above		
Bartosova	1967	- transparent matrix and dark keratogenous zone in depigmented hair roots	- epithelial sac partially present or absent	- bulb darker than that of telogen root		- segmentally divided or cut - angulation of bulb or keratogenous zone
Moll	1968	- strong pigmentation - trapezoid shape	- see Van Scott et al. 1957	- more pigmented than telogen root sheaths	- remnants of root sheaths	- no root sheaths
Rapprich	1969			- root sheaths shorter and narrower		
Heilgemeir	1975	- see Van Scott et al. 1957	- see above			- thin hair root without root sheaths, tapering in proximal direction until breaking-point

4.2 Hair root types

The following hair root types can be microscopically distinguished:

1) anagen hair roots
2) telogen hair roots
3) catagen hair roots
4) dysplastic hair roots
5) dystrophic hair roots

The characteristic features of each type are discussed below.

4.2.1 Anagen hair roots (fig.18)

Anagen hair roots are characterized by a darkish keratogenous zone immediately distal to the hair bulb. Melanin pigment is usually visible in the matrix of the bulb. Internal and external root sheaths can be present and intact, partially present, or absent (see illustrations in: Van Scott et al. 1957; Braun-Falco and Zaun 1962; Braun-Falco 1966; Heilgemeir 1975).

Bandmann and Bosse (1966) reported that most anagen hair roots are widest at their proximal end and have a relatively sharply defined border perpendicular to their longitudinal axis. At a more distal level they taper down to the diameter of the hair shaft. A clear zone is visible between the darkish keratogenous zone and the melanin-pigmented matrix.

Bartosova (1967) noticed a transparent matrix in depigmented hairs, while the keratogenous zone wass still dark.

Moll (1968) emphasized that anagen hair roots are strongly pigmented and have a trapezoid shape.

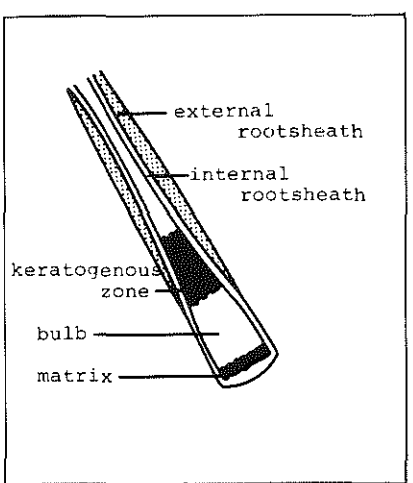


FIG. 18
THE ANAGEN HAIRROOT

4.2.2 *Telogen hair roots (fig.19)*

Telogen hair roots have no keratogenous zone and as a rule contain no melanin. Although they have no internal and external hair root sheaths, their club-shaped keratinized tip is surrounded by an epithelial sac (Van Scott et al. 1957; Moll 1968; Heilgemeir 1975) which, according to Braun-Falco and Zaun (1962), is sometimes only partially present.

Bartosova (1967) mentioned that the epithelial sac may be partially present but in many cases is absent, as demonstrable in telogen hair roots which have detached themselves spontaneously.

Witzel and Braun-Falco (1963) pointed out the similarity between telogen hair roots and typical "club" hairs, which occasionally contain pigment.

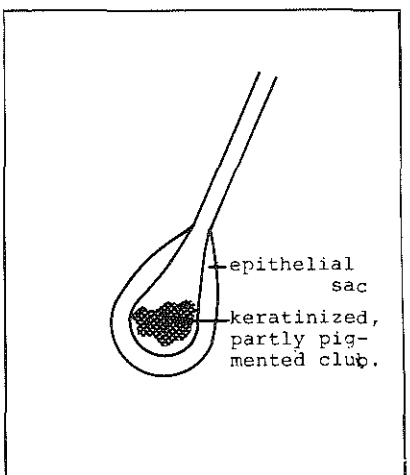


FIG. 19
THE TELOGEN HAIRROOT

4.2.3 *Catagen hair roots (fig.20 and 21)*

Catagen hair roots characteristically have internal and external root sheaths as well as a keratinized bulb (fig.4) (Van Scott et al. 1957) and a club-shaped keratinized tip (Van Scott 1958; Braun-Falco and Zaun 1962; Witzel and Braun-Falco 1962; Bandmann and Bosse 1966).

Braun-Falco and Zaun (1962) and Rapprich (1969) noticed the similarity between catagen and anagen hair roots. Rapprich reported that the diameter of the catagen hair root is smaller, and that its internal and external hair roots sheaths are shorter and narrower. Braun-Falco and Zaun (1962) also found that, unlike the telogen hair root, the catagen root has distinct root sheaths.

Moretti (1965) describe catagen hair roots as showing hardly any keratinization, while Bartosova (1967) reported that they have a darker bulb than telogen roots and mostly possess external and internal root sheaths.

In a hair root status study, Braun-Falco (1966) distinguished several catagen subphases:

a. early catagen I (fig.20):

The root resembles the dysplastic anagen root (below) in that it has a large dark keratogenous zone, but has the shape of a normal anagen root. In cross-section its diameter is smaller than that of the hair shaft. This is explained by regression and reduction in size of the hair bulb at the start of the catagen phase, and consequently reduced activity of the hair matrix in this phase. The internal root sheath is usually absent (Braun-Falco and Kint 1965).

b. catagen II:

The "presumptive" club shows a thickening, and the proximal part of the root is surrounded only by the external hair root sheath.

c. catagen III (fig.21):

This is characterized by
- shortening, mainly of the distal part of the keratogenous zone,
- definite keratinization proceeding from distal to proximal until a club shape is attained and the root more and more begins to resemble a telogen root,
- thinness of the hair root with a typical club and no external root sheath (or only a remnant of one).

Moll (1968) found some catagen hair roots that had more pigmentation than telogen roots.

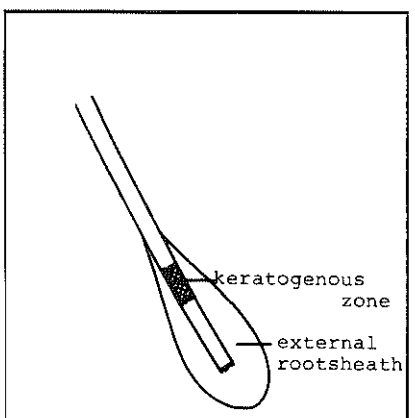


FIG. 20
EARLY CATAGEN I

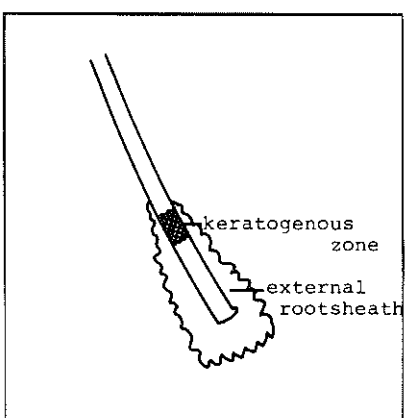


FIG. 21
THE CATAGEN HAIRROOT

4.2.4 Dysplastic hair roots (fig.22)

Morphological changes in hair roots were first described by Van Scott et al. (1957) in two studies of the effects of Amethopterin (a folic acid antagonist) and of exposure to X-rays, respectively, on hair roots of the

human scalp.

Both treatments affected only anagen hair roots, while telogen hair roots remained unchanged. The earliest changes seen in anagen hair roots after Amethopterin medication were confined to the matrix of the bulb, which diminished in diameter. Marked constriction of scalp hair shafts was observed two weeks after medication (fig.23), and many hairs had broken at points of severe constriction. After discontinuation of treatment the bulb recovered promptly and again produced a hair shaft of normal diameter.

X-ray irradiation (Van Scott and Reinertsen 1957) caused reduction of the hair bulb diameter and apparent thinning of the internal root sheath (which contained dispersed pigment granules and seemed abnormally thick due to the decreased diameter of the encasing bulb remnant). Plucking at this stage revealed that many hair roots had broken off at a level immediately below the keratogenous zoune. The proportion of hair roots showing these changes was directly related to the irradiation dosage: patients given larger doses showed a higher proportion of changed roots than those who had received smaller doses. The entire hairbulb undergoes a progressive

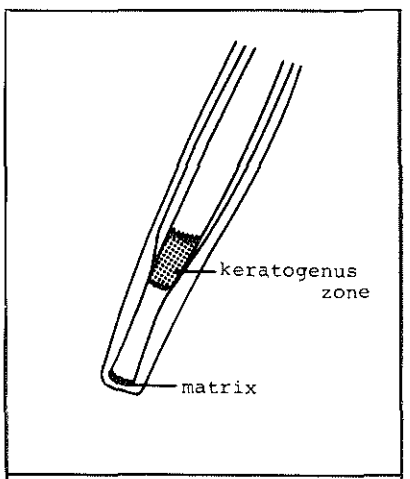


FIG. 22
DIMINISHED HAIR BULB DIAMETER

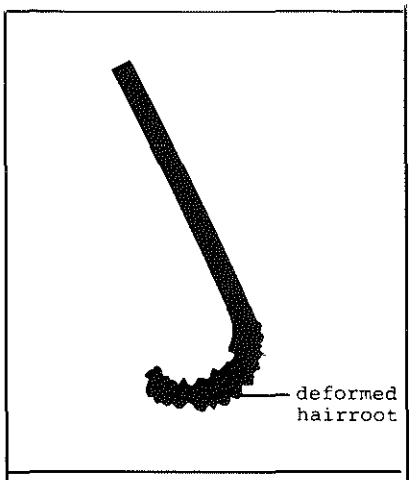


FIG. 23
THE DYSPLASTIC HAIRROOT

Hair roots with tapered shafts and small keratinized bulbs were found 2-3 weeks after exposure to X-rays (fig.24). The keratogenous zone was absent and there was evidence of complete cessation of growth. Other roots had retained the keratogenous zone and had evidently produced hair shafts, but these were decidedly thinner.

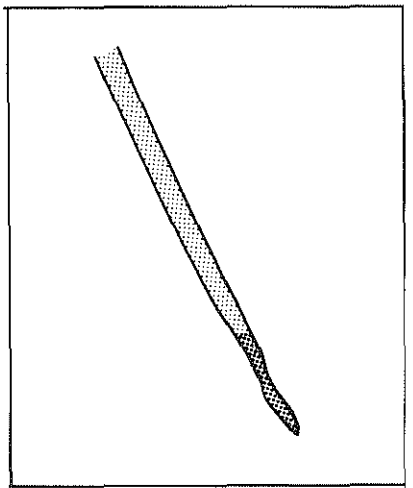


FIG. 24 TAPERING HAIRSHAFT, SMALL KERATINIZED BULB.

The effect of ionizing rays is generally progressive, but effects of chemotherapeutic drugs on the roots of growing scalp hairs are reversible. Anagen roots showing any of the above changes are called dysplastic hair roots.

Crounse and Van Scott (1960) described the hair root as a sensitive indicator of toxic effects of chemotherapy with such drugs as methotrexate, 5-fluorouracil, actinomycin D, etc.. They found a close correlation between hair root damage and haematological evidence of drug toxicity. Archer and Luell (1960) described dysplastic hair roots as represented by:

- resting or growing hairs with constriction of the bulb or shaft,
- growing hairs with constriction of the keratogenous zone,
- hairs broken at a level of evident shaft constriction,
- "hooked" hairs, i.e. hairs showing more than 90^{o} angulation at the level of the bulb or the keratogenous zone.

Moll (1968) characterized dysplastic hair roots simply as: hair shafts with remnants of root sheaths.

4.2.5 *Dystrophic hair roots (fig.25)*

Dystrophic anagen hair roots characteristically have neither a matrix nor a bulb (both having been torn off by the epilation force at their thinnest point) (Braun-Falco and Zaun 1962). According to Witzel and Braun-Falco (1963), dystrophic anagen roots have neither roots sheaths nor a matrix. They become thinner at more distal levels and this is where they are easily torn off.

On the basis of hair matrix damage, Braun-Falco (1966) distinguished three phases in the transition from anagen root to dystrophic root:

a. matrix dystrophy I:

- The hair matrix is reduced in volume but the dermal papilla is relatively big, while cuticle and internal root sheath are both intact.
- The hair root structure resembles that of the dysplastic or the normal anagen hair root but its diameter is smaller due to the reduced matrix volume.
- Hair root sheaths are more frequently absent.
- This hair root is virtually indistinguishable from the early catagen hair root.

b. matrix dystrophy II:

- The hair matrix volume is markedly reduced.
- The development of the root and its internal root sheath is impaired by incomplete and/or abnormal keratinization.
- Root sheaths are absent, and the hair shaft shows tapering in proximal direction.

c. matrix dystrophy III:

- The matrix has totally lost its mitotic activity.
- The production of hair keratin and internal root sheaths has ceased, or is so disturbed that only a "parakeratotic" shape remains.
- The hair breaks at its narrowest level and falls out.
- Root sheaths are absent.

Bartosova (1967) maintained that morphological differences in the dystrophic hair root are found mainly in its proximal part:

- Anagen and telogen hair roots could be segmentally divided or could even be cut.
- Anagen hair roots could be bent at the level of the bulb or the keratogenous zone, or between these two levels.

Moll (1968) characterized dystrophic hair roots simply as: hair shafts without root sheaths.

Heilgemeir (1975) characterized dystrophic hair roots as thin roots without root sheaths, tapering in proximal direction until their breaking-point is reached.

FIG. 25
THE DYSTROPHIC HAIRROOT

4.3 *Conclusive comments*

The descriptions in the literature generally show no discrepancies so far as the hair growth cycle of anagen and telogen hair roots is concerned. Descriptions of the structural characteristics of anagen and telogen hair roots are generally in agreement, although some authors describe minor morphological differences.

Views expressed in the literature on similarities between catagen on one hand, and anagen roots on the other, however, differ to some extent (Braun-Falco and Zaun 1962; Rapprich 1969). Some authors mention that catagen hair roots have internal and external root sheaths (Van Scott et al. 1957; Braun-Falco and Zaun 1962), but histological studies in rats (Braun-Falco and Kint 1965) have demonstrated that in catagen the external root sheath diminishes to a single layer of thin cells, while the internal root sheath disappears (chapter 1, page 14 and 15).

Braun-Falco and Kint (1965) and Braun-Falco (1966) elucidated this question by dividing catagen into three subphases:

- early catagen I, in which the root resembles the dysplastic anagen root,
- catagen II, with club-like thickening, and
- catagen III, in which the root more and more resembles the telogen hair root.

Description of dysplastic and dystrophic hair roots in the literature are rather confusing, and sometimes at odds with each other.

Van Scott et al. (1957), Van Scott and Reinertsen (1957) published a detailed description of hair root changes after treatment with Amethopterin and after exposure to X-rays. They found diminution of the diameter of the hair bulb matrix, constrictions in the hair shaft, and finally breaking of the shaft and changes in the internal root sheath. The latter depend on the irradiation dosage. These changes finally lead to what is known as a dysplastic hair root.

Braun-Falco (1966) on the other hand, stated that the transition from anagen to dystrophic hair root is characterized by three different stages of matrix dystrophy.

Our review of the literature warrants the conclusion that the nomenclature of dysplastic and dystrophic hair roots shows some diversity.

4.4 *Summary*

This chapter presents a review of the literature on the morphological changes in hair roots during the growth cycle.

The anagen hair root is characterized by a darkish keratogenous zone and, in most cases, a pigmented hair matrix. Internal and external root sheaths may be present or absent.

The telogen hair root has no keratogenous zone, and its club-shaped keratinized tip is surrounded by an epithelial sac.

The catagen hair root represents the transition from anagen to telogen. Morphological descriptions of catagen hair roots so far published in the literature show unfortunate discrepancies. In an effort to solve this problem, Braun-Falco (1966) distinguished three subphases of catagen.

Dysplastic and dystrophic hair roots are aberrant roots. Dysplastic hair roots are characterized by a diminished hair bulb diameter, constrictions and sometimes ruptures of the hair shaft, and "hooked" hair roots.

The question of the presence or absence of hair root sheaths in these aberrant hair roots has remained controversial, and Braun-Falco (1966) introduced a division into three subphases in an effort to facilitate accurate classification.

CHAPTER 5

GENERAL INTRODUCTION TO HAIR ROOT DIAGNOSTICS

5.1 *Introduction*

The preceding chapter has shown that the criteria applied by various authors in assessing the morphology of the various phases of the hair growth cycle, vary and sometimes conflict.

The literature has so far failed to present examples of systematic representation of hair root types observed. Only a few authors indicate differences in transparency. Bartosova (1967) observed that, when the external hair is not pigmented, the matrix is transparent while the keratogenous zone still has a dark colour; this publication, however, lacks photographic illustrations.

Some authors regard the pigmentation of the hair root as one of the characteristics of the phase of the hair growth cycle (Van Scott et al.1957; Braun-Falco and Zaun 1962; Witzel and Braun-Falco 1963; Bandmann and Bosse 1966; Braun-Falco 1966; Moll 1968; Heilgemeir 1975) (see chapter 4, page 37).

The same authors relate the morphology, the presence or absence of hair root sheaths, not only to the phase of the hair growth cycle but also to the diagnosis of morphological abnormalities. The characteristics of the contours and the angulation of the hair root are usually related to abnormal hair root types. However, the nomenclature used in the literature is not unequivocal.

Purely objective assessment of the many hair root types observed can be impeded by the smooth transitions of the various phases of the hair growth cycle and also between physiological and pathological hair root types. Moreover, some differences in the hair root pattern may be due to the investigator's subjective influence.

The introduction of strict criteria was therefore required to ensure proper classification of hair root types.

5.2 *Morphological characteristics*

The morphological characteristics of hair roots were recorded in a diagram (fig.26) with the observations schematically divided into:

1. differences in transparency (transparency pattern)
2. differences in hair root shape
3. presence or absence of hair root sheaths
4. characteristics of the contours of the hair root and/or shaft
5. the degree of angulation of the hair root at the level of the bulb and/or the keratogenous zone.

(For photographs see chapter 7, page 58 and 59).

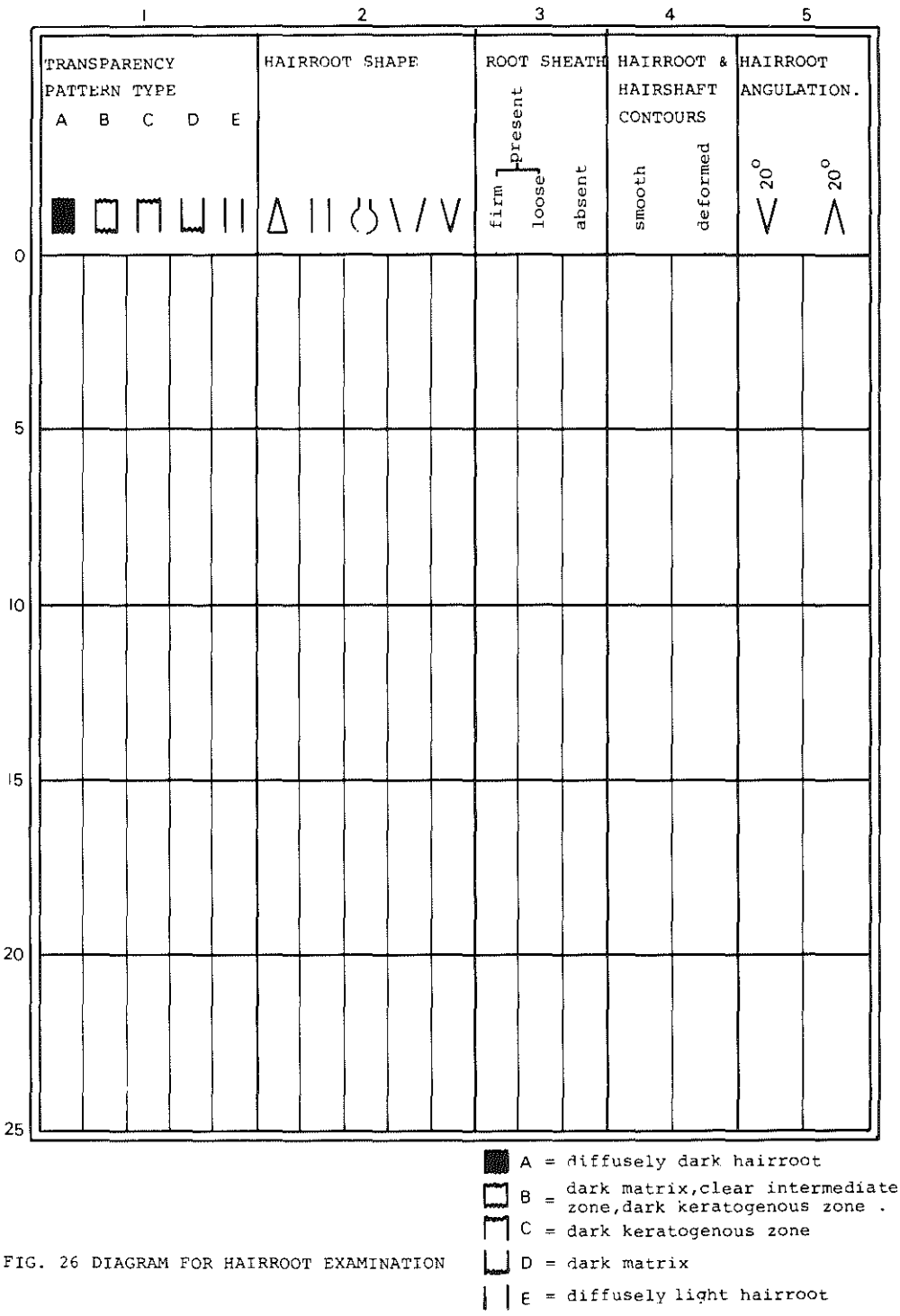


FIG. 26 DIAGRAM FOR HAIRROOT EXAMINATION

5.2.1 *Differences in transparency*

The transparency pattern can be subdivided into:

type A: a diffusely dark hair root: (photograph 1)
type B: a dark (pigmented) matrix, a dark keratogenous zone and a clear intermediate zone: (photograph 2)
type C: a light hair root with a dark keratogenous zone: (photograph 3)
type D: a light hair root with a dark (pigmented) matrix: (photograph 4)
type E: a diffusely light hair root: (photograph 5).

5.2.2 *Differences in hair root shape*

The hair root can assume different shapes, namely:

/\ (a), photographs 1, 4, 9, 16 and 21
|| (b), photographs 2, 10 and 14
ω (c), photographs 6, 18 and 19
\/ (d), photographs 7, 11 and 15
V (e), photographs 8, 17 and 20.

5.2.3 *Presence or absence of hair root sheaths*

Hair root sheaths can be present firmly (photographs 4, 9, 14 and 21) or loosely (photographs 6, 10, 18 and 19) encasing the hair shaft and/or hair root or absent (photographs 11, 12, 13, 15, 16, 17 and 20).

5.2.4 *Hair root and/or hair shaft contours*

Hair root and/or hair shaft contours can be smooth or deformed (photographs 5, 12, 13, 14, 15, 17 and 20).

5.2.5 *Degree of hair root angulation*

The degree of angulation shown by hair root and/or hair shaft was subdivided into two categories: $< 20^{\circ}$ and $> 20^{\circ}$ (photographs 4, 5, 7, 12, 13, 15, 16, 17 and 20).

5.3 *Comments*

The differences in hair root transparency and their diagnostic implications will be discussed and elucidated in chapter 6, while chapter 7 through 10 will deal with differences in hair root shape, presence or absence of hair root sheaths, contours of hair root and/or hair shafts, and angulation of the hair root, respectively. The data obtained in healthy persons will be compared with those obtained in groups of patients.

The diagram was constructed in an attempt to gain more insight into the morphological characteristics, structure and growth of the hair root, and possible abnormalities in these respects.

The diagnostic importance of these characteristics will be statistically analysed in the subsequent chapters in an effort to achieve standardization of the terms "anagen", "catagen", "telogen", "dysplastic" and "dystrophic".

5.4 *Summary*

A diagram is presented in which all the characteristics of hair roots are schematized and subdivided into five groups.

CHAPTER 6

THE HAIR ROOT TRANSPARENCY PATTERN

6.1 *Introduction*

Differences in hair root transparency are caused by pigmentation. Variations in the shade and intensity of hair colour depend mainly on the type of melanin involved: eumelanin produces a brown or black hair colour, while phaeomelanin gives a blond hair colour. The two melanin types are chemically related.

In the anagen of every hair growth cycle, the melanocytes in the matrix release melanin to the cells of the cortex and medulla (Rook 1965). Pigment formation ceases in catagen, as described in chapter 1 (page 14).

The diagram presented in chapter 5 subdivides differences in transparency into five types (A through E), which are described in some detail (chapter 5). Factors possibly determining and influencing these differences in vitro are:

1) hair colour
2) presence or absence of hair root sheaths
3) medium in which the hair roots are collected.

These three possible factors are separately discussed in this chapter in an effort to assess, on the basis of the findings, the extent to which the differences in transparency have implications for hair root diagnostics.

6.2 *Material and methods*

Hair root diagrams were prepared for ten healthy male (table 5) and ten healthy female adults (table 6) in age group 20-45, as discussed in chapters 3 and 5, using Depex as collecting medium. Transparency pattern types A and B were compared with types D and E (chapter 5, page 46). Type C was found in only two out of 1000 hair roots in the entire material (tables 5 and 6), and this incidence is too low for further analysis. The following subsections separately discuss the three abovementioned factors possibly of influence on the transparency pattern.

Table 5 Hair roots of 10 healthy adult males in age group 20-45

No.	Hair colour	Transparency type					Hair root shape					Hair root sheaths			Contours		Hair root angulation	
		A	B	C	D	E	⟨	|	↺	\/	V	present firm	present loose	absent	smooth	deformed	<20°	>20°
1	blond	3	0	0	27	20	25	21	2	2	0	26	2	22	27	23	30	20
2	dark blond	5	0	0	40	5	22	21	3	4	0	36	2	12	38	12	36	14
3	black	43	0	0	2	5	33	14	3	0	0	32	5	13	38	12	34	16
4	dark blond	3	21	0	9	17	19	23	5	3	0	31	6	13	37	13	42	8
5	black	45	0	1	1	3	32	15	2	1	0	40	2	8	43	7	41	9
6	brown	15	1	0	13	21	20	28	2	0	0	14	4	32	19	31	30	20
7	reddish-golden	2	1	0	19	28	18	27	4	0	1	19	4	27	24	26	26	24
8	blond	4	1	0	23	22	23	14	3	10	0	26	4	20	36	14	41	9
9	blond	12	0	0	24	14	27	20	3	0	0	30	6	14	39	11	37	13
10	blond	4	2	0	41	3	38	8	4	0	0	38	4	8	42	8	43	7

Table 6 Hair roots of 10 healthy female adults in age group 20-45

No.	Hair colour	Transparency type					Hair root shape					Hair root sheaths			Contours		Hair root angulation	
		A	B	C	D	E						present firm	present loose	absent	smooth	deformed	<20°	>20°
1	reddish-golden	0	9	0	36	5	12	35	3	0	0	43	4	3	46	4	46	4
2	blond	22	0	0	15	13	27	15	0	7	1	31	1	18	25	25	31	19
3	dark blond	15	0	0	7	28	18	18	11	2	1	18	14	18	33	17	30	20
4	auburn	17	7	0	10	16	28	17	1	3	1	32	1	17	38	12	37	13
5	blond	26	0	1	5	18	23	22	3	1	1	38	3	9	38	12	41	9
6	dark blond	11	1	0	17	21	26	19	0	1	4	30	1	19	38	12	38	12
7	blond	7	5	0	37	1	21	28	1	0	0	41	1	8	44	6	44	6
8	black	47	1	0	0	2	41	8	1	0	0	37	3	10	41	9	49	1
9	auburn	20	0	0	4	26	10	21	9	10	0	16	12	22	26	24	34	16
10	blond	11	7	0	24	8	35	13	1	0	0	26	3	21	33	17	34	16

6.2.1 *Hair colour*

The twenty health test subjects were divided into two groups:

a) 10 persons with blond hair (blond being defined as any colour tending towards a golden yellow);
b) 10 persons with dark hair (i.e. ranging in colour from dark-blond to black).

6.2.2 *Presence or absence of hair root sheaths*

In human hairs melanin granules are mainly in the cortex and occasionally they occur in the inner and outer root sheaths (Spearman, 1977). Consequently their absence in the hair root sheaths might certainly influence the transparency pattern.

Transparency types A and B were compared with types D and E in the presence and absence of the hair root sheath, respectively.

6.2.3 *Collecting medium*

Four healthy adults in age group 20-45 were submitted to epilation of 50 hair roots as described in chapter 3. The roots were then deposited in the media cedar oil, Depex and water, respectively, whereupon the root characteristics were recorded in the diagram.

The collecting medium most frequently mentioned in the literature is water, followed by cedar oil and Depex; the latter was used in our study.

Transparency types A through E were separately studied after collection of hair roots in:

a) cedar oil and Depex,
b) water and Depex.

6.3 Results

6.3.1 Hair colour

Table 7 presents the transparency patterns in 10 persons with blond hair and 10 persons with dark hair. The table shows that the two categories of persons differed significantly in transparency types (A and B) and (D and E). This finding warrants the conclusion that the colour of the external hair significantly influences the transparency pattern.

The Mann-Whitney U-test was used in the statistical analysis of these data.

Table 7 Transparency patterns in 10 healthy adults with blond and 10 with dark hair

Adults with blond hair	Transparency types		Adults with dark hair	Transparency types	
	A and B	D and E		A and B	D and E
1	3	47	11	44	6
2	5	45	12	46	4
3	24	26	13	16	34
4	3	47	14	6	44
5	5	45	15	15	35
6	12	38	16	24	26
7	9	41	17	27	23
8	22	28	18	48	2
9	12	38	19	20	30
10	12	38	20	18	32

$\mu = 14.5 \quad \alpha = 0.05 \quad$ (critical value of $\mu = 23$)

6.3.2 Presence or absence of hair root sheaths

The question whether the presence or absence of hair root sheaths influences the transparency pattern was studied in these 20 test subjects. Fisher's test was used in the statistical analysis of the data.

Table 8 shows that, in the presence of hair root sheaths, transparency types A (diffusely dark root) and B (root with dark matrix, clear intermediate zone and dark karatogenous zone) was significantly more frequent in seven of the 20 persons. In five of these seven persons, hair root sheaths were more frequently absent in transparency types D (light root with dark matrix) and E (diffusely light root), while in the other two they were as frequently present as absent.

Table 8 Transparency types in 20 healthy adults, in the absence and in the presence of hair root sheaths

Healthy adults	types A and B		types D and E		p (α = 0.05)
	root sheath present	root sheath absent	root sheath present	root sheath absent	
1	9	0	36	5	0.70
2	18	4	14	14	0.04 S
3	11	6	21	12	0.60
4	23	1	10	16	<0.001 S
5	26	1	15	8	0.01 S
6	14	0	17	19	<0.001 S
7	11	1	31	7	0.70
8	38	10	2	0	0.63
9	15	5	13	17	0.05 S
10	11	7	18	14	0.77
11	3	0	25	22	0.33
12	2	3	36	9	0.16
13	31	12	6	1	0.81
14	24	0	13	13	<0.001 S
15	39	7	3	1	0.51
16	9	7	7	27	0.03 S
17	1	2	22	25	0.56
18	5	0	25	20	0.13
19	9	3	27	11	0.55
20	4	2	38	6	0.48

S = significant

6.3.3 *Collecting medium*

Tables 9 and 10 show the difference in hair root transparency pattern in four healthy adults after root collection in the media:

a) cedar oil and Depex
b) water and Depex

Statistical analyses were performed per individual with the aid of the chi-square test for a 2 x 2 table. Transparency type A was compared with types B through E combined.

a) cedar oil and Depex:

Table 9 shows that, in the two persons with dark hair, significant differences in hair root transparency pattern were demonstrable between roots collected in cedar oil and those collected in Depex. In the two persons with blond hair, these differences were not demonstrable.

Table 9 Difference in transparency of hair roots collected from four healthy adults in cedar oil and in Depex

Healthy adult	Hair colour	medium: cedar oil					medium:Depex					χ^2
		transparency type					transparency type					
		A	B	C	D	E	A	B	C	D	E	
1	blond	16	0	0	6	28	18	2	0	0	30	p = 0.8
2	dark	38	0	0	0	12	48	0	0	0	2	p = <0.01 S
3	dark blond	46	0	0	0	4	36	0	0	8	6	p = 0.02 S
4	blond	14	0	0	12	24	20	0	2	4	24	p = 0.3

S = significant

b) water and Depex:

Table 10 shows that, in each of the four persons, transparency type A was significantly more frequent after collection in Depex than after collection in water.

Table 10 Difference in transparency of hair roots collected from four healthy adults in water and in Depex

Healthy adult	Hair colour	medium: water					medium: Depex					χ^2
		transparency type					transparency type					
		A	B	C	D	E	A	B	C	D	E	
1	blond	0	24	14	4	8	18	2	0	0	30	$p << 0.001$ S
2	dark	0	34	4	0	12	48	0	0	0	2	$p << 0.001$ S
3	dark blond	2	42	0	0	6	36	0	0	8	6	$p << 0.001$ S
4	blond	2	0	42	0	6	20	0	4	2	24	$p << 0.001$ S

S = significant

6.4 *Discussion*

Factors of influence on the hair root transparency pattern have not so far been systematically studied. Feliner et al. (1979) did examine the intensity of auto-fluorescence of skin and hair, and found that dark (brown to black) hair caused more fluorescence than lighter (blond) hair. The intensity of fluorescence was thought to depend on the concentration of melanin and its degradation products.

Our study demonstrates that the hair root transparency pattern is dependent on the colour of the external hair.

The presence or absence of hair root sheaths seems to play an important role in this respect. In the presence of root sheaths, transparency types A and B were significantly more frequent, as were types D and E in the absence of root sheaths in persons with, for the most part, dark hair.

We know from the literature (Spearman 1977) that occasionally melanin granules occur in the cuticular cells and also in the inner and outer root sheaths, and this finding may be an aid in explaining this phenomenon.

A difference in transparency pattern was found between roots collected in water and those collected in Depex in all persons studied; between roots collected in cedar oil and those collected in Depex, a difference was found only in persons with darker hair colour. The absorption coefficient and the dispersion indices of the collecting media probably play an important role in these different observations, and the same probably applies to the hair colour as such.

The findings obtained warrant the conclusion that the hair root transparency pattern depends on:

1) the colour of the external hair

2) the collecting media used
3) the presence or absence of hair root sheaths.

In particular the positive influence of the colour of the external hair on the hair root transparency pattern constitutes an argument in support of the conclusion that differences in transparency cannot play a role in hair root diagnostics.

6.5 *Summary*

This study of the diagnostic implications of the hair root transparency pattern revealed that hair colour, presence or absence of hair root sheaths, and type of collecting medium used, exert an influence on the transparency pattern.

The transparency pattern therefore would seem to be unsuitable as a criterion in hair root diagnostics.

CHAPTER 7

SCALP HAIR ROOT SHAPE, HAIR ROOT SHEATHS, ANGULATION OF HAIR ROOT AND/OR SHAFT, AND DEFORMITIES IN THEIR CONTOURS COMPARISON BETWEEN PATIENTS AND HEALTHY SUBJECTS

7.1 *Introduction*

In order to facilitate the diagnosis of phases in the hair root growth cycle and of aberrant hair root shapes on the scalp, the hair root characteristics in health and disease will be discussed in detail with reference to the diagram in which they are recorded (chapter 5, fig.26). The hair root characteristics can be divided into three main groups:

A. Differences in hair root shape.
B. Presence or absence of hair root sheaths.
C. Angulation of the hair root and/or shaft, and deformities in their contours.

A. Differences in hair root shape:

The following hair root shapes are distinguishable in microscopic specimens:


(a) broad proximal base, which narrow distally : photographs 1, 4 9, 16 and 21.

(b) equal diameter throughout : photographs 2, 10 and 14.


(c) club-shaped thickening of proximal end : photographs 6, 18 and 19.

(d) proximal diameter smaller than distal diameter : photographs 7, 11 and 15.


(e) proximal tapering : photographs 8, 17 and 20.

B. Presence or absence of hair root sheaths:

Beneath the surface of the skin, the hair root and part of the hair shaft are surrounded by the internal and external root sheaths. A study of the epilated hair root in a microscopic specimen can reveal these root sheaths in the following situations:

a. firmly encasing the hair root and part of the hair shaft (photographs 4, 9 and 21)
b. loosely encasing the hair root or part of the shaft (photographs 6, 10, 18 and 19)
c. absent, or visible as frayed remnants around root and/or shaft (photographs 11, 12, 13, 15, 16, 17 and 20).

C. Angulation of hair root and/or shaft, and deformities in their contours:

Angulation of the hair root can be found at any level, but is usually seen at the level of the bulb or the keratogenous zone. The liminal value accepted in our study is 20°: the hair root angulation may either exceed (photographs 4, 5, 7, 12, 13, 15, 16, 17 and 20) or fall short of this value.

The contours of the hair root and/or shaft can be smooth or irregular. Irregularities (deformities) in the contours can be: invaginations, evaginations, indentations, constrictions (photographs 12, 13, 15 and 20).

(for photographs 1 - 21, see page 58 and 59)

The scalp hair roots of healthy subjects and patients, arranged in seven groups, were studied in order to establish:

a. the incidence of characteristics described in healthy subjects;
b. differences in incidence between groups of patients and groups of healthy subjects;
c. interrelations between the three groups of characteristics.

This was done in an attempt to gain insight into the value of these characteristics in the diagnostics of the growth phases and the aberrant hair root types of the scalp hair in physiological and pathological conditions.
For this study we chose diseases known or suspected to influence scalp hair growth or to be associated with loss of hair, namely:

1. infectious diseases:

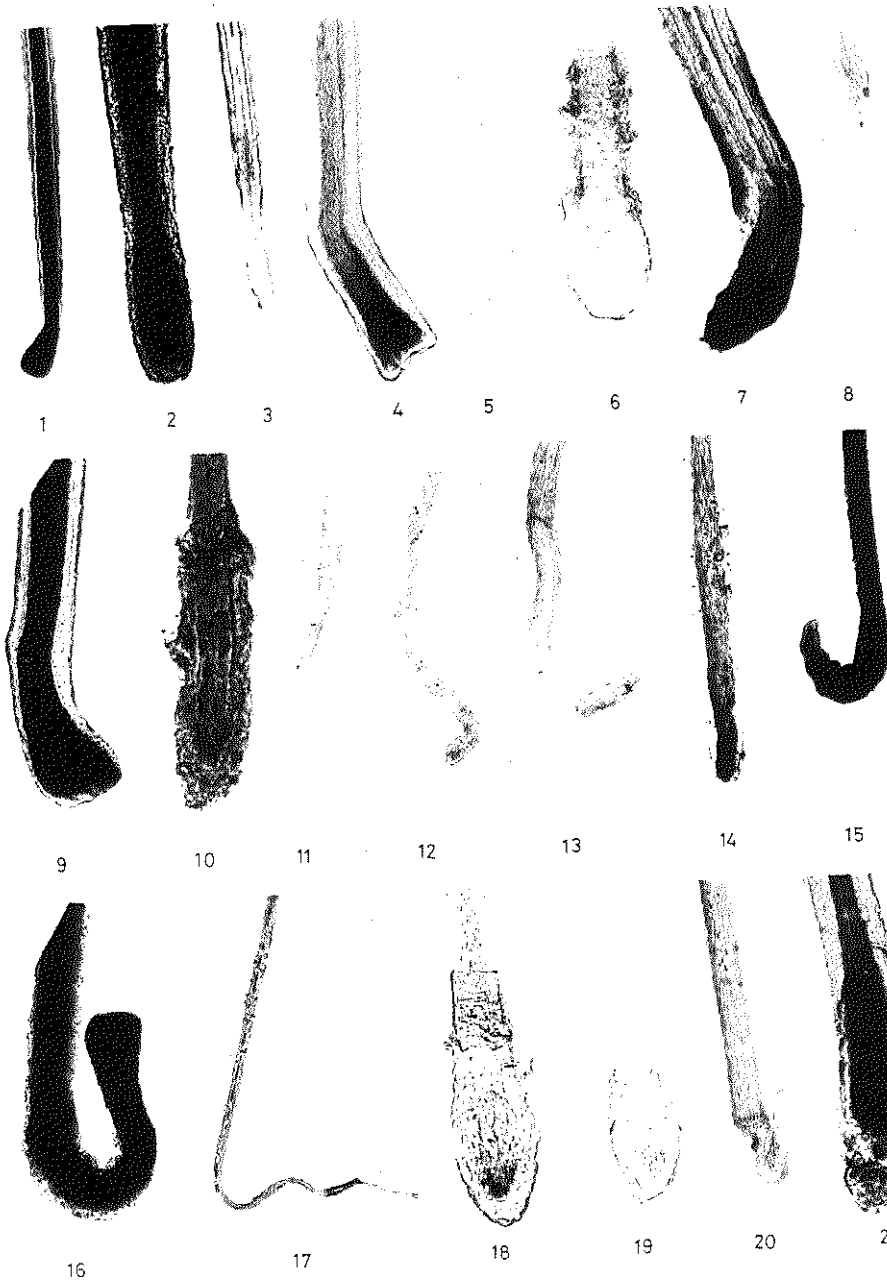
- acute local infectious diseases with generally a short incubation period, e.g. acute gonorrhoea (1-5 days' incubation) and non-specific urethritis (5-14 days' incubation);
- chronic infectious diseases, i.e. infectious primary and secondary syphilis. The incubation period of primary syphilis is 17-28 days (range: 9-90 days). Secondary syphilis begins 6 weeks after the onset of the primary lesion (range: 1-6 months).

2. types of alopecia:

- alopecia diffusa (loss of hair evenly distributed over the entire scalp) in consulting-room patients;
- alopecia areata with circumscribed areas of hair loss in consulting-room patients.

Photograph nr.:

1. Hair root shape a, diffusely dark hair root (type A)
2. Hair root shape b, a dark (pigmented) matrix, a dark keratogenous zone and a clear intermediate zone (type B)
3. A light hair root, with a dark keratogenous zone (type C)
4. Hair root shape a, a light hair root with a dark (pigmented) matrix (type D), hair root sheaths firmly encasing the hair shaft and hair root, $> 20^{o}$ angulation
5. A diffusely light hair root (type E), $> 20^{o}$ angulation
6. Hair root shape c, hair root sheaths loosely encasing the hair shaft and hair root
7. Hair root shape d, $> 20^{o}$ angulation
8. Hair root shape e
9. Hair root shape a, hair root sheaths firmly encasing the hair shaft and hair root
10. Hair root shape b, hair root sheaths loosely encasing the hair shaft and hair root
11. Hair root shape d, hair root sheaths absent
12. Hair root sheaths absent, deformed contours, $> 20^{o}$ angulation
13. Hair root sheaths absent, deformed contours, $> 20^{o}$ angulation
14. Hair root shape b, hair root sheaths firmly encasing the hair shaft and hair root
15. Hair root shape d, hair root sheaths absent, deformed contours $> 20^{o}$ angulation
16. Hair root shape a, hair root sheaths absent, $> 20^{o}$ angulation
17. Hair root shape e, hair root sheaths absent, deformed contours, $> 20^{o}$ angulation
18. Hair root shape c, hair root sheaths loosely encasing the hair shaft and hair root
19. Hair root shape c, hair root sheaths loosely encasing the hair root
20. Hair root shape e, hair root sheaths absent, deformed contours, $> 20^{o}$ angulation
21. Hair root shape a, hair root sheaths firmly encasing the hair root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7.2 *Material and methods*

Material was obtained from a random sample of:

a. co-workers, of the Rotterdam Department of Dermatology and Venereology, aged 20-45
b. patients aged 20-45 who attended the out-patient clinic of the Department of Dermatology and Venereology, Academical Hospital 'Dijkzigt', Rotterdam.

The healthy subjects and patients were divided into the following seven groups:

- 10 healthy male adults and 10 healthy female adults (already discussed in chapter 6, tables 1 and 2)
- 10 male patients suffering from acute gonorrhoea (Go)
- 10 male patients suffering from non-specific urethritis (NSU)
- 10 male patients suffering from primary syphilis (PS)
- 7 male patients suffering from secondary syphilis (SS)
- 5 male and 5 female patients with chronic alopecia diffusa (CAD)
- 5 male and 5 female patients with alopecia areata (AA) of the left temporal region (T-region) and of the margin of the expanding efflorescence (M-region).

In this and in subsequent chapters, the material obtained will be discussed to establish:

- to what extent the abovementioned hair root characteristics are features of the physiological hair root growth pattern, with special reference to the question whether these characteristics are of necessity always seen in combination or can also occur separately in physiological conditions;
- whether the findings obtained in the patients differ from those in the healthy subjects.

Moreover, this systematic study of these groups of characteristics affords a possibility to refine the diagnostics of hair root growth phases and of abberant hair root shapes.

The method used to obtain the hair roots has been described in detail in chapter 3 and can be summarized as follows:

- From every healthy adult and patient, 50 hair roots were epilated at the fixed sample site and deposited on an object slide, using Depex as collecting medium.
- In the patients with alopecia areata, the margin of the efflorescence was likewise submitted to hair root examination.

The hair roots were studied microscopically at 40x magnification, and their characteristics were recorded in accordance with the diagram presented in chapter 5 (fig.26).

7.3 *Results*

7.3.1 *Differences in hair root shape*

In this study, differences in hair root shape were considered in morpho-

logical and in clinical terms.

1. Morphological aspects:

Tables 11 through 15 show the incidence of the various hair root shapes in the groups studied. The Mann-Whitney test was used in statistical analysis (tables 11 through 14), while Fisher's exact probability test was used for the small numbers (level of significance $\alpha = 0.05$) (table 15).

Table 11 Incidence of hair root shape a (Δ) in healthy subjects and patients

No.	Healthy group		Patient groups					AA T- region	AA M- region
	m	f	Go	NSU	PS	SS	CAD		
1	25	12	18	39	32	6	40	13	12
2	22	27	26	9	8	21	2	13	8
3	33	18	37	33	3	4	7	4	2
4	19	28	19	27	27	14	26	3	8
5	32	23	25	26	26	29	31	10	2
6	20	26	26	40	37	16	18	7	0
7	18	21	31	11	13	15	23	8	2
8	23	41	17	20	34		14	1	5
9	27	10	45	36	34		31	22	12
10	38	35	14	22	38		1	11	9
			NS	NS	NS	S	NS	S	S
		U =	98	89	87.5	27.5	74.5	13	13
critical value		U =	55	55	55	34	55	55	55

NS = not significant

S = significant

Table 11 shows that the incidence of hair root shape a was significantly lower in SS and AA (T- and M-region) than in the group of healthy subjects.

Table 12 Incidence of hair root shape b (%) in healthy subjects and patients

No.	Healthy group m	Healthy group f	Patient groups Go	NSU	PS	SS	CAD	AA T-region	AA M-region
1	21	35	11	5	14	7	8	15	18
2	21	15	8	18	16	3	16	13	13
3	14	18	8	1	40	3	23	14	12
4	23	17	25	5	20	20	9	11	7
5	15	22	15	14	20	10	14	15	13
6	28	19	14	7	9	18	11	13	0
7	27	28	8	9	34	16	15	21	4
8	14	8	23	8	11		20	4	6
9	20	21	3	8	15		12	19	11
10	8	13	12	7	11		41	4	11
			S	S	NS	S	NS	S	S
		U =	48.5	16.5	83	28	70	45	19.5
critical value		U =	55	55	55	34	55	55	55

NS = not significant

S = significant

Table 12 shows that the incidence of hair root shape b was significantly lower in Go, NSU, PS, SS and AA (T- and M-region) than in the group of healthy subjects.

Table 13 Incidence of hair root shape c (ʊ) in healthy subjects and patients

No.	Healthy group		Patient groups					AA T-region	AA M-region
	r	f	Go	NSU	PS	SS	CAD		
1	2	3	15	4	0	20	1	3	3
2	3	0	5	11	3	13	7	14	22
3	3	11	3	9	0	30	5	15	8
4	5	1	4	10	1	8	3	2	3
5	2	3	2	4	0	3	2	1	0
6	2	0	4	2	0	5	6	8	27
7	4	1	8	14	0	2	8	6	1
8	3	1	3	4	0		12	10	6
9	3	9	1	2	1		7	1	3
10	4	1	1	7	1		4	1	11
			NS	S	S	S	S	NS	NS
		U =	73	42	30	25	51	73.5	63.5
critical value		U =	55	55	55	34	55	55	55

NS = not significant

S = significant

Table 13 shows that the incidence of hair root shape c was significantly higher in NSU, SS and CAD, and significantly lower in PS.

Table 14 Incidence of hair root shape d (\/) in healthy subjects and patients

No.	Healthy group m	Healthy group f	Patient groups Go	NSU	PS	SS	CAD	AA T-region	AA M-region
1	2	0	2	2	4	14	1	18	17
2	4	7	11	12	9	13	25	10	7
3	0	2	1	7	6	12	15	15	25
4	3	3	2	8	1	8	10	34	29
5	1	1	8	6	3	3	3	24	35
6	0	1	5	1	4	8	14	17	21
7	0	0	3	1	2	17	4	15	14
8	10	0	7	17	5		4	35	27
9	0	10	1	3	0		0	7	24
10	0	1	21	14	0		3	32	19
			S	S	NS	S	S	S	S
		U =	46.5	39.5	69	9	44	3.5	2.5
critical value		U =	55	55	55	34	55	55	55

NS = not significant

S = significant

Table 14 indicates a significantly higher incidence of hair root shape d in Go, NSU, SS, CAD and AA (T- and M-region).

Table 15 Incidence of hair root shape e (V) in healthy subjects and patients

No.	Healthy group		Patient groups					AA T-region	AA M-region
	m	f	Go	NSU	PS	SS	CAD		
1	0	0	4	0	0	3	0	1	0
2	0	1	0	0	1	0	0	0	0
3	0	1	1	0	1	1	0	2	3
4	0	1	0	0	1	0	2	0	3
5	0	1	0	0	1	0	0	0	0
6	0	4	1	0	0	3	1	5	2
7	1	0	0	0	1	0	0	0	29
8	0	0	0	1	0		0	0	6
9	0	0	0	1	0		0	1	0
10	0	0	2	0	0		1	2	0
			NS	NS	NS	NS	NS	NS	NS
		p =	0.69	1	0.43	0.65	1	0.43	0.43
critical value p =			0.05						

NS = not significant

Table 15 shows that the healthy groups did not significantly differ from the patient groups in the incidence of hair root shape e

A brief survey of the results obtained is presented in table 16.

Table 16 Incidence of hair root shapes and present/absent root sheaths in the patient groups; significance of increase/decrease versus healthy group

Hair root shape		Patient groups					AA T-region	AA M-region
		Go	NSU	PS	SS	CAD		
	a	NS	NS	NS	S<	NS	S<	S<
	b	S<	S<	NS	S<	NS	S<	S<
	c	NS	S>	S<	S>	S>	NS	NS
	d	S>	S>	NS	S>	S>	S>	S>
	e	NS	NS	NS	NS	NS	NS	NS
Hair root sheaths								
present	firm	NS	NS	NS	S<	NS	S<	S<
	loose	NS	S>	NS	S>	S>	NS	NS
absent		NS	NS	NS	NS	NS	S>	S>

S< = significantly less

S> = significantly more

NS = not significant

2. Clinical aspects:

Table 16 reveals several patterns in the incidence of the various hair root shapes in the different groups of patients.

- Go and NSU:

  lower incidence of hair root shape b
  higher incidence of hair root shape d (in NSU also of shape c)

- PS:

  lower incidence of hair root shape c

- SS:

  lower incidence of hair root shapes a and b

  higher incidence of hair root shapes c and d

- CAD:

  higher incidence of hair root shapes c and d

- AA (T- and M-region):

  lower incidence of hair root shapes a and b
  higher incidence of hair root shape d.

The above indications are all given in comparison with the healthy group.

7.3.2 *Presence or absence of hair root sheaths*

Table 17 indicates the extent to which the five possible hair root shapes and firmness, looseness or absence of hair root sheaths did or did not correlate in the healthy subjects.

Table 17 The presence (firm or loose) and absence of hair root sheaths on hair roots of the five different shapes in healthy subjects

Hair root shape	Total	Percentage of hair root sheaths firm	loose	absent
/\ (a)	494	89.3	0	10.7
| | (b)	393	43.8	4.8	51.4
⌒ (c)	57	0	96.5	3.5
\/ (d)	47	14.9	2.1	83.0
V (e)	9	0	0	100.0

Hair root shape a was associated with a firm root sheath in 89.3%, with a loose root sheath in 0% and with an absent root sheath in 10.7% of cases.

The respective figures for hair root shape b were 43.8%, 4.8% and 51.4%.

For hair root shape c the figures were 0%, 96.5% and 3.5%.

For hair root shape d they were 14.9%, 2.1% and 83%.

For hair root shape e they were 0%, 0% and 100%.

Next, the incidence of firm, loose and absent root sheaths in the patient groups was compared with that in the healthy group (tables 18, 19 and 20).

Table 18 Hair roots with firm root sheaths in patient groups versus the healthy group

No.	Healthy group		Patient groups						
	m	f	Go	NSU	PS	SS	CAD	AA (T-region)	AA (M-region)
1	26	43	24	43	36	13	2	12	10
2	37	31	30	6	11	31	10	10	5
3	32	18	42	36	11	0	29	6	8
4	31	32	27	25	43	18	41	5	9
5	40	38	29	19	43	32	25	8	1
6	14	30	20	43	44	16	23	10	0
7	19	41	32	24	6	25	15	10	0
8	26	37	26	20	33		35	1	5
9	30	16	45	42	24		1	25	11
10	38	26	15	22	41		43	12	8
			NS	NS	NS	S	NS	S	S
			U = 87.5	90.5	92.5	30	67	4	0
critical value U =			55	55	55	34	55	55	55

Table 19 Hair roots with loose root sheaths in patient groups versus the healthy group

No.	Healthy group		Patient groups						
	m	f	Go	NSU	PS	SS	CAD	AA (T-region)	AA (M-region)
1	2	4	6	4	3	25	8	4	4
2	2	1	6	11	10	14	9	16	27
3	5	9	3	8	8	36	4	16	10
4	6	1	4	13	2	14	3	2	3
5	2	3	2	7	4	15	6	1	0
6	4	3	4	2	5	11	11	9	28
7	4	1	9	13	25	2	13	9	4
8	4	3	5	4	6		8	10	8
9	6	2	2	2	6		4	1	3
10	4	3	3	8	1		1	2	11
			NS	S	NS	S	S	NS	NS
			U = 73	46	59.5	15	47	74.5	56
critical value U =			55	55	55	34	55	55	55

Table 20 Hair roots with absent root sheaths in patient groups versus the healthy group

No.	Healthy group		Patient groups						
	m	f	Go	NSU	PS	SS	CAD	AA (T-region)	AA (M-region)
1	22	3	20	3	11	12	40	34	36
2	11	18	14	33	29	5	31	24	18
3	13	23	5	6	31	14	17	28	32
4	13	17	19	12	5	18	6	43	38
5	8	9	19	24	3	3	19	41	49
6	32	17	26	5	1	23	16	31	22
7	27	8	9	13	19	13	22	31	46
8	20	10	19	26	11		7	39	37
9	14	22	3	6	20		45	24	36
10	8	21	32	20	8		6	36	31
			NS	NS	NS	NS	NS	S	S
		U =	95	88	76	56	88	13.5	13
critical value		U =	55	55	55	34	55	55	55

Patient groups SS and AA (T- and M-region) showed a significantly lower incidence of firm hair root sheaths (table 18) while patient groups NSU, SS and CAD showed a significantly higher incidence of loose hair root sheaths (table 19). The incidence of absent hair root sheaths was significantly higher in AA (T- and M-region) patient groups (table 20).

A survey of these findings is presented in table 16 (page 66).

These significant differences in incidence of various types of hair root sheaths between the healthy group and the patient groups cannot be entirely explained by the significant differences in incidence of hair root shapes between these groups. We will revert to this subject in the discussion.

7.3.3 *Angulation of the hair root and/or shaft and deformities in their contours*

Attempts were made to establish whether a correlation would be demonstrable between presence or absence of the hair root sheath on one hand, and the degree of angulation of hair root and/or shaft and deformities in their contours on the other hand, in healthy subjects.

The presence or absence of hair root sheaths may conceivably be associated with a changed vulnerability of the hair root, which could possibly give rise to angulation of the root and/or shaft, and deformities in their

contours.

Should a correlation be demonstrable between the presence (loose or firm) or absence of the hair root sheath and the incidence of angulation and deformities of hair root and/or shaft, then - in view of the correlation between hair root shapes and the presence (firm or loose) or absence of root sheaths - it might be of little or no use to study the incidence of angulations and deformities of the hair root and/or shaft in the patient groups.

Differences in incidence between patient groups and healthy group might then be explained simply on the basis of the already established differences in incidence of the two characteristics mentioned, and their importance in the diagnosis of pathological conditions would not be demonstrable. A special study of the material is required in view of these considerations.

The results of the study concerning the presence (firm or loose) or absence of hair root sheaths on the various hair root shapes in correlation with angulations and deformities of the hair root and/or shaft will be discussed next.

Table 23 shows the correlation of the hair root shapes with the presence (firm or loose) or absence of hair root sheaths, smooth or irregular (deformed) contours and angulation ($\ll 20^{\circ}$ or $> 20^{\circ}$) in healthy subjects, in absolute numbers and in percentages.

The findings presented in this table can be summarized as follows.

Hair root shape a
shows the highest incidence of firm root sheaths, $< 20^{\circ}$ angulation and smooth contours (82.8%);
deformities and $> 20^{\circ}$ angulations are less frequently seen (1.6%) in association with firm root sheaths;
loose root sheaths are not found in this hair root shape;
the incidence of $> 20^{\circ}$ angulations and deformed contours of hair root and/or shaft is higher (6.1%) when the root sheath is absent.

Hair root shape b
shows a firm root sheath, $< 20^{\circ}$ angulation and smooth contours in 39.2% of cases;
the incidence of $> 20^{\circ}$ angulation and deformities is low (1.4%) in association with firm root sheaths, as in hair root shape a;
no deformities and/or $> 20^{\circ}$ angulations are seen in association with a loose root sheath;
absence of root sheaths is seen in 51.3% of cases, and in these cases the incidence of deformities and $> 20^{\circ}$ angulations is markedly increased.

Hair root shape c
is always smooth and shows no $> 20^{\circ}$ angulations of root and/or shaft;
the root sheath is usually loose, and absent in only a few cases (3.5%).

Hair root shape d
has a root sheath in 6.3% of cases and the incidence of deformed hair roots and/or shafts is. 4.2%;
the hair root sheath is loose in 10% of cases, with no deformities and $> 20^{\circ}$ angulations;

in the remaining 83% the hair root sheath is absent, and $> 20^{\circ}$ angulation and deformities of hair root and/or shaft are seen in 43%.

Hair root shape e
always shows absence of the root sheath;
smooth contours and $< 20^{\circ}$ angulations are seen in 44.5%, while deformities and $> 20^{\circ}$ angulations occur in 55.5%.

The data in table 23 thus warrant the conclusion that, in the absence of hair root sheaths, $> 20^{\circ}$ angulations and deformities of root and/or shaft are relatively more frequent in hair root shape a and especially in hair root shapes b and d, particularly when $> 20^{\circ}$ angulation is associated with deformities in hair root and/or shaft.

The question now arises whether there is a correlation between the absence of hair root sheaths and the incidence of $> 20^{\circ}$ angulation and deformities of root and/or shaft.

For further analysis of this question, correlations between absence of hair root sheaths and $> 20^{\circ}$ angulation and deformities were studied in the healthy group and in each of the patient groups separately (tables 21 and 22).

Table 21 **Correlation between present (firm) hair roots sheaths and hair root angulation in healthy subjects and patients**

$\alpha = 0.05$ $G_o > 3.84$ = significant

Healthy subjects	root sheaths firm root angulation		root sheaths absent root angulation		G_o
	$<20^{\circ}$	$>20^{\circ}$	$<20^{\circ}$	$>20^{\circ}$	
1	27	1	3	19	31.9
2	33	5	3	9	14.4
3	32	5	3	10	15.5
4	37	0	5	8	22.7
5	42	0	1	7	35.1
6	16	0	14	20	13.3
7	21	1	4	23	29.4
8	29	1	10	10	12.8
9	36	0	1	13	40.5
10	41	1	2	6	23.7
11	46	1	1	2	11.0
12	24	8	7	11	4.9
13	28	4	2	16	24.9
14	32	1	5	12	23.2
15	37	4	4	5	7.6
16	30	1	9	10	14.0
17	41	1	3	5	17.7
18	40	0	9	1	0.6
19	23	5	15	7	0.7
20	29	0	5	16	29.1

Go patients					
1	21	9	14	6	0.1
2	29	7	4	10	9.9
3	43	2	0	5	26.7
4	27	4	2	17	25.3
5	22	9	6	13	5.9
6	22	2	8	18	16.8
7	37	4	4	5	7.6
8	24	7	3	16	15.6
9	47	0	0	3	33.8
10	11	7	4	28	10.8
NSU patients					
1	42	5	0	3	10.8
2	17	0	4	29	32.1
3	32	12	0	6	9.2
4	33	5	3	9	14.4
5	25	1	8	16	19.2
6	45	0	1	4	29.0
7	31	6	2	11	17.1
8	19	5	6	20	13.5
9	38	6	3	3	2.6
10	30	0	8	12	20.5
PS patients					
1	29	10	4	7	4.0
2	8	14	6	22	0.7
3	29	2	9	10	11.4
4	29	10	5	6	2.1
5	30	0	12	8	11.5
6	38	4	4	4	5.5
7	13	6	6	25	10.0
8	21	24	3	2	0.01
9	40	9	0	1	0.6
10	44	3	0	3	15.4
SS patients					
1	38	0	7	5	13.3
2	39	6	3	2	0.8
3	36	0	5	9	24.0
4	26	6	5	13	11.8
5	45	2	0	3	19.1
6	26	0	9	15	20.2
7	11	26	1	12	1.5
CAD patients					
1	41	3	1	5	17.7
2	10	0	6	34	22.8
3	19	0	4	27	32.5
4	33	0	3	14	33.8
5	43	1	1	5	25.6
6	30	1	2	17	34.4
7	25	9	3	13	11.1
8	22	6	5	17	13.3
9	40	3	2	5	14.1
10	5	0	8	37	11.8

TAA patients					
1	14	2	7	27	17.3
2	20	6	4	20	15.8
3	21	1	5	23	26.7
4	5	2	5	38	10.0
5	9	0	8	33	17.9
6	19	0	25	6	2.5
7	19	0	11	20	17.8
8	11	0	11	28	15.2
9	25	1	9	15	17.1
10	9	5	32	4	2.6
MAA patients					
1	11	3	18	18	2.3
2	30	2	3	15	27.2
3	15	3	25	7	0.0054
4	10	2	7	31	14.4
5	1	0	13	36	0.25
6	27	1	22	0	0.0149
7	3	1	45	1	0.82
8	11	2	17	20	4.4
9	13	1	12	24	12.0
10	18	1	10	21	16.2

Table 22 Correlation between presence (firm) or absence of hair root sheaths and deformities of hair root and/or shaft, in healthy subjects and patient groups

Healthy subjects	Firm hair root sheaths not deformed	Firm hair root sheaths deformed	Absent hair root sheaths not deformed	Absent hair root sheaths deformed	G_o
1	27	1	0	22	42.3
2	37	1	1	11	34.9
3	37	0	1	12	40.0
4	37	0	0	13	44.9
5	42	0	1	7	35.8
6	16	0	3	31	34.6
7	23	0	1	26	42.4
8	29	1	7	13	19.7
9	36	0	3	11	31.8
10	41	1	1	7	30.2
11	46	1	1	2	10.9
12	19	13	4	14	5.0
13	30	2	2	16	30.6
14	33	0	5	12	26.9
15	36	5	2	7	14.0
16	30	1	8	11	16.4
17	42	0	2	6	29.0
18	37	3	4	6	11.6
19	22	6	4	18	15.7
20	29	0	3	18	35.2
Go patients					
1	20	10	12	8	0.0326
2	35	1	1	13	35.2
3	44	1	0	5	32.0
4	28	3	2	17	28.0
5	30	1	0	19	42.0
6	19	5	5	21	15.6
7	39	2	1	8	27.5
8	19	12	0	19	16.3
9	45	2	0	3	19.1
10	15	3	4	28	21.6

NSU patients

1	42	5	0	3	10.8
2	17	0	5	28	29.4
3	32	12	0	6	9.2
4	33	5	0	12	26.9
5	26	0	7	17	24.8
6	43	2	1	4	17.7
7	35	32	2	11	27.4
8	17	7	1	25	21.5
9	40	4	3	3	4.3
10	0	30	4	16	4.1

PS patients

1	27	12	2	9	7.2
2	14	8	2	26	15.6
3	30	1	4	15	27.2
4	28	11	3	8	5.5
5	28	2	12	8	6.4
6	35	7	5	3	0.8
7	16	3	10	21	10.7
8	17	28	2	3	0.2
9	28	21	0	1	0.01
10	46	1	0	3	24.6

SS patients

1	38	0	5	7	21.2
2	42	3	3	2	2.5
3	36	0	0	14	45.2
4	25	7	4	14	12.6
5	44	3	0	3	15.4
6	25	1	2	22	35.3
7	9	28	0	13	2.4

CAD patients

1	44	0	2	4	23.5
2	10	0	2	38	34.6
3	19	0	1	30	42.0
4	33	0	2	15	37.5
5	44	0	0	6	41.0
6	28	3	1	18	31.6
7	34	0	4	12	29.6
8	28	0	6	16	26.7
9	43	0	2	5	26.7
10	5	0	1	44	32.0

TAA patients

1	13	3	8	26	12.6
2	19	7	0	24	25.3
3	22	0	5	23	30.2
4	4	3	0	43	19.5
5	9	0	5	36	24.0
6	18	1	22	9	2.8
7	19	0	6	25	27.5
8	11	0	3	36	31.8
9	23	3	3	21	25.9
10	10	4	29	7	0.10

MAA patients

1	12	2	9	27	12.9
2	30	2	2	16	30.6
3	15	3	22	10	0.6
4	10	2	4	34	28.5
5	1	0	3	46	2.4
6	27	1	2	20	35.1
7	3	1	43	3	0.11
8	13	0	12	25	15.0
9	14	0	0	36	45.2
10	18	1	0	31	41.9

Table 23. Survey of hair root shapes with present (firm / loose) or absent root sheaths, smooth or deformed contours and <20° or >20° angulation, in various combinations. in absolute numbers and percents, in the healthy group

Hair root shapes	Hair root sheaths	Contours	Angulation	Number	%
a (I)					
total 494	firm	smooth	<20°	409	82.8
	firm	smooth	>20°	8	1.6
	firm	deformed	<20°	15	3.1
	firm	deformed	>20°	99	1.8
	loose	smooth	<20°	0	0
	loose	smooth	>20°	0	0
	loose	deformed	<20°	0	0
	loose	deformed	>20°	0	0
	absent	smooth	<20°	8	1.6
	absent	smooth	>20°	7	1.4
	absent	deformed	<20°	8	1.6
	absent	deformed	>20°	30	6.1
b (II)					
total 393	firm	smooth	<20°	154	39.2
	firm	smooth	>20°	11	2.8
	firm	deformed	<20°	2	0.5
	firm	deformed	>20°	5	1.4
	loose	smooth	<20°	19	4.8
	loose	smooth	>20°	0	0
	loose	deformed	<20°	0	0
	loose	deformed	>20°	0	0
	absent	smooth	<20°	16	4.0
	absent	smooth	>20°	8	2.0
	absent	deformed	<20°	46	11.7
	absent	deformed	>20°	132	33.6
c (III)					
total 57	firm	smooth	<20°	0	0
	firm	smooth	>20°	0	0
	firm	deformed	<20°	0	0
	firm	deformed	>20°	0	0
	loose	smooth	<20°	55	96.5
	loose	smooth	>20°	0	0
	loose	deformed	<20°	0	0
	loose	deformed	>20°	0	0
	absent	smooth	<20°	2	3.5
	absent	smooth	>20°	0	0
	absent	deformed	<20°	0	0
	absent	deformed	>20°	0	0
d (IV)					
total 47	firm	smooth	<20°	1	2.1
	firm	smooth	>20°	0	0
	firm	deformed	<20°	2	4.2
	firm	deformed	>20°	0	0
	loose	smooth	<20°	5	10.7
	loose	smooth	>20°	0	0
	loose	deformed	<20°	0	0
	loose	deformed	>20°	0	0
	absent	smooth	<20°	7	14.9
	absent	smooth	>20°	1	2.1
	absent	deformed	<20°	11	23.0
	absent	deformed	>20°	20	43.0
e (V)					
total 9	firm	smooth	<20°	0	0
	firm	smooth	>20°	0	0
	firm	deformed	<20°	0	0
	firm	deformed	>20°	0	0
	loose	smooth	<20°	0	0
	loose	smooth	>20°	0	0
	loose	deformed	<20°	0	0
	loose	deformed	>20°	0	0
	absent	smooth	<20°	4	44.5
	absent	smooth	>20°	0	0
	absent	deformed	<20°	0	0
	absent	deformed	>20°	5	55.5

7.4 *Statistical Analyses*

Tables 21 and 22 were statistically analysed with the aid of the test for double dichotomy, accepting as null hypothesis that the absence of hair root sheaths does not correlate with the presence of $> 20^{\circ}$ angulations and deformities.

The tests were performed with G_2 as test statistic and $\alpha = 0.05$ as level of significance (De Jonge and Rümke 1974). The critical value of G at $\mu = 1$ and $\alpha = 0.05$ is 3.84.

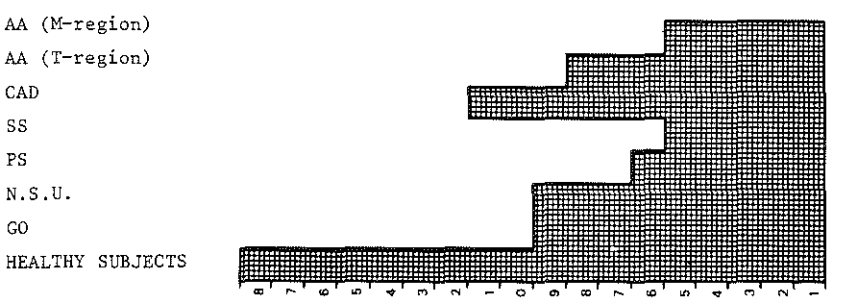
Considering table 21, we find that the null hypothesis is rejected if $G > 3.84$ (i.e. that absence of hair root sheaths correlates with the presence of $> 20^{\circ}$ angulations) in:

18	of the 20	healthy subjects	: 90%
9	of the 10	Go patients	: 90%
9	of the 10	NSU patients	: 90%
6	of the 10	PS patients	: 60%
5	of the 7	SS patients	: 71%
10	of the 10	CAD patients	:100%
8	of the 10	AA patients (T-region)	: 80%
5	of the 10	AA patients (M-region)	: 50%

Considering table 22, we find that the null hypothesis is rejected if $G > 3.84$ (i.e. that absence of hair root sheaths correlates with the presence of deformities of root and/or shaft) in:

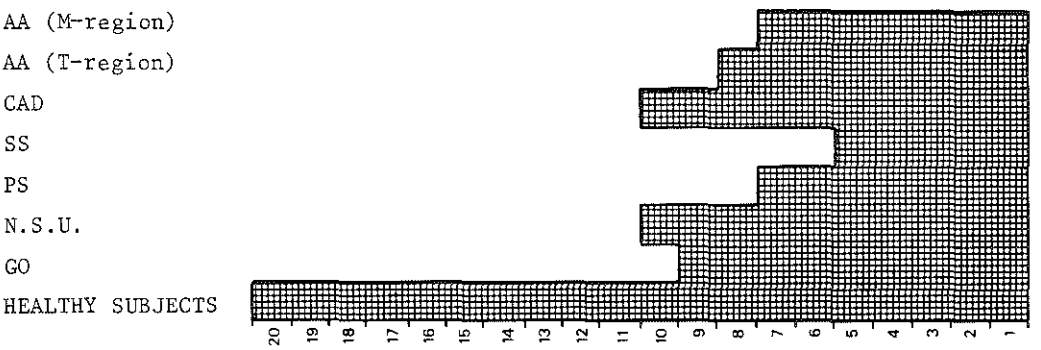
20	of the 20	healthy subjects	:100%
9	of the 10	Go patients	: 90%
10	of the 10	NSU patients	:100%
7	of the 10	PS patients	: 70%
5	of the 7	SS patients	: 71%
10	of the 10	CAD patients	:100%
8	of the 10	AA patients (T-region)	: 80%
7	of the 10	AA patients (M-region)	: 70%

The data of tables 21 and 22 are schematically represented in histograms in figures 27 and 28.



shaded columns: significantly increased incidence of absent root sheaths in combination with $> 20^{\circ}$ angulation.

FIG. 27 INCIDENCE OF THE CORRELATION BETWEEN ABSENCE OF HAIR ROOT SHEATHS AND $> 20^{\circ}$ ANGULATION .



shaded columns: significantly increased incidence of absent hairroot sheaths in combination with deformities of the root and/or shaft.

FIG. 28. INCIDENCE OF THE CORRELATION BETWEEN ABSENCE OF HAIR ROOT SHEATHS AND DEFORMITIES OF THE HAIR ROOT AND/OR SHAFT.

The groups of healthy subjects and patients studied are shown on the x-axis, and the significant incidences of absent hair root sheaths in combination with $> 20^{\circ}$ angulation and contour deformities, respectively, are shown on the y-axis.

Both histograms show a positive correlation between absence of hair root sheaths and $> 20^{\circ}$ angulation and contour deformities, respectively, in 90% and 100% of healthy subjects and Go, NSU and CAD patients, and in 80% of AA patients (T-region). The PS, SS and AA patients (M-region) showed lower rates: 60% and 70%, 71% and 70%, and 50% and 70%, respectively.

7.5 *Discussion*

In morphological terms, it can be stated that table 6 (which presents differences in the incidence of hair root shapes and hair root sheath morphology according to significance, sometimes reveals 'concomitance' of two hair root abnormalities which might indicate a correlation, while in other instances this 'concomitance' is absent. Examples:

1. The hair roots of PS, AA patients (T- and M-region) show a significantly decreased incidence of firm hair roots sheaths which is concomitant with a proportional significant decrease in the incidence of hair root shapes a and b.
   The hair roots of PS and CAD patients show no difference in incidence between firm hair root sheaths and hair root shapes a and b.
   The high incidence of firm root sheaths in hair root shape a (89.3%) and in hair root shape b (43.8%) in the healthy group (table 17) can explain this. This correlation between hair root sheath and hair root

shape, however, is not evident in the hair roots of Go and NSU patients.
In spite of a significantly decreased incidence of hair root shape b, a significantly decreased incidence of firm hair root sheaths is not demonstrable in these two groups.

2. The hair roots of NSU, SS and CAD patients show a significantly increased incidence of loose root sheaths and an identically increased incidence of hair root shape c versus the healthy group.
No significant difference in incidence of loose root sheaths and hair root shape c is seen between the healthy group and the groups of Go, AA patients (T- and M-region). These findings are synchronous with the correlation found between loose root sheaths and hair root shape c (96.5%, table 17).

3. The hair roots of AA patients (T-region and M-region) show a significantly decreased incidence of hair root shape b and a significantly increased incidence of hair root shape d as compared with the healthy group. The fact that in healthy subjects hair root shape d shows absence of the hair root sheath in 83%, explains this.
The hair roots of Go, NSU, SS and CAD patients, however, show a significantly increased incidence of hair root shape d, associated with a significantly increased incidence of absent hair root sheaths. This is possibly explained by the fact that Go, NSU, SS, AA patients (T- and M-region) show a significantly lower incidence of hair root shape b.
Although the hair root shape therefore seems to correlate with the presence (firm or loose) or absence of hair root sheaths, we find that in the diseases considered these two discernible hair root characteristics can occur independently. It is therefore necessary to record both hair root characteristics.
The same applies, if to a less marked degree, to the other group of characteristics (presence or absence of hair root sheaths versus angulation and contour deformities).

Table 23 shows that, in the absence of hair root sheaths, $\geq 20^{\circ}$ angulations and contour deformities are more frequently seen in healthy subjects.

It is a striking finding that both histograms (figures 27 and 28) show virtually the same pattern. An unmistakable correlation is found between absence of hair root sheaths and $\geq 20^{\circ}$ angulation and contour deformities.

It is conceivable that a hair root without hair root sheath is more vulnerable than one with a sheath. The abovementioned correlation is less frequently found in hair roots of PS, SS and AA patients (M-region). A possible explanation of the varying findings in these patients might be that the abnormalities of the hair root per se are responsible for the decreased incidence of $\geq 20^{\circ}$ angulations and contour deformities in the absence of root sheaths.

Very likely, the deformities (invaginations, indentations, constrictions) and angulations have so increased in number in PS, SS and AA patients (M-region), that the hair root and/or shaft has broken off at this vulnerable level.

Despite the correlation between absence of root sheaths on one hand and

angulations and contours deformities on the other, the recording of angulations and deformities in the contours of the hair root and/or shaft proves to be of importance for diagnosis.

In clinical terms it can be stated that, in the infectious diseases and alopecia types studied, significant differences have been demonstrated in the incidence of the five hair root types, root sheath morphology and angulations and contour deformities.

Not until the morphological hair root characteristics of each growth phase and of each aberrant form have been determined (chapter 8) and the normal limits in the hair root status have been established (chapter 9) will the question of the clinical implications of various hair root characteristics be discussed (chapters 10 through 11).

7.6 *Summary*

The incidence of the various hair root shapes and hair root sheath features, and their correlations, were studied in healthy subjects, and the findings were compared with those obtained in groups of patients.

A positive correlation was established between absence of hair root sheaths on one hand and the incidence of $> 20^{\circ}$ angulations and contour deformities on the other in the hair roots of healthy subjects and those of:

90 - 100% of Go, NSU and CAD patients,
60 - 70% of PS and SS patients,
80 % of AA patients (T-region), and
50 - 70% of AA patients (M-region).

This study disclosed the importance of recording the abovementioned morphological characteristics in the hair root status; moreover, it was demonstrated that pathological processes can influence the characteristics of the scalp hair root. The possible clinical implications of the hair root morphology are left undiscussed in this chapter.

CHAPTER 8

DETERMINATION OF THE MORPHOLOGICAL CHARACTERISTICS OF HAIR ROOT GROWTH PHASES AND ABERRANT HAIR ROOT TYPES

8.1 Introduction

The phases of the hair root growth cycle are:

1) anagen (growth phase)
2) catagen (phase of transition)
3) telogen (resting phase)

while in addition we distinguish aberrant hair root types such as

4) dysplastic roots, and
5) dystrophic roots

The morphological profile of the growth phases and aberrant hair root type will be determined on the basis of the four discernible characteristics discussed in the preceding chapters, namely:

- hair root shape a (photographs 1, 4, 9, 16 and 21)
  hair root shape b (photographs 2, 10 and 14)
  hair root shape c (photographs 6, 8 and 19)
  hair root shape d (photographs 7, 11 and 15)
  hair root shape e (photographs 8, 17 and 20)
- presence: firm (photographs 4, 9, 14 and 21)
  loose (photographs 6, 10, 18 and 19)
  or absence (photographs 11, 12, 13, 15, 16, 17 and 20) of root sheaths.
- degree of angulation of hair root and/or shaft
  $< 20^{o}$ (photographs 2, 3, 6, 8, 10, 14, 18, 19 and 21)
  or $> 20^{o}$ (photographs 4, 5, 7, 12, 13, 15, 16, 17 and 20)
- hair root and hair shaft contours
  smooth (photographs 1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 18, 19 and 21)
  or deformed (photographs 5, 12, 13, 14, 15, 16, 17 and 20)

While employing these characteristics in defining the abovementioned phases and aberrant hair root types, data mentioned in and culled from the literature (chapter 4) will be referred to so far as possible.

8.2 Morphological characteristics

8.2.1 Anagen hair roots

Van Scott (1957, 1958), Bandmann and Bosse (1966), Braun-Falco (1966) and Heilgemeir (1975) described the hair root in anagen as follows:

The proximal end has the largest diameter (Λ, hair shape a). Later in anagen the hair root assumes shape b (I), with an equal diameter throughout; the internal hair root sheaths can be intact, partially presence, or absent.

Reports on hair root shapes a and b in the literature do not mention the presence or absence of deformities of the contours of hair root and/or shaft, and seldom specify the degree of angulation of root and/or shaft.

In view of the data presented in the literature, and on the basis of personal observations, it can be stated that the hair root in anagen is characterized by hair root shapes a and b. The shape of the hair root is of importance in determining this growth phase. Root sheaths are as a rule present in this phase, although in a few instances they may be absent. The 'loose' root sheath in association with hair root shape b is not characteristic of anagen. Angulations in excess of 20° and deformities of hair root and/or shaft can occur in this phase. Their incidence will be discussed in the next chapter, in which the limits of the normal values will be determined.

8.2.2 *Catagen hair roots*

Van Scott et al. (1957) reported that the hair in catagen is still encased in the root sheath. Braun-Falco (1966) divided catagen into three subphases (I, II and III). They held that the proximal diameter in particular diminishes in subphase I, whereas the length of the hair root sheaths diminishes in subphases II and III.

The activity of the hair matrix diminishes in catagen, and consequently the hair root may assume shape b (𝍐) or even shape d (\/). The hair root ascends to the skin surface, partly leaving the root sheaths behind. In microscopic specimens these root sheaths are seen as 'loose' (sometimes wrinkled) around the hair shaft (photograph 10).

One thus finds loose hair root sheaths in root shapes b and d, and a firm hair root sheath in hair root shape d.

In this phase there are hardly any angulations, and the contours of root and/or shaft are seldom deformed.

In view of the data in the literature and on the basis of personal observations, the catagen hair root can be described as characterized by two hair root shapes (b and d) with loose root sheaths (photograph 10), or by hair root shape d with firm root sheaths (photograph 7).

8.2.3 *Telogen hair roots*

Van Scott et al. (1957) characterized the hair root in telogen as one showing club-shaped thickening of the proximal end (hair shape c (𝍋)) (photographs 6, 18 and 19), encased in a 'loose' epithelial sac. Our study of healthy subjects likewise revealed that in this phase the hair root has shape c and, in 96.5% of cases, loose root sheaths. It always shows $<20^{\circ}$ angulation and smooth contours.

These findings warrant the conclusion that the telogen hair root is characterized by shape c and a loose root sheath (the latter may be rarely absent).

8.2.4 *Aberrant hair roots*

Braun-Falco (1966) reported that the matrix of the dysplastic or dystrophic hair root is diminished in diameter and that the root has no root sheaths.

8.2.4.1 *Dysplastic hair roots*

Archer and Luell (1960) added that any hair root with $> 90^{\circ}$ angulation of root and/or shaft can be described as dysplastic.

In our study (chapter 7) we found that the dysplastic hair root is characterized by shape d (\/), absence of hair root sheaths, $> 20^{\circ}$ angulation in 44.7% of cases, and deformed contours of root and/or shaft in 65.9% of cases (photographs 7, 11, and 15).

8.2.4.2 *Dystrophic hair roots*

The changes in dystrophic hair roots have so increased in severity that the root has broken off at its narrowest level and has assumed hair root shape e (V). Hair root sheaths are always absent (photographs 8, 17 and 20).

8.3 *Material and Methods*

The material was obtained from the healthy group and the six patient groups described in chapter 7. The findings obtained in this material and the data from the literature (chapter 7 and chapter 4, respectively) were used in combination in order to determine the morphological characteristics of the hair root in its various physiological and pathological forms.

8.4 *Results*

The morphological hair root characteristics in the various phases of the hair growth cycle can now be summarized as follows.

8.4.1 *Anagen hair roots*

- hair root shape : a (/\) in early anagen
  : b (||) in late anagen
- hair root sheath : firm, partially present or absent
- angulation : $< 20^{\circ}$ or $> 20^{\circ}$
- contours : smooth or deformed

8.4.2 *Catagen hair roots*

- hair root shape : b (||) and d (\/)
- hair root sheath : loose in hair root shapes b and d
  : firm in hair root shape d
- angulation : $< 20^{o}$
- contours : smooth, rarely deformed

8.4.3 *Telogen hair roots*

- hair root shape : c (club)
- hair root sheath : loose, rarely absent
- angulation : $< 20^{o}$
- contours : smooth

8.4.4 *Dysplastic hair roots*

- hair root shape : d (\/)
- hair root sheath : absent
- angulation : $< 20^{o}$ or $> 20^{o}$
- contours : smooth or deformed

8.4.5 *Dystrophic hair roots*

- hair root shape : e (V)
- hair root sheath : absent
- angulation : $< 20^{o}$ or $> 20^{o}$
- contours : smooth or deformed

8.5. *Discussion*

The morphological characteristics of the anagen hair root described in the literature (Van Scott et al. 1957, 1958) are in agreement with our personal observations so far as the hair root shape (a and b) is concerned, and also with regard to the presence (firm) or absence of hair root sheaths.

The literature on this phase mentions the growth rate remains constant in any individual follicle (Saitoh et al. 1969).
Studies on the guinea-pig (an animal which has been believed to share with man a mosaic pattern of follicle activity) however revealed the growth rate depends upon the time for which the activity of the follicle has been in progress (Jackson and Ebling, 1971). This could be thought to indicate a higher degree of matrix activity in late anagen.

In our study (chapter 7) table 12 shows the incidence of hair root shape b (||) to be significantly lower in Go-, NSU-, SS- and AA (M- and T-regions)-patients in contrast to our findings with hair root shape a (/\), which is significantly lower in SS- and AA (M- and T-regions)-patients only. These data suggest the level of mitotic activity of the hair matrix to be at its height in late-anagen.

Further, the recording of angulations and deformities in the contours of the hair root and/or shaft has been proved to be of importance for diagnosis (chapter 7).

Descriptions of the catagen hair root in the literature vary and often show discrepancies (Van Scott et al. 1957, 1958; Braun-Falco 1966); consequently we decided to establish our own criteria for this phase from the abovementioned data (8.4, page 82).

Descriptions of the telogen hair root in the literature are entirely in agreement with our personal observations; the latter revealed, moreover, that the hair root sheath may be absent in a small percentage of hairs.

The principal criteria for the aberrant (dysplastic and dystrophic) hair roots are that the root diameter diminishes proximally (hair root shape d) or even tapers down (shape e), and that hair root sheaths are always absent. Our findings and the data in the literature (chapter 4) are in agreement on the fact that $> 20^{\circ}$ angulations and deformities are observed in a far larger percentage of these hairs than in the other hair root shapes.

8.6 *Summary*

The morphological characteristics of the hair root in various phases of its growth cycle and in aberrant hair root types were determined.

Anagen hair roots are characterized by shape a in early anagen and shape b in late anagen. Root sheaths are usually present and firm, and angulations and deformities of root and/or shaft may occur in a small percentage of hairs.

Catagen hair roots are characterized by shape b or d; the root sheath is loose in shapes b and d or firm in shape d. There are no angulations and the contours of root and/or shaft are nearly always smooth.

Telogen hair roots show hair root shape c, and root sheaths may be present (loose) or absent (rarely). No angulations are seen, and the contours of root and/or shaft are smooth.

Dysplastic and dystrophic hair roots show shape d or e, and hair root sheaths are always absent. A large percentage of these hair roots show $>20^{\circ}$ angulation and deformed contours of root and/or shaft.

CHAPTER 9

DETERMINATION OF THE LIMITS OF NORMAL VALUES OF VARIOUS HAIR ROOT CHARACTERISTICS IN HEALTHY SUBJECTS

9.1 *Introduction*

A hair root status showing the values of the various hair root characteristics is of importance only if the normal limits of these values have been determined as well. Tables with limits of normal values are regularly consulted in medicine in order to establish whether a result obtained - e.g. a laboratory test result - lies within these limits.

Rümke and Bezemer (1972) hold that determination of the limits of normal values can have two purposes:

1. a cautionary purpose,
   in which case the limits determined can be used in diagnosis and the risk of failing to detect values which deviate from the usual is small;
2. a descriptive purpose,
   in which case the risk of finding values outside the limits in healthy subjects is small.

The use of inner limits for percentiles is recommended for cautionary purposes, while that of outer limits for percentiles is advised for descriptive purposes. Inner and outer limits together constitute limits of the confidence interval for percentiles of a distribution.

An insufficient cautionary function is to be considered undesirable for limits used in medicine because in that case proper diagnosis may be impeded and institution of therapy consequently delayed.

Rümke and Bezemer therefore prefer to calculate limits of normal values by procedures which guarantee that, in healthy subjects, at least 2.5% of the results for a given parameter are outside each of the limits. Such limits are suitable par excellence for cautionary purposes.

In our study we used P=2.5 as lower and P=97.5 as upper limit in the calculation of limits of normal values. A certain confidence was accepted for the upper and for the lower limit; this confidence is indicated as γ, and γ=90% was accepted as confidence level in our healthy group.

9.2 *Material and methods*

The group studied consisted of the 20 healthy subjects aged 20-45 already discussed in chapters 3 and 5.

It is not certain that the data obtained in this group show a gaussian distribution, for comparable material has never been tested elsewhere on a large scale. Moreover, statistical testing of the hypothesis that a gaussian distribution exists, is not sufficiently discriminative in a small number of observations.

Since the group studied was small (n=20), the inner percentile limits are best calculated distribution-free. We opted in favour of the cautionary purpose with confidence level γ=90%.

We always accepted as limits the second lowest and second highest observations per hair root shape, taking into account the presence or absence of hair root sheaths as well as angulation and contours of root and/or shaft as classified for various hair root shapes in the phases of the growth cycle and for aberrant hair roots (chapters 7 and 8).

9.3 *Results*

The limits of normal values in our group of 20 healthy subjects can now be established for the various hair root shapes and correlated to hair growth phases and aberrant hair roots.

Table 24 Incidence of hair root shapes a and b with firm and with absent hair root sheaths

Patient no.	
1	46
2	43
3	45
4	41
5	46
6	48
7	45
8	36
9	44
10	46
11	45
12	41
13	33
14	45
15	45
16	44
17	49
18	47
19	29
20	47

Table 24 shows that, for hair root shapes a and b with firm and with absent hair root sheaths (anagen),

- the second lowest observation was 33
- the second highest observation was 48

Table 25 Incidence of hair root shape a

a. with firm and with absent hair root sheaths

b. with firm root sheaths, >20° angulation and deformity of root and/or shaft

c. with absent root sheaths, >20° angulation and deformity of root and/or shaft

No.	a hair root sheath		b firm hair root sheath		c absent hair root sheath	
	firm	absent	>20°	deformity	>20°	deformity
1	24	1	1	1	2	2
2	20	2	3	0	4	2
3	26	7	6	0	9	6
4	19	0	0	0	0	0
5	31	1	0	0	1	1
6	13	7	0	0	6	6
7	18	0	0	0	0	0
8	22	1	1	1	1	2
9	25	2	0	0	2	1
10	35	3	1	1	3	4
11	11	1	1	1	2	2
12	22	6	3	11	6	13
13	15	3	0	0	3	3
14	27	1	0	0	0	0
15	23	0	3	1	3	1
16	26	0	1	1	1	1
17	19	2	1	0	3	1
18	35	6	0	4	1	6
19	9	1	2	1	2	2
20	25	10	0	0	6	7

Table 25 shows that, for hair root shape a (early anagen), with firm hair root sheaths

- the second lowest observation was 11
- the second highest observation was 35,

for > 20° angulation

- the second lowest observation was 0
- the second highest observation was 3,

for deformed contours of hair root and/or shaft

- the second lowest observation was 0
- the second highest observation was 4,

with absent hair root sheaths

- the second lowest observation was 0
- the second highest observation was 7,

for $> 20^{\circ}$ angulation

- the second lowest observation was 0
- the second highest observation was 6,

for deformed contours of hair root and/or shaft

- the second lowest observation was 0
- the second highest observation was 7.

Table 26 Incidence of hair root shape b

a. with firm and with absent hair root sheaths

b. with firm root sheaths, $>20^{\circ}$ angulation and deformity of root and/or shaft

c. with absent root sheaths, $>20^{\circ}$ angulation and deformity of root and/or shaft

No.	a		b		c	
	hair root sheath		firm hair root sheath		absent hair root sheath	
	firm	absent	$>20^{\circ}$	deformity	$>20^{\circ}$	deformity
1	2	19	1	0	16	19
2	15	6	2	0	7	6
3	9	3	1	0	5	6
4	12	10	0	0	5	10
5	9	5	1	0	6	5
6	2	26	0	0	14	24
7	1	26	0	0	22	25
8	3	10	0	0	7	9
9	6	12	0	0	11	10
10	3	5	0	0	3	4
11	31	2	0	0	2	1
12	11	3	2	1	6	6
13	3	12	1	0	11	11
14	5	12	0	0	10	9
15	14	8	1	3	5	9
16	4	14	0	0	8	9
17	22	6	0	0	3	5
18	2	4	0	0	0	3
19	7	12	4	8	10	13
20	3	9	0	0	8	8

Table 26 shows that, for hair root shape b (late anagen), with firm hair root sheaths

- the second lowest observation was 2
- the second highest observation was 22,

for $\geqslant 20^{\circ}$ angulation

- the second lowest observation was 0
- the second highest observation was 2,

for deformed contours of hair root and/or shaft

- the second lowest observation was 0
- the second highest observation was 3,

with absent hair root sheaths

- the second lowest observation was 3
- the second highest observation was 26,

for $> 20^{\circ}$ angulation

- the second lowest observation was 2
- the second highest observation was 16,

for deformed contours of hair root and/or shaft

- the second lowest observation was 3
- the second highest observation was 24.

The catagen of the hair growth cycle is determined by hair root shapes b and d with loose root sheath and hair root shape d with firm root sheath.

Table 27 Incidence of hair root shape b with loose root sheath, hair root shape d with loose root sheath, hair root shape d with firm root sheath.

No.	b loose	d loose	d firm	Total
1	0	0	0	0
2	0	0	1	1
3	2	0	0	2
4	1	0	0	1
5	1	0	0	1
6	0	0	0	0
7	0	0	0	0
8	1	0	1	2
9	3	0	0	3
10	0	0	0	0
11	2	0	0	2
12	1	0	1	2
13	3	0	0	3
14	0	0	0	0
15	0	0	1	1
16	1	0	0	1
17	0	0	0	0
18	2	0	0	2
19	2	1	0	3
20	2	0	0	2

Table 27 shows that, for hair root shape b with loose root sheath,
hair root shape d with loose root sheath,
hair root shape d with firm root sheath,

- the second lowest observation was 0
- the second highest observation was 3.

The telogen of the hair growth cycle is determined by hair root shape c. Table 13 in chapter 7 lists 20 observations for the group of healthy subjects with hair root shape c, showing a loose root sheath in 96.5% and an absent root sheath in 3.5%. In this group

- the second lowest observation was 1
- the second highest observation was 9.

Dysplastic and dystrophic hair roots are found only in small numbers in healthy subjects. For determination of the limits of normal values, the numbers of these two hair root shapes were therefore lumped. In these hair root shapes (d and e), the root sheath is absent.

Table 28 Incidence of hair root shapes d and e with absent hair root sheaths
a. with $>20^{\circ}$ angulation
b. with deformed contours of hair root and/or shaft

No.	d and e	a $>20^{\circ}$ angulation	b deformity
1	2	2	2
2	3	2	3
3	0	1	1
4	3	3	3
5	1	3	3
6	0	2	2
7	1	0	0
8	9	1	3
9	0	0	0
10	0	0	0
11	0	4	0
12	7	0	6
13	3	3	2
14	4	3	3
15	1	1	1
16	5	2	0
17	0	0	0
18	0	0	0
19	9	3	9
20	1	1	1

Table 28 shows that, in this group,

- the second lowest observation was 0
- the second highest observation was 9.

In these hair root shapes d and e, $> 20^{\circ}$ angulation and deformed contours of hair root and/or shaft do not occur in association with firm hair root sheaths, but do occur when hair root sheaths are absent.

Table 28 therefore shows that for $> 20^{\circ}$ angulation,

- the second lowest observation was 0
- the second highest observation was 3,

for deformed contours of hair root and/or shaft

- the second lowest observation was 0
- the second highest observation was 6.

In each subject, 50 hair roots were obtained and examined. The values found therefore serve as cautionary limits, and consequently further medical examination is required whenever a value outside these limits is found.

Table 29 Limits of normal values of 50 hair roots in the hair root status of healthy subjects

Growth phase	Hair root shape	Root sheath		$>20^{\circ}$ angulation	Deformed	Total
anagen	a	firm	11-35	0-3	0-4	33-48
	a	absent	0-7	0-6	0-7	
	b	firm	2-22	0-2	0-3	
	b	absent	3-26	2-16	3-24	
catagen	b	loose	0-1	0	0	0-3
	d	loose	0	0	0	
	d	firm	0-1	0	0	
telogen	c	loose	1-9	0	0	1-9
	c	absent	0-1	0	0	
dysplastic and dystrophic	d/e	absent	0-9	0-3	0-6	0-9

In summary, table 29 shows the limits of the normal values in the phases of the growth cycle and in aberrant hair roots as determined in the group of 20 healthy subjects aged 20-45 at the fixed site of epilation: the left temporal region of the hairy scalp.

Since 50 hair roots were examined in each individual case, the limits of normal values have been expressed, not in percentages but in absolute figures.

9.4 Discussion

Table30 Data from the literature on the normal trichogram

Authors	Year	Number of test subjects	% anagen	% catagen	% telogen	% dysplastic	% dystrophic
Van Scott et al.	1957	11 m/5 f	63-96	nm	4-37	nm	nm
Kligman	1961	28 m	80-96	nm	4-20	nm	nm
Witzel/Braun-Falco	1963	70 m/70 f	88	nm	11	nm	1-2
Bartosova	1967	53	70-75	nm	25-30	nm	nm
Braun-Falco/Christophers	1968	80 m	81	nm	19	nm	nm
Rapprich	1969	nm	80-85	1-3	10-15	nm	1-2
Peereboom-Wynia	1981	10 m/10 f	66-96	0-6	0-18	0-18	

nm = not mentioned

Table 30 summarizes the data found in the literature on the limits of the normal values in the hair root status of the left temporal region of the hairy scalp. The data obtained in this study are unmistakably in agreement with the literature on the following points:

1) the percentage of hair roots (in anagen) found in this study approximates most closely that found by Van Scott et al. (1957) in 16 healthy adults aged 18-38;

2) the literature makes little mention of the presence of catagen and dysplastic and/or dystrophic hair roots in healthy subjects. Only Witzel and Braun-Falco (1963) and Rapprich (1969) reported 1-2% dystrophic hair roots (the latter author reporting 1-3% catagen hair roots) in the normal hair root status.

The clinical implications of this method of determining the hair root status will be demonstrated and discussed in the following chapters. The method used in this study provides more differentiated data on the growth phases of the hair roots and on aberrant hair roots.

9.5 Summary

In accordance with the recommendations of Rümke and Bezemer (1972), the limits of the normal hair root values in the hair root status were calculated distribution-free; they were used as cautionary limits with confidence level γ=90%.

The values found do not contradict data obtained in earlier studies. The increased differentiation achieved in this study enhances the value of the hair root status.

CHAPTER 10

THE HAIR ROOT STATUS OF PATIENTS IN THE FIRST TWO STAGES OF INFECTIOUS SYPHILIS

10.1 Introduction

The hair root can respond to noxious influences of various kinds: toxic, infectious, iatrogenic, traumatic, etc.

Using the new scheme (chapter 9, table 29) an attempt will be made to establish which changes in the hair root develop in response to infectious syphilis. Infectious syphilis seems a suitable model to study the influence of an infectious agent on the hair root.

The first stage of early infectious syphilis has a incubation period of 17-28 days (range 9-90 days). This stage is clinically characterized by a (genital or extragenital) primary effect. The literature reports no instances of hair loss in this stage, with the exception of cases in which the primary effect is localized on the hairy scalp (Druelle 1923).

Within a few hours of infection, syphilis is no longer a local condition, and Treponema pallidum (noxious agent) can reach and affect the hair root.

The second stage of infectious syphilis begins some 6 weeks after the development of the primary effect (range 1-6 months). In this stage two types of hair loss may be seen:

1) Acute 'moth-eaten' alopecia clinically characterized by a number of lentil- to penny-sized hairless areas. Not only the hairy scalp but all other normally hairy regions of the body can be affected (e.g. eyebrows, eyelashes, beard, axillary and pubic region). The hair substrate shows normal features, and hair growth resumes spontaneously after a few weeks.
2) Diffuse syphilitic alopecia entails hair loss evenly distributed over the entire hairy scalp, and resembles the diffuse hair loss observed in infectious diseases associated with high fever, e.g. typhus or severe influenza (Finger 1930).

10.2 Material and methods

Material as described and analysed in chapter 7 was used to study the hair roots of 10 patients with primary syphilis (PS) and 7 with secondary syphilis (SS), none of whom was suffering from any other disease at the time. Syphilis patients with clinical evidence of moth-eaten alopecia were excluded. All SS patients in this study complained of varying degrees of diffuse alopecia when specifically questioned about it.

The method used to obtain hair roots for microscopic examination was that described in chapter 3, the fixed sample site being the left temporal region.

10.3 Results

The data on the PS patients are presented in tables 31 and 32, and in a histogram giving an overall view of findings in fig. 29

Table 31 Hair root status of 10 patients with primary syphilis

Patient	sero-	anagen	catagen	telogen	dyspl/dystr
1	neg	43	5	0	2
2	neg	42	5	1	2
3	pos	19	24	0	7
4	pos	40	6	0	4
5	pos	45	3	0	2
6	pos	39	9	0	2
7	pos	44	5	0	1
8	pos	46	3	1	0
9	pos	45	4	1	0
10	pos	19	10	3	18

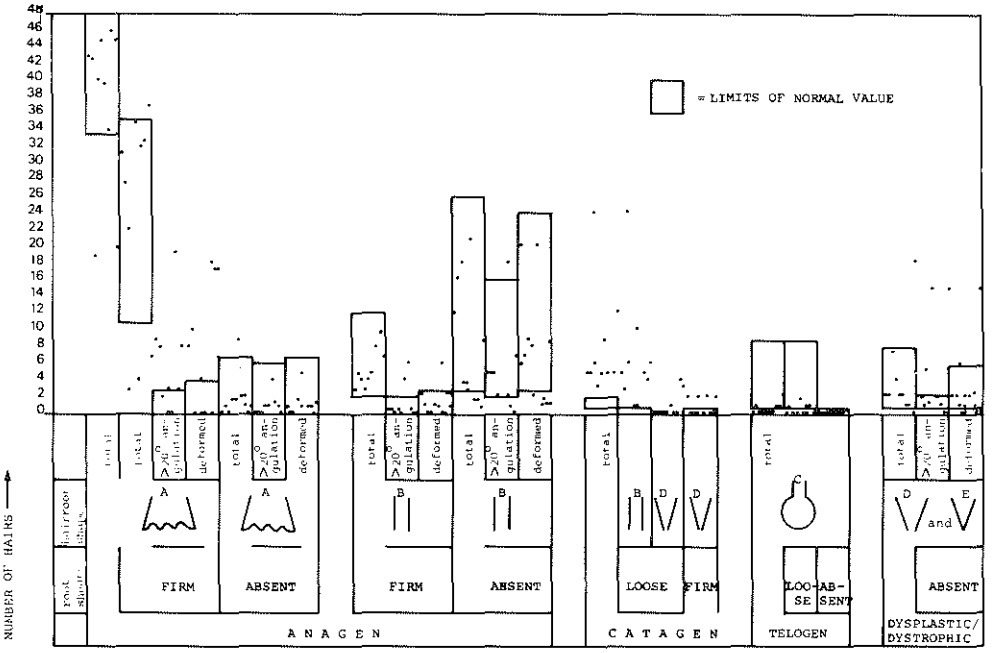


FIG. 29 HISTOGRAM OF THE HAIRROOTS OF 10 PATIENTS WITH PRIMARY INFECTIOUS SYPHILIS

Table 32 Hair root status in anagen and catagen of 10 patients with primary syphilis

		ANAGEN												CATAGEN								
		hair root shape a						hair root shape b						root shape b			root shape d			root shape d		
Patient	Sero-	hair firm	root sheath >20°	root sheath def.	hair abs.	root sheath >20°	root sheath def.	hair firm	root sheath >20°	root sheath def.	hair abs.	root sheath >20°	root sheath def.	hair loose	root sheath >20°	root sheath def.	hair loose	root sheath >20°	root sheath def.	hair firm	root sheath >20°	root sheath def.
1.	neg	31	9	8	1	0	1	3	1	2	8	5	6	3	0	0	0	0	0	2	0	0
2.	neg	27	8	10	0	0	0	5	1	1	10	5	7	5	0	0	0	0	0	0	0	0
3.	pos	3	2	0	0	0	0	4	0	0	12	5	9	24	0	0	0	0	0	0	0	0
4.	pos	22	0	0	2	1	2	2	1	0	14	5	8	6	0	1	0	0	0	0	0	0
5.	pos	35	3	4	2	1	1	4	0	1	4	2	2	1	0	0	0	0	0	2	0	0
6.	pos	4	1	1	9	4	5	5	4	1	21	18	20	8	0	0	0	0	0	1	0	1
7.	pos	32	19	18	2	1	1	8	6	6	2	0	1	1	0	0	1	0	0	3	2	2
8.	pos	33	4	1	1	1	1	10	1	0	2	1	2	3	0	0	0	0	0	0	0	0
9.	pos	32	8	17	0	0	0	7	0	3	1	1	1	4	1	1	0	0	0	0	0	0
10.	pos	7	2	7	1	1	1	2	0	1	9	7	9	5	0	0	3	0	0	2	2	0

def. = deformity
abs. = absent

The data on the SS patients are presented in tables 33 and 34 and in a histogram in fig.30.

Table 33 Hair root status of 7 patients with secondary syphilis.

Patient	anagen	catagen	telogen	dyspl/dystr
1	11	8	20	11
2	23	8	13	6
3	32	4	13	1
4	28	6	8	8
5	7	6	30	7
6	30	4	5	11
7	31	8	2	9

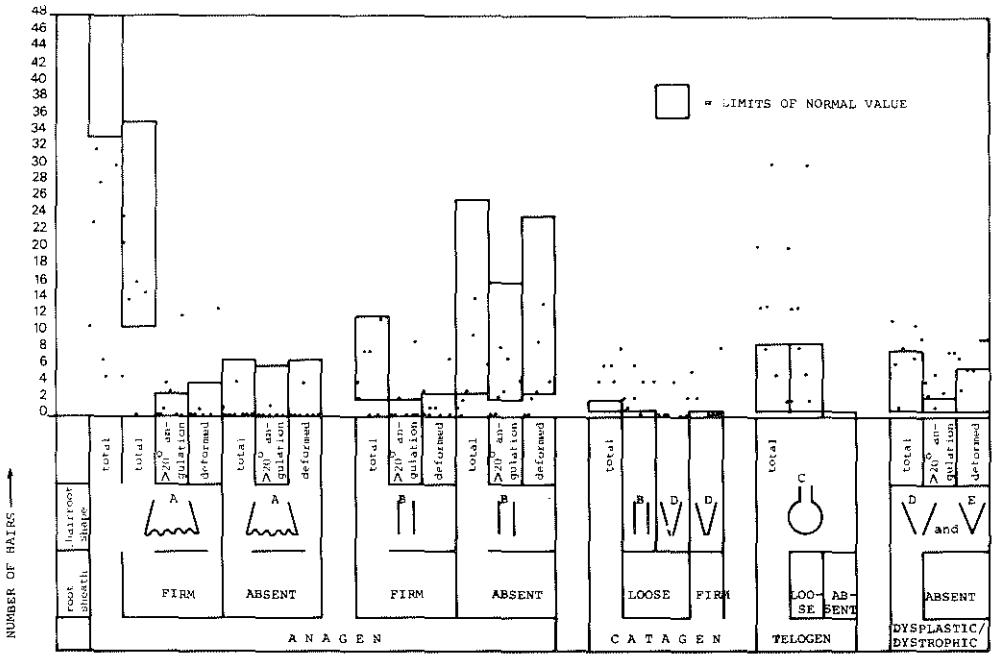


FIG. 30 HISTOGRAM OF THE HAIRROOTS OF 7 PATIENTS WITH SECUNDARY INFECTIOUS SYPHILIS

Table34 Hair root status in anagen and catagen of 7 patients with secondary syphilis

	ANAGEN												CATAGEN								
	root shape a						root shape b						root shape b			root shape d			root shape d		
Patient	hair firm	root >20°	sheath def.	hair abs.	root >20°	sheath def.	hair firm	root >20°	sheath def.	hair abs.	root >20°	sheath def.	hair loose	root >20°	sheath def.	hair loose	root >20°	sheath def.	hair firm	root >20°	sheath def.
1.	5	0	0	1	0	0	4	0	0	1	1	1	2	0	0	4	0	0	2	0	0
2.	21	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	7	6	2
3.	24	1	1	0	0	0	6	0	1	2	2	2	2	0	0	0	0	0	2	1	0
4.	14	4	4	0	0	0	4	1	1	10	8	9	6	1	1	0	0	0	0	0	0
5.	0	0	0	4	1	4	0	0	0	3	3	3	0	0	0	6	0	0	0	0	0
6.	16	0	1	0	0	0	0	0	0	14	7	13	4	0	0	0	0	0	0	0	0
7.	15	12	13	0	0	0	12	9	7	4	4	4	0	0	0	0	0	0	8	6	8

def. = deformity
abs. = absent

Classifying the material as hair roots in anagen, catagen and telogen and as dysplastic/dystrophic hair roots, we found that the number of hair roots in anagen was below the normal lower limit in 2 of the 10 PS patients and in all SS patients.

The number of hair roots in catagen exceeded the upper normal limit in all PS and SS patients.

The number of hair roots in telogen was within normal limits in 4 and below the normal lower limit in 6 PS patients, the corresponding numbers of SS patients being 3 and exceeding the upper normal limit: 4.

The number of dysplastic/dystrophic hair roots was within normal limits in 9 PS patients and exceeded the normal limit in 1, the corresponding numbers of SS patients being 5 and 2.

A more differentiated pattern was outlined with the aid of the trichogram shown in table 29 (chapter 9).

The anagen hair roots in PS patients, though not different in number from those in normal subjects, nevertheless showed some distinct morphological changes. In SS patients morphological changes were found as well.

The number of hair roots of shape a with firm root sheaths was below the normal lower limit in 3 and within normal limits in 7 PS patients, the corresponding numbers of SS patients being 2 and 5.

Hair roots of shape a showed $> 20^{\circ}$ angulation and deformity of root and/or shaft in 5 of the 10 PS patients and in 2 of the 7 SS patients. The number of hair roots of shape a with absent root sheaths exceeded the normal upper limit in only 1 PS patient, and in none of the SS patients. In both PS and SS patients the number of hair roots with $> 20^{\circ}$ angulation and deformity was within normal limits.

The number of hair roots of shape b with firm root sheaths was within normal limits in both PS and SS patients; $> 20^{\circ}$ angulation exceeded the normal upper limit in 2 PS patients, and deformity did so in 1. In SS patients these values were within normal limits.

The number of hair roots of shape b with absent root sheaths was below the normal lower limit in 3 of the 10 PS patients and 3 of the 7 SS patients; $> 20^{\circ}$ angulation and deformity was below the normal lower limit in 3 PS and in 2 SS patients.

The number of hair roots of shape b with loose root sheaths (catagen) exceeded the normal upper limit in 9 of the 10 PS patients; $> 20^{\circ}$ angulation and deformity exceeded the normal upper limit in 1 and in 2 cases, respectively. The corresponding numbers of SS patients were 4 and 1.

Hair roots of shape d with loose root sheaths (catagen) exceeded the normal upper limit in 2 of the 10 PS patients and 2 of the 7 SS patients; $> 20^{\circ}$ angulation and deformity fell within normal limits.

Hair roots of shape d with firm roots sheaths (catagen) exceeded the normal upper limit in 3 of the 10 PS patients and 4 of the 7 SS patients; $>20^{\circ}$ angulation exceeded the normal upper limit in 3 of the 10 PS patients and 3 of the 7 SS patients; deformity exceeded the normal upper limit in 2 of the 10 PS patients and 2 of the 7 SS patients.

The number of hair roots of shape c in telogen has already been mentioned (page 96). Deformities and $>20^{\circ}$ angulations were not seen in this phase (chapter 7).

The number of dysplastic/dystrophic hair roots has already been specified (page 96); $>20^{\circ}$ angulation and deformity exceeded the normal upper limit in 3 and in 2 PS patients, respectively, the corresponding numbers of SS patients being 6 and 4.

10.4 Discussion

In anagen with a high level of mitotic activity of the hair matrix, the hair root is highly suspectible of the influence of noxae. The intensity and nature of the noxa as well as the duration of exposure to it are factors determining the changes observed. The literature describes the following hair root reactions in infectious processes.

Braun-Falco (1966) mentioned typhus, influenza, erysipelas, secondary syphilis, etc. Zaun (1975) distinguished between acute febrile diseases (influenza, typhus, secondary syphilis, erysipelas, etc.) and chronic infectious diseases such as tuberculosis, in which diffuse alopecia is rarely observed. He described the following hair root abnormalities:

In response to the noxa, the hair follicle changes directly from catagen to telogen at a too early time. The number of hair roots in telogen increases. Two to three months later, at the end of the physiological telogen, these hairs are shed, giving rise to a telogen "effluvium" (Braun-Falco 1966). This process was thought to develop when the damage to the hair root was limited (subsequently confirmed in animal experiment by Zaun (1964)).

When several noxious influences are active, the hair root is subject to dystrophic changes in anagen. This is manifested by a catagen-like shortening of the lower ("infraseboglandular") segment of the hair follicle; and the dysplastic/dystrophic hair root is morphologically indistinguishable from the catagen hair root (Braun-Falco 1966).

Heilgemeir (1979) divided his patients into those with internal inflammatory diseases, with focal infection and with infectious diseases, without differentiating between chronic and acute forms. He found a telogen, a dystrophic and a telogen/dystrophic effluvium. In one case of secondary syphilis he observed telogen/dystrophic hair loss in the frontal, but only a telogen effluvium in the parietal and the occipital region. Although he distinguished catagen hair roots in three phases, this hair root played no distinct role in his assessment. This type was observed only once.

Our study revealed a not previously described morphological change and $>20^{\circ}$ angulation in anagen in PS patients.

We also found an increased number of catagen hair roots, and observed that the hair root status of PS patients showed a harmonious transition to that of SS patients. The small number of telogen hair roots in PS patients, however, is inexplicable.

Six SS patients showed an increased number of telogen and/or dysplastic/dystrophic hair roots - a phenomenon described in the literature as telogen/dystrophic effluvium (Heilgemeir 1979; Orfanos 1979). Using the technique described in chapter 3, we expanded this observation and found a markedly increased number of catagen hair roots both in PS and in SS patients. This phenomenon in early infectious syphilis is not readily interpretable. In the literature, the role of catagen hair roots in infectious diseases remains uncertain.

The observations discussed here are two "snapshots" of the behaviour of the hair roots as a result of early infectious syphilis. It is possible that an increase in catagen hair roots can be found in numerous other infectious diseases. The extent to which the time of examination and the nature of the causative agent play a role in this respect, is still to be investigated.

10.5 Summary

Using our new scheme, we studied the hair root status in two groups of patients suffering from primary and secondary syphilis, respectively.

In patients with primary infectious syphilis we found a normal number of anagen hair roots with an increased incidence of $>20^{o}$ angulation and deformity of the contours of hair root and/or hair shaft in hair roots of shape a, an increased number of catagen and a decreased number of telogen hair roots. The number of dysplastic/dystrophic hair roots was increased in only one case.

In patients with secondary infectious syphilis we found a decreased number of anagen hair roots but an increased number of catagen and telogen hair roots; the number of dysplastic/dystrophic hair roots was likewise increased.

CHAPTER 11

THE SIGNIFICANCE OF THE HAIR ROOT STATUS FOR THE PROGNOSIS OF ALOPECIA AREATA

11.1 Introduction

The aetiology of alopecia areata is obscure, and its pathogenesis is the subject of many theories (Eckert et al. 1968).

The clinical onset of alopecia areata as a rule primarily involves circumscribed hair loss from the hairy scalp, with extension to the periphery of the scalp during the first few weeks.

The course of the disease is very variable and ill-defined. The duration of the first attack is less than 6 months in one-third of cases, and hair growth is restored to normal within a year in some 50% of these. No restoration of hair growth is seen in 20-30% of cases, and the ultimate result is total alopecia in 5-10% (Ebling and Rook, 1979).

Factors determining the prognosis of alopecia areata are: the extent of hair loss from the scalp and/or other hairy body regions, the clinical features (the so-called ophiasis form has a poor prognosis), the duration of the condition, and the patient's age. Other factors can also play a role; specifically, alopecia areata in patients suffering from atopy and from auto-immune diseases is thought to have a poor prognosis. Clinical experience has shown, however, that the course of alopecia areata is exceedingly erratic and shows marked individual differences (Runne 1979).

The possibility of making the prognosis of alopecia areata was studied on the basis of data obtained in hair root analyses of:

a) the margin of the expanding focus (M-region),
b) the left temporal region with "apparently" healthy hair growth (T-region).

11.2 Material and methods

In 65 alopecia areata patients, presenting for treatment over a 12-month period, the hair root status was determined at the first visit at the M-region and in the T-region. Patients who already showed the clinical features of progressive alopecia areata at admission were eliminated from further study.

The remaining patients, who were under observation for a year, were used to form two random groups of 10 alopecia areata patients each. The first group comprised 10 patients, whose hair loss proved to be progressive (progressive alopecia areata), while the second consisted of 10 patients whose hair growth was restored to normal within a year (benign alopecia areata).

11.3 Results

An overall view of the results obtained is presented in four histograms (figs.31 through 34), while various individual data are shown in tables 33 through 37. (For these figures and tables see page 102 through 106). These results can be summarized as follows.

11.3.1 Progressive alopecia areata

There was no difference in hair root status between the margin of the expanding focus and the left temporal region with seemingly normal hair growth.

The decreased number of hair roots in anagen was caused by a marked decrease in the number of all hair roots in anagen (hair root shape a and b with firm root sheath). Anagen hair roots with absent root sheath numbered within normal limits in all cases.

There was no increased incidence of $\geq 20^{\circ}$ angulation and deformed contours of root and/or shaft.

A slightly increased number of hair roots in catagen was found in fewer than 50% of the cases. An increased number of hair roots in telogen was likewise found in fewer than 50% of the cases.

The number of dysplastic/dystrophic hair roots was increased in all cases, and in most of these cases $\geq 20^{\circ}$ angulation and deformed contours of root and/or shaft were observed.

11.3.2 Benign alopecia areata

The hair root status at the margin of the focus roughly showed the same changes as that in progressive alopecia areata.

A decreased number of hair roots in anagen was observed in eight of the ten cases; a decreased number of hair roots in anagen (hair root shape a with firm root sheath) was found in only four of the ten cases. The slight increase in the number of catagen hair roots did not differ from that found in progressive alopecia areata, and the same applied to the increased number of hair roots in telogen (table 37). It may also be mentioned that the number of dysplastic/dystrophic hair roots exceeded the normal limit in five of the cases.

However, essential differences were found between the hair root status of patients with benign AA (T-region) (fig.33) and that of patients with benign AA (M-region) and progressive AA (T- and M-region) (fig.31, 32 and 34); the patients with benign AA (T-region) had a hair root status which was virtually normal!

11.4 Discussion

The large number of telogen hair roots and dystrophic hair roots in patients with benign and progressive AA (M-region) and progressive AA (T-region) in this study, is in agreement with data found in the literature

(Runne 1979).

Braun-Falco and Zaun (1962) studied the hair root status of the contralateral scalp area with normal hair growth and found a decreased number of hair roots in anagen, an increased number of dysplastic/dystrophic hair roots, and in some cases an increased number of hair roots in telogen. These findings are in good agreement with our data on patients with progressive alopecia areata.

Braun-Falco and Zaun's hypotheses that the hair roots of the entire scalp are affected, could apply to progressive alopecia areata.

Our study shows that it does not apply to all types of alopecia areata, for in the group of patients whose hair growth was restored to normal within a year (benign alopecia areata) we found abnormalities only at the margin of the focus.

Eckert et al. (1968) performed systematic annular hair root status studies and found a margin of telogen hair roots surrounding the focus, with wave-like extension to the periphery. They also found a large number of dystrophic hair roots around the lesions of alopecia areata, which were not found in control areas of the same scalp. They concluded from their findings that it is difficult to predict whether an area with apparently normal hair growth is soon to be affected.

Our study, in which the patients were divided into two groups after a year of clinical observation, supplies more information on the prognosis at presentation for treatment.

The prognosis for restoration of hair growth seems to be poor when the changes of alopecia areata are distinctly seen in the left temporal region with seemingly normal hair growth. The prognosis seems to be good when the hair root status of the left temporal region is normal.

Further clinical observation and collection of hair root data will be required to demonstrate how accurate the prognosis at first examination can be, and to define the significance of slight changes in the left temporal region, e.g. a decreased number of hair roots in anagen and an increased number of hair roots in telogen, or increased incidence of $> 20^{\circ}$ angulation and deformity of the contours of root and/or shaft in early anagen (as observed in two cases).

11.5 Summary

In patients with alopecia areata presenting for treatment, the hair root status was determined at the margin of the focus and in the left temporal region with apparently normal hair growth. Patients who already showed the clinical features of progressive alopecia areata at admission were eliminated from further study.

After clinical observation over a one-year period, two groups of 10 patients each were formed at random: one group of 10 patients whose hair loss proved to be progressive (progressive alopecia areata) and one of 10 patients whose hair growth was restored to normal within a year (benign alopecia areata).

The hair root status at the margin of the focus showed a decreased number of anagen hair roots, a varying increase in the number of catagen and telogen hair roots, and a marked increase in the number of dysplastic/dystrophic hair roots with $> 20^{o}$ angulation and deformed contours of root and/or shaft.

In patients with progressive alopecia areata, the hair root status of the left temporal region with apparently normal hair growth was found to be identical to that of the margin of the focus.

In patients with benign alopecia areata whose hair growth was restored to normal within a year, the hair root status of the left temporal region was within normal limits.

This chapter discusses the possibility of using hair root status studies to determine the prognosis of alopecia areata at presentation for treatment.

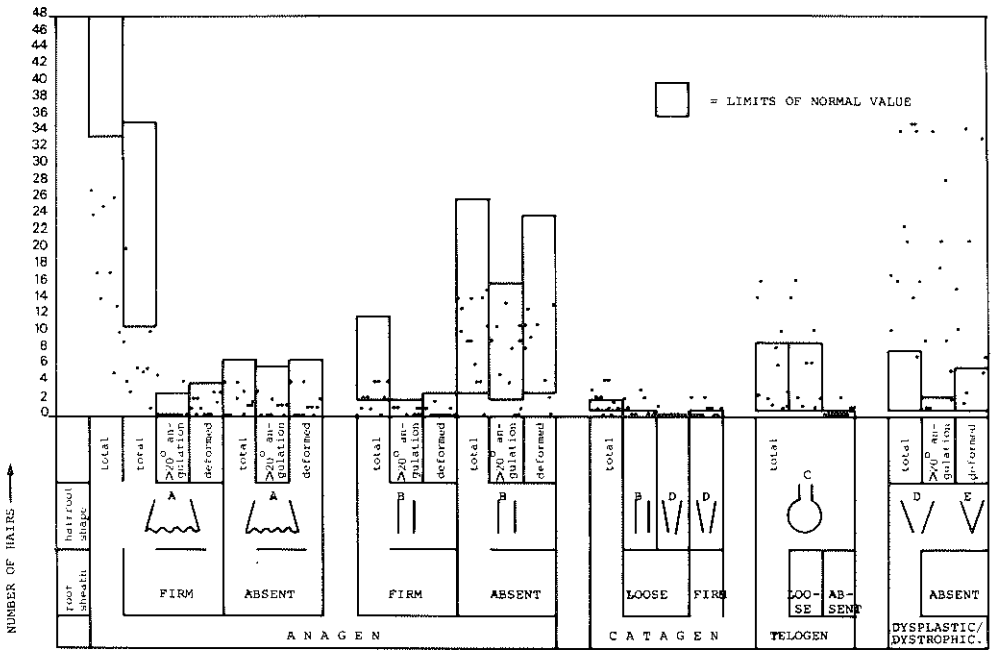


FIG. 31 HISTOGRAM OF THE HAIRROOTS OF 10 PATIENTS WITH PROGRESSIVE AA (T-region)

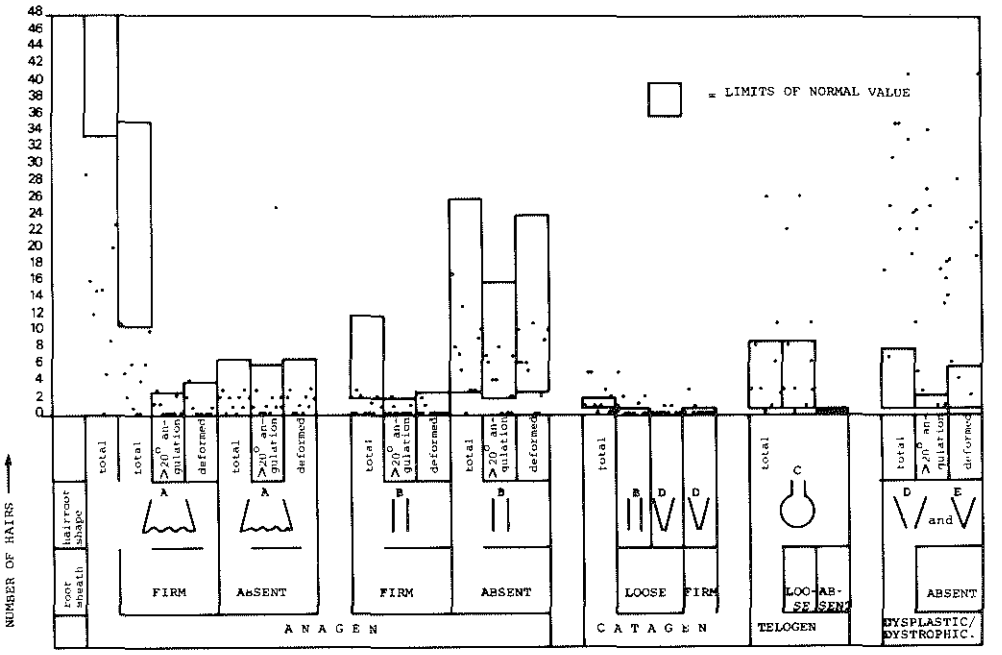


FIG. 32 HISTOGRAM OF THE HAIRROOTS OF 10 PATIENTS WITH PROGRESSIVE AA (M-region)

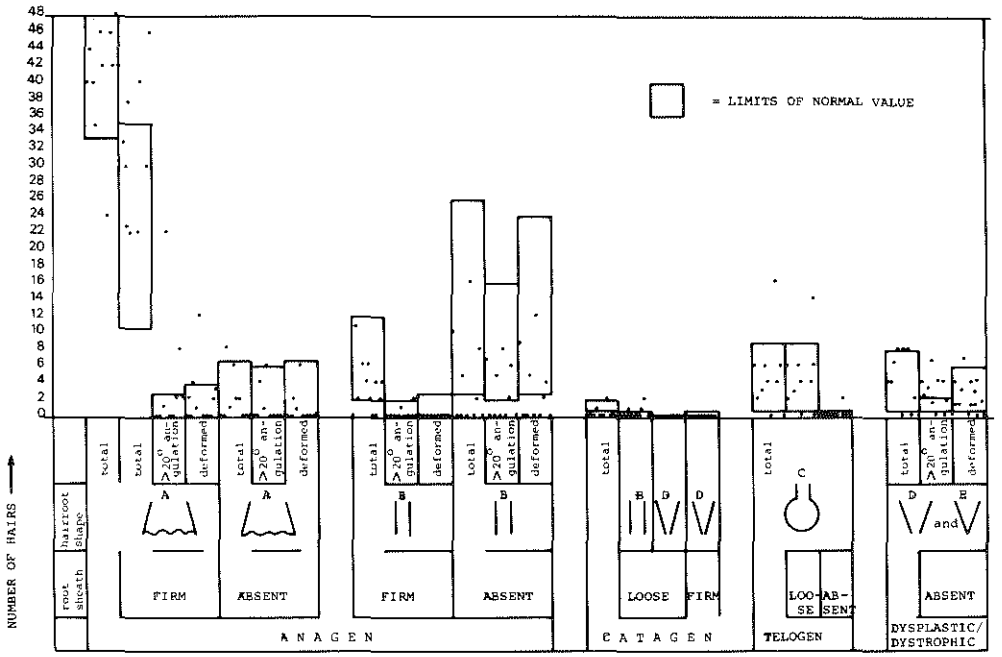


FIG. 33 HISTOGRAM OF THE HAIRROOTS OF 10 PATIENTS WITH BENIGN AA (T-region)

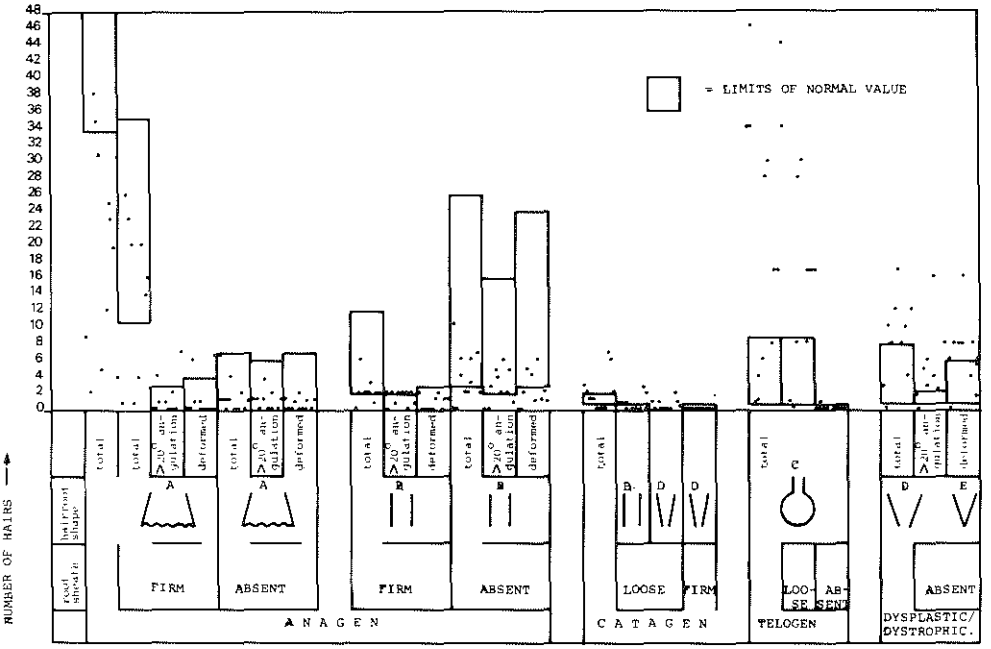


FIG. 34 HISTOGRAM OF THE HAIRROOTS OF 10 PATIENTS WITH BENIGN AA (M-region)

Table 33 Hair root status of ten patients with progressive AA (T- and M-regions)

	AA (T-region)				AA (M-region)			
Patient	anagen	catagen	telogen	dyspl/dystr	anagen	catagen	telogen	dyspl/dystr
1	27	3	3	17	29	1	3	17
2	24	2	14	10	16	5	22	7
3	17	2	15	16	12	5	8	25
4	14	0	2	34	15	1	3	31
5	25	1	1	23	15	0	0	35
6	17	4	8	21	0	1	27	22
7	26	4	6	14	5	3	1	41
8	5	0	10	35	9	2	6	33
9	13	2	1	34	20	0	11	19
10	10	4	25	11	23	0	3	24

Table 34 Progressive AA (T-region) in anagen and catagen. Incidence of hair root sheaths, $>20^{\circ}$ angulation and deformities.

	ANAGEN												CATAGEN								
	root shape a						root shape b						root shape b			root shape d			root shape d		
Patient	root sheath firm			>20°		def	root sheath abs			>20°		def	root sheath firm			>20°		def	root sheath loose			>20°		def	root sheath loose			>20°		def	root sheath firm			>20°		def
1	10			0		1	3			0		0	0			0		0	14			11		11	1			0		0	0			0		0	2			2		2
2	9			5		2	4			3		4	1			1		1	10			9		8	2			0		0	0			0		0	0			0		0
3	4			0		0	0			0		0	2			1		0	11			11		11	1			0		0	1			0		0	0			0		0
4	3			0		1	0			0		0	2			2		2	9			5		9	0			0		0	0			0		0	0			0		0
5	6			0		0	4			2		4	1			0		0	14			13		11	0			0		0	0			0		0	1			0		0
6	5			0		0	2			1		1	4			0		0	6			4		4	3			0		0	0			0		0	1			0		0
7	5			0		0	3			1		1	4			0		0	14			8		11	3			0		0	0			0		0	1			0		0
8	1			0		0	0			0		0	0			0		0	4			0		3	0			0		0	0			0		0	0			0		0
9	10			4		3	1			1		1	2			1		1	0			0		0	2			0		0	0			0		0	0			0		0
10	6			0		1	0			0		0	3			0		0	1			1		1	0			0		0	1			0		0	3			0		0

def = deformed
abs = absent

Table 35 Progressive AA (M-region) in anagen and catagen. Incidence of hair root sheaths, $>20^{\circ}$ angulation and deformities.

	ANAGEN												CATAGEN								
	root shape a						root shape b						root shape b			root shape d			root shape d		
Patient	root sheath firm			>20°		def	root sheath abs			>20°		def	root sheath firm			>20°		def	root sheath loose			>20°		def	root sheath loose			>20°		def	root sheath firm			>20°		def
1	10			1		2	2			1		2	0			0		0	17			7		10	1			0		0	0			0		0	0			0		0
2	5			3		4	3			3		3	0			0		0	8			6		6	5			0		0	0			0		0	0			0		0
3	2			1		1	0			0		0	3			2		2	7			4		6	2			0		0	0			0		0	3			0		0
4	6			0		0	2			0		0	2			1		1	5			4		5	0			0		0	0			0		0	1			1		1
5	1			0		0	1			0		1	0			0		0	13			10		11	0			0		0	0			0		0	0			0		0
6	0			0		0	0			0		0	0			0		0	0			0		0	0			0		0	1			1		1	0			0		0
7	0			0		0	2			2		2	0			0		0	3			0		0	1			0		0	2			0		0	0			0		0
8	4			2		0	1			1		1	1			0		0	3			2		2	2			0		0	0			0		0	0			0		0
9	6			0		1	3			1		3	2			1		0	9			7		9	0			0		0	0			0		0	0			0		0
10	10			0		0	2			2		2	1			1		0	10			6		10	0			0		0	0			0		0	0			0		0

def = deformed
abs = absent

Table 36 Hair root status of 10 patients with benign AA (T- and M-regions)

	AA (T-region)				AA (M-region)			
Patient	anagen	catagen	telogen	dyspl/dystr	anagen	catagen	telogen	dyspl/dystr
1	40	0	6	4	9	3	35	3
2	44	0	2	4	2	2	46	0
3	40	0	3	7	38	1	1	10
4	35	1	6	8	35	1	6	8
5	46	0	4	0	30	0	8	12
6	42	0	0	8	5	0	28	17
7	24	2	16	8	12	0	30	8
8	46	0	4	0	25	7	8	10
9	42	0	6	2	23	6	17	4
10	50	0	0	0	19	2	17	12

Table 37 Benign AA (T- and M-regions) in anagen.

	AA (T-region)												AA (M-region)											
	hair root shape a						hair root shape b						hair root shape a						hair root shape b					
Patient	root sheath firm			>20°		def	root sheath abs			>20°		def	root sheath firm			>20°		def	root sheath abs			>20°		def
1	30		0	0		0	0		0	0		0	10		7	9	4		0	0	1		1	0	4		2	2	0		0	0
2	33		0	0		0	0		0	11		0	0		0	0	1		0	0	1		0	0	0		0	0	0		0	0
3	30		0	4		8	4		2	2		0	0		0	0	26		4	5	0		0	0	2		2	0	10		3	2
4	23		1	1		1	1		1	6		1	0		5	5	23		1	1	1		1	1	6		1	0	5		5	5
5	38		22	12		6	6		6	4		0	0		0	0	20		1	1	4		4	2	2		2	0	4		4	4
6	22		0	0		2	0		0	2		0	0		16	8	12	1		0	0	0		0	0	2		2	1	2		2	1
7	22		0	0		2	0		0	0		0	0		0	0	0	4		2	0	0		0	0	3		2	2	6		6	6
8	40		2	0		0	0		0	4		2	0		2	2	2	20		0	0	2		2	1	1		0	0	3		2	1
9	30		8	2		0	0		0	2		0	0		10	6	4	14		0	0	0		0	0	2		2	1	7		5	2
10	46		2	3		0	0		0	4		0	0		0	0	0	16		7	6	1		1	1	2		1	1	2		1	1

def = deformed

abs = absent

SUMMARY

This thesis discusses the morphological characteristics of hair roots of human scalp hairs and its clinical significance.

Chapter 1 presents a survey on some aspects of human hair, i.e. embryology: the development of different hair types and patterns after birth and its influence by sex, age, race, heredity and hormonal factors. It further discusses the various phases of the hairgrowth cycle, i.e. the active growth phase (= anagen), regression phase (= catagen), rest phase (= telogen), its histomorphology and ultrastructure, mechanisms controlling the hair growth cycle such as hair plucking, influences of hormonal factors, sex, age and especially body regions. The preparation of a hair root status involves a simple, atraumatic technique of obtaining material and the study of the physiology and pathology of hair growth, which could be of great help in evaluating differing hair diseases and determining therapeutic indications.

Chapter 2 presents a survey of the literature on various methods used to obtain hair roots and media in which the hair roots are embedded before they are examined under low microscopic magnification.

Chapter 3 describes a comparative study of techniques of epilation. The technique used in this study was that with the epilating forceps and Depex as collecting medium.

Chapter 4 reviews the literature on the morphological changes of the hair root during its growth phases, and aberrant hair roots; the anagen hair root is characterized by a darkish keratogenous zone and, in most cases, a pigmented hair matrix. Internal and external root sheaths may be present or absent. The telogen hair root has no keratogenous zone, and its club-shaped keratinized tip is surrounded by an epithelial sac. The catagen hair root represents the transition from anagen to telogen and is distinguished in three subphases. Dysplastic and dystrophic hair roots are characterized by a diminished hair bulb diameter constrictions, sometimes ruptures in the hair shaft and 'hooked' hair roots.

Chapter 5 presents a general introduction leading to the description of a diagram in which all characteristics of the hair root are divided into five categories, namely:

1) transparency pattern
2) hair root shape
3) presence or absence of the root sheath
4) the contours of the hair root and/or shaft
5) angulation in the bulb and/or keratogenic zone.

Chapter 6 demonstrates that the transparency pattern is unsuitable as diagnostic criterion because it is influenced by the hair colour, the presence or absence of the root sheaths, and the nature of the collecting medium used.

Chapter 7 demonstrates - on the basis of the hair root status in a group of healthy adults and groups of patients with acute gonorrhoea, non-specific urethritis, primary and secondary syphilis, chronic diffuse alopecia and alopecia areata - that pathological processes can influence the hair roots on the hair scalp.

It was found to be of importance for diagnosis to record the hair root shape, presence or absence of root sheaths, deformities in the contours and angulations of the hair root and/or shaft in the hair root status.

Chapter 8 describes morphological characteristics of hair root growth phases and aberrant hair root types.
Anagen hair roots are characterized by shape a (/\) in early anagen and shape b (||) in late anagen. Root sheaths are usually present and firm, and angulations and deformities of root and/or shaft may occur in a small percentage of hairs.
Catagen hair roots are characterized by shape b or d (\/): the root sheath is loose in shapes b or d and firm in shape d. There are no angulations and the contours of root and/or shaft are nearly always smooth.
Telogen hair roots show hair root shape c (ℓ), and root sheaths may be present (loose) or absent (rarely). No angulations are seen, and the contours of root and/or shaft are smooth.
Dysplastic and dystrophic hair roots show shape d or e (V), and hair root sheaths are always absent. A large percentage of these hair roots show $\succ 20^{\circ}$ angulation and deformed contours of root and/or shaft.

Chapter 9 determines the limits of normal values of various hair root characteristics on the basis of the findings obtained in the group of healthy adults, and summarizes these values in a new diagram.

Chapter 10 discusses the hair root status of patients in the first two stages of infectious syphilis. In patients with primary infectious syphilis the number of anagen hair roots is normal, but an increased incidence of $\succ 20^{\circ}$ angulation and deformity of the contours of hair root and/or shaft in early anagen, an increased number of catagen and a decreased number of telogen hair roots.
The number of dysplastic/dystrophic hair roots was increased in only one case. In patients with secondary infectious syphilis we found a decreased number of anagen hair roots, but an increased number of catagen and telogen hair roots; the number of dysplastic/dystrophic hair roots was likewise increased.

Chapter 11 discusses the possibility of using hair root status studies to determine the prognosis of alopecia areata at presentation of treatment. In patients with progressive alopecia areata, the hair root status of the left temporal region with apparently normal hair growth was found to be identical to that of the margin of the focus, namely a decreased number of anagen hair roots, a varying increase in the number of catagen and telogen hair roots and a marked increase in the number of dysplastic/dystrophic hair roots with $\succ 20^{\circ}$ angulation and deformed contours of root and/or shaft, while in patients with benign alopecia areata - whose hair growth was restored to normal within a year - the hair root status of the left temporal region was within normal limits.

SAMENVATTING

In dit proefschrift worden de morfologische karakteristica van de haarwortels van het hoofdhaar bij de mens en de betekenis voor de kliniek besproken.

Hoofdstuk 1 geeft een overzicht over enige aspecten van het menselijk haar,namelijk de embryologie, de ontwikkeling van de verschillende haartypen en patronen na de geboorte en de beïnvloeding ervan door de sexe, leeftijd, ras, erfelijkheid en hormonale faktoren. Verder wordt ingegaan op de verschillende phasen van de haargroeicyclus, namelijk de aktieve groeifase (= anageen), de overgangsfase (= catageen) en de rustfase (= telogeen). De histomorfologie, ultrastructuur, verschillende controlemechanismen van de haargroeicyclus en de beïnvloeding ervan door sommige exogene, hormonale faktoren, sexe, leeftijd en speciaal het lichaamsgebied wordt besproken.
Het verkrijgen van haarwortels voor microscopisch onderzoek behelst een eenvoudige, atraumatische techniek en de bevindingen bij dit onderzoek kunnen een belangrijk hulpmiddel zijn voor de studie van de fysiologie en pathologie van de haargroei en in het bijzonder de evaluatie van verschillende haarziekten en therapeutische invloeden.

Hoofdstuk 2 geeft een literatuuroverzicht van de verschillende methoden, die toegepast worden voor het verkrijgen van haarwortels, en de media waarin de haarwortels ingebed worden alvorens zij onder geringe microscopische vergroting onderzocht worden.

Hoofdstuk 3 beschrijft een vergelijkend onderzoek naar de techniek van het epileren. Gekozen werd voor het gebruik van een epilatiepincet en het medium Depex.

Hoofdstuk 4 geeft een literatuuroverzicht van de morfologische veranderingen van de haarwortel gedurende zijn groeifasen en van de afwijkende vormen:
de anagene haarwortel is gekaraktiseerd door een donker keratogene zone en in de meeste gevallen een gepigmenteerde matrix. Interne en externe wortelscheden kunnen wel of niet aanwezig zijn.
De telogene haarwortel heeft geen keratogene zone. Zijn knop-vormige gekeratiniseerde, proximale uiteinde is omgeven door een epitheliale zak.
De catagene haarwortel representeert de overgang van anageen naar telogeen. Er worden drie subfasen onderscheiden.
Dysplastische en dystrofische haarwortels worden gekarakteriseerd door een vermindering van de diameter van de haarbulbus, constricties, soms breuken in de haarschacht en hoekvormige haarwortels.

In hoofdstuk 5 worden via een algemene inleiding aan de hand van een diagram alle eigenschappen van de haarwortel in vijf hoofdgroepen ingedeeld, te weten:
1. het helderheidspatroon
2. de vorm van de haarwortel
3. het wel of niet aanwezig zijn van de wortelscheden
4. de contouren van de haarwortel en/of haarschacht
5. de hoekvormige buiging in de bulbus en/of keratogene zone.

Hoofdstuk 6 laat zien dat het helderheidspatroon niet geschikt is als diagnostisch kriterium, vanwege de beïnvloeding hierop door de kleur van het haar, het wel of niet aanwezig zijn van de wortelscheden en de aard van het opvangmedium.

In hoofdstuk 7 wordt aangetoond dat - aan de hand van een haarwortelonderzoek bij een groep van gezonde volwassenen en groepen van patienten, lijdende aan gonorrhoea acuta, niet specifieke urethritis, het eerste en tweede stadium van infectieuze syphilis, alopecia diffusa chronica en alopecia areata - ziekelijke processen die de haarwortels op de behaarde hoofdhuid kunnen beïnvloeden. Het blijkt van belang voor de diagnostiek om de vorm van de haarwortel, het wel of niet aanwezig zijn van wortelscheden, veranderingen in de contouren en hoekvormige buigingen in de haarwortel en/of haarschacht te noteren in de haarwortelstatus.

Hoofdstuk 8 beschrijft de morfologische kriteria van de haarwortel in zijn groeifasen en die van de afwijkende vormen.
Anagene haarwortels worden gekenmerkt door een vorm a (/\) in vroeg-anageen en door vorm b (||) in laat-anageen.
Wortelscheden zijn meestal vast aanwezig en hoekvormige buigingen en afwijkingen in de contouren van de haarwortel en/of haarschacht kunnen in een klein percentage voorkomen.
Catagene haarwortels worden gekenmerkt door vorm b of d (\/): de wortelscheden zijn "los" aanwezig in de vormen b en d en vast aanwezig in de vorm d. Er zijn géén hoekvormige buigingen en de contouren van de haarwortel en/of haarschacht zijn bijna altijd glad.
Telogene haarwortels tonen een vorm c (U): wortelscheden kunnen "los" aanwezig zijn of zelden aanwezig. Er worden géén hoekvormige buigingen gezien en de contouren van de wortel en/of schacht zijn glad.
Dysplastische en dystrofische haarwortels tonen vorm d en e (V), terwijl de wortelscheden altijd afwezig zijn. Een groot percentage van deze wortels tonen een hoekvormige buiging $> 20^{\circ}$ en misvormingen van de contouren van de haarwortel en/of haarschacht.

In hoofdstuk 9 worden aan de hand van gevonden verschijningsvormen van de haarwortel in zijn groeifasen en die van de afwijkende haarwortels de grenzen van de normale waarden vastgesteld bij de groep van gezonden. Deze grenzen (gevonden bij de groep van gezonden) zijn in een nieuw schema samengevat.

Hoofdstuk 10 illustreert het gedrag van de haarwortel in de eerste twee stadia van infectieuze syfilis. Bij patienten in het eerste stadium is het aantal anagene haarwortels normaal, maar het aantal hoekvormige buigingen $> 20^{\circ}$ en vervormingen van de haarwortel en/of haarschacht is in de vroeg-anagene fase vermeerderd. Er is een toename van het aantal catagene, en een afname van het aantal telogene haarwortels. Het aantal dysplastische/dystrofische haarwortels is in één geval verhoogd. Bij patienten in het tweede stadium is het aantal anagene haarwortels verlaagd, maar het aantal catagene en telogene haarwortels is verhoogd; eveneens is er een verhoogd aantal dysplastische en dystrofische haarwortels.

Hoofdstuk 11 bespreekt de mogelijkheid om met behulp van de haarwortelstatus de prognose van alopecia areata bij het eerste spreekuurbezoek te bepalen. Bij patienten met een progressieve vorm van alopecia areata, werd de haarwortelstatus van het linker temporale hoofdhuidgebied met ogenschijnlijk normale haargroei identiek gevonden met die van de rand

van de haard, namelijk een verminderd aantal anagene haarwortels, een in wisselende mate verhoogd aantal catagene en telogene haarwortels, en een duidelijk verhoogd aantal dysplastische en dystrofische haarwortels met hoekvormige buigingen $> 20^{0}$ en vervormingen van de contouren van de haarwortel en/of haarschacht. Bij patienten met alopecia areata met goedaardig beloop - wiens haargroei zich binnen het jaar had hersteld - was het aantal haarwortels en afwijkende vormen in het linker temporale hoofdhuidgebied binnen de grenzen van de normale waarden.

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CURRICULUM VITAE

De schrijfster van dit proefschrift werd in 1930 te 's-Gravenhage geboren.
Het einddiploma Gymnasium β werd in 1948 behaald.
Na haar huwelijk in 1956 met L.P.J. Peereboom, arts, behaalde zij in 1957 het arts-examen aan de Rijks-universiteit te Leiden.
Van 1958 tot 1962 specialiseerde zij zich tot dermato-venereologe in het Westeinde Ziekenhuis te 's-Gravenhage (hoofd: Prof. Dr. C.H. Beek), alwaar zij tot 1967 werkte als chef de clinique.

Vanaf 1964 is zij gevestigd in het Nebo-Ziekenhuis te 's-Gravenhage.
In het Academisch Ziekenhuis Rotterdam (Dijkzigt), afdeling dermato-venereologie, werd zij in 1972 benoemd als hoofdgeneeskundige A, voor twee-tiende dagtaak, in 1979 voor vier-tiende dagtaak, onder leiding van Prof. Dr. C.H. Beek en vervolgens Prof. Dr. E. Stolz.