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# Alterations in the morphology of the epidermis of human skin as a possible variable of skin function.

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# ALTERATIONS IN THE MORPHOLOGY OF THE EPIDERMIS OF HUMAN SKIN AS A POSSIBLE VARIABLE OF SKIN FUNCTION

By

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# ABSTRACT

Human skin is a complicated organ concerned with a variety of functions. This complexity is reflected in the wide diversity of integumentary morphology as skin is examined from different body sites. It is understood that skin morphology is under genetic control and is further affected by hormone levels, age and nutrition. Little, however, has been said or implied concerning the possible effect of the use to which skin is subjected in man as a factor influencing its morphology. It is to this problem that this thesis is directed.

Fifty diverse sites have been studied from six human cadavers. Histologic cross sections of the tissues were analysed for distinctive epidermal features including the thickness of stratum corneum, the product of the process of keratinization, and suprapapillary stratum Malpighii, the stratum of cells undergoing differentiation. An additional parameter of number and length of rete pegs provided some new insights: All measurements increase as demands on the skin are intensified. Six functional categories were established, and it was found that weight bearing regions of the epidermis developed the greatest degree of thickness of stratum corneum and stratum Malpighii with the rete peg expression being likewise exaggerated. Parts involved in flexing and extending were also increased in thickness of the epidermal features, but to a lesser degree than those found in weight bearing areas. The more passive categories of coverings, rounded coverings, firmly fixed skin and special skin types were of noticeably thinner dimensions.

The measurement used only partially reflected the morphology of epidermis, and all sites were subjected to maceration to separate dermis

from epidermis to allow site by site analysis in three dimensions of the epidermal-dermal interface.

The heloma durum (human corn) was studied from the same viewpoints as applied to the fifty sites as an example of the most extreme expression of keratinization and hypertrophy of rete Malpighii. This lesion develops in response to external irritative stimulation and can be considered to be an experiment in nature supplemental to our view that functional demands influences epidermal morphology.

Additional study in terms of histochemistry, morphologic variation and electron microscopy have been included in the section on heloma durum.

Possible mechanisms for modulation of skin morphology by manipulation of cell cycle, influence of epidermal chalone, the "diffusable mitogenic dermal influencing factor" were postulated in conclusion.

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

Page

LIST OF TABLES

PART I



PART II



LIST OF FIGURES

PART I

TABLE OF CONTENTS (cont.)



LIST OF PLATES

PART I

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

# INTRODUCTION

Human skin has many functions and it is a structurally complicated organ (Montagna, 1965). The integument is adaptable in a remarkable way to a wide variety of environments providing the biologist with an extensive range of examples for study (Cohen, 1969).

There is now a necessity for a change in the traditional medical outlook to encourage exploration into skin biology in the widest sense in order that new approaches to skin pathology be achieved (Pinkus and Mehregan, 1969).

It is with this interest and background that the present study was undertaken. A good body of knowledge exists as to how skin relates to its internal environment. Considerably less is known about external influences. Almost no attention has been given to how the integument is morphologically related to external stimulation of a mechanical nature as the skin functions to provide support and form to the human body.

The present study responds to this need by analysing the epidermis as to relative thickness and cross sectional area in a variety of functional situations. The extent of variability is examined by means of a parallel study of the epidermal-dermal interface.

While these parameters are sufficiently comprehensive to provide a meaningful contribution to the understanding of skin morphology, they provide, at the same time, the foundation for any number of related future studies.

## REVIEW OF THE LITERATURE AND FOUNDATION OF THE PROBLEM

### Internal Factors Affecting Skin Morphology

The genetic influence - Over one hundred abnormal conditions of the integument exhibit Mendelian control. *Ichthyosis vulgaris*, *neurofibromatosis* or von Recklinghausen's disease both result from autosomal dominant genes. *Keratoderma palmare* and *epidermolysis bullosa* are controlled from autosomal recessive alleles. Among the more than twelve X-linked recessive genetic skin diseases are *ichthyosis* and *keratosis follicularis* (Fitzpatrick, 1971). Familial, racial and ethnic skin characteristics further give evidence that the integument is genetically controlled. Consider the sallow or often oily complexion found in Eurasians as compared with the fair complexions of the Scandinavian. Ample opportunity for observations on the effects of intermarriage between these and other ethnic and racial groups on skin color and texture support reliance of these features on the operation of genes (Fitzpatrick, 1971).

Hormonal influences - It has been observed that hormones profoundly affect integumentary morphology (Fitzpatrick, 1971). Atrophy of the epidermis can be produced by local and systemic administration of corticosteroids or the adrenocorticotrophic hormone itself. Epidermal hypertrophy has been observed following the prolonged use of testosterone. Aging, alterations in metabolic and/or nutritional states are additional factors which influence skin morphology (Fitzpatrick, 1971).

Embryology - In embryogeny, the ridging characteristics of the finger print and sole print, as well as the flexor foldings of the hands and feet are apparent before these parts become functional (Cummins and Midlo, 1943).

Local biochemical balance - In normal skin, the morphology depends on the interactions of substances stimulating basal cell mitosis and others which inhibit cell division. At the epidermal level, interference with intra-epidermal adenosine 3', 5' - monophosphate (cyclic AMP) favors cell proliferation and may produce pathological states of the skin (Voorhees and Duell, 1971). The 'diffusable mitogenic dermal influencing factor' stimulates basal cell mitosis in normal states, but likewise may be altered in disease (Cohen, 1969).

External Factors Effecting Skin Morphology

The skin is not only morphologically responsive to numerous internal influences, but may be altered by external environmental factors which alter local tissue interactions of dermis and epidermis at the biochemical level (Cohen, 1969). Mechanical stimuli modify relative thickness of skin strata as well as its interface characteristics (see glossary).

The function of the skin may dictate its morphology within limits since certain likenesses have been shown to exist among similarly functioning regions in different animals. For example, the weight bearing areas of the sole of the foot in man which is characterized by parallel ridging of the dermal papillae, bears a morphological similarity to the ventral tail and abdomen of the lizard, and to the dorsal knuckle of quadripedal apes. Both of these dissimilar parts support weight during locomotion (Fitzpatrick, 1971).

When the number of factors, both internal and external, effecting skin morphology are considered, it is not surprising that so much structural variability exists from site to site. Pinkus and Mehregan (1969) state that one can not really speak of "the skin" as an entity unto itself, but only in an abstract sense. The variations observed in skin as it occurs at different sites in the human body have been investigated along two lines. One approach studies measurements of epidermis and and dermis or the total skin, and other compares features of the epidermal dermal interface.

Measurement of Skin Components

Pinkus (1964) compiled numerous measurements from four previous studies in which thicknesses of epidermis and dermis and/or total skin within single individuals were determined. This summary revealed the results of the previous studies to be highly inconsistent. Differences of three and four fold between measurements at the same site in different individuals were noted. The skin from the face in two separate studies varied from 750 $\mu$ to 2950 $\mu$. In another study only epidermal thickness was determined for the face: 52 $\mu$. Dermal thicknesses for the face in still another study ranged from 1411 $\mu$ to 2271 $\mu$. Epidermal thickness of the abdominal region in two different studies ranged from 23 to 70 $\mu$ and the dermal from 301 u to 1933 $\mu$. Skin from the sole of the foot (a rather generalized description) had an epidermal thickness from 529 $\mu$ to 1377 $\mu$, and the dermal thickness was from 867 $\mu$ to 1805 $\mu$.

The inconsistencies observed in measuring dermis and epidermis and/or total skin could conceivably be too broad for a meaningful analysis.

Moreover, the dermis is difficult to define morphologically into layers other than the reticular layer and the papillary layer. These layers are composed of an amorphous ground substance in which bundles of collagenic, elastic and reticular fibers interweave in all three dimensions (Pinkus, 1971). However, the role of the dermis is not to be underestimated since it exerts the inducting influence on the histodifferentiation of the epidermis itself (Cohen, 1969). Vascularization and innervation of the skin occurs at the level of the dermis as well. The epidermis, on the other hand, is a well ordered layering of nucleated and differentiating cells sharply demarcated from the non-nucleated stratum corneum, the end product of the keratinization process. The two layers; stratum Malpighii and stratum corneum are involved in a carefully ordered sequence of morphological and biochemical events (Zelickson, 1967). Both strata are measureable in terms of thickness and area. They can be compared from site to site both in terms of total epidermal thickness and component parts. Relative shifts as to the percentage that the stratum corneum or stratum Malpighii in relation to the whole epidermis as it reflects whether the differentiating or the differentiated stratum predominates is another meaningful calculation. The number and length of the rete ridges of the stratum Malpighii as they interdigitate into the papillary structure of the dermis provide additional parameters of study which can be coupled with the innovative epidermal-dermal interface technique.

This more restricted study involving epidermal features which have biological inter-relationships permits testing of the concept that morphological alteration may be a variable of skin function as it operates mechanically with the external environment.

The second line of investigation utilized the maceration technique of the skin. In this method, the epidermis is removed from its underlying dermis and the 'hand and glove' relationship can be examined microscopically (Oberste-Lehn, 1962). Horstmann (1952a) reported several differences among epidermal-dermal interface preparations from various areas of the skin. According to Horstmann (1952b), the regional differences of the papillar body in human skin are related to the arrangement of hair follicles and sweat glands together with their ducts. The "Horstmann view" is that there are three expressions of the interface morphology: dial-plate, rosette and cockade. These are further subject to modification according to their local distribution. The dial-plate motif is that in which there is a concentric arrangement of sweat ducts about a hair follicle with epidermal ridges relating to these structures. A rosette motif has epidermal ridges arranged radially about sweat glands. In the cockade arrangement, epidermal ridges form concentric rings about two hair follicles. Doubtless the adnexa exert an influence on epidermal-dermal interface morphology, but this may be a too simplistic explanation. Bullous, inflammatory and exfoliative skin diseases present pathognomonic epidermal-dermal interface structural change (Horstmann 1952a,b, Oberste-Lehn, 1962).

Remarkable changes in the epidermal-dermal interface with concomitant alterations in thickness of stratum corneum and stratum Malpighii have been observed at the interphalangeal skin of the digits of the feet under the influence of external mechanical irritation (McCarthy and Habowsky, 1972b).

This phenomenon brings to mind the laws of Wolff and Davis, axiomatic in orthopedic medicine which state in substance that any change in the use of an anatomical part (muscle and/or bone) is accompanied by a corresponding alteration in the morphology of that part...hypertrophy, atrophy (Wolff, 1870, Davis, 1934, Morton, 1952 Evans, 1961). There is striking hypertrophy of the epidermal ridges and deepening of the cavities receiving the dermal papillae which are equally enlarged and distorted in interphalangeal skin involved in forming heloma durum (the human corn or clavus). This observation suggests that skin, like muscle and bone, may be structurally altered if its function is changed.

This thesis has been prepared in two parts. Part I investigated the variations of epidermal morphology at fifty sites selected from the human body having a variety of functions. Part II compares normal (control) interphalangeal epidermis with interphalangeal skin involved in the formation of heloma durum (human corn). The latter is presented as an experiment of nature in which external irritation produces alterations which increase the dimensions of all epidermal features of interest to this study as well as striking changes of the epidermal-dermal interface.

PART I

# THE EXAMINATION OF THE EPIDERMIS FOR MORPHOLOGICAL ALTERATIONS FROM DIFFERENT FUNCTIONAL LOCATIONS OF THE HUMAN SKIN

# MATERIALS AND METHODS

## The Nature of the Anatomical Material

The material used in this study was allocated by the Department of Anatomy, School of Medicine, Wayne State University, Detroit, Michigan, U.S.A. The following is the description of the nature of the seven human cadavers at the time of dissection.

Case 1 - Caucasian male, age 80 in good state of nutrition, expired with arteriosclerotic coronary disease.

Case 2 - Negro male, age 65 in good nutritional state with well muscled physique, expired in cardio-pulmonary arrest.

Case 3 - Caucasian male, age 44 in fair state of nutrition expired in acute vascular shock, pancreatitis and portal cirrhosis.

Case 4 - Caucasian male, age 68 in poor nutritional state expired in respiratory failure secondary to chronic obstructive lung disease, and non-ketotic, hyperosmolar diabetes mellitus co-existent.

Case 5 - Caucasian male, age 61 in fair state of nutrition expired from cardiac arrest, cardiac arrythmia. Also present were chronic renal failure and a ruptured diverticulum.

Case 6 - Caucasian female, age 47 in good nutritional state, somewhat obese, expired in coronary artery infarction.

Case 7 - Caucasian male, age 70 expired from coronary artery infarction. The body was in fair to good nutritional state.

## Specimen Preparation

A skin map was prepared from rostral to caudal position comprising

50 selected locations in the human body. This number was deemed a wide enough sampling for a statistical analysis of functional and morphological trends within the epidermal strata. The sites represented an even distribution from upper and lower extremities, head and torso on both dorsal and ventral aspects of the body. The different locations had a variety of functional similarities and dissimilarities which would allow logical grouping according to the mechanical function of the integument. These locations are identified by number as follows:

| Number | Location |
| --- | --- |
| 1. | scalp |
| 2. | eyelid |
| 3. | posterior fold of the neck |
| 4. | cheek |
| 5. | chin |
| 6. | neck fold below larynx |
| 7. | chest at body mid line |
| 8. | mid chest |
| 9. | axilla of arm |
| 10. | linea alba |
| 11. | groin |
| 12. | back at body mid line at level of clavicle |
| 13. | back at body mid line at level of lumbar vertebrae 4 and 5 |
| 14. | buttox |
| 15. | back at mid portion of upper later quadrant |
| 16. | gluteal fold |
| 17. | shaft of the penis |
| 18. | middle portion of lateral margin of ear |
| 19. | ear lobe |
| 20. | inner aspect of the elbow |
| 21. | posterior ankle above the insertion of the tendo-achilles |
| 22. | posterior thigh, mid point |
| 23. | popliteal space |
| 24. | anterior thigh, mid point |
| 25. | knee, anterior to the patella |
| 26. | lateral thigh, mid point |
| 27. | medial thigh |
| 28. | middle portion of the tibial crest |
| 29. | posterior leg, mid point |
| 30. | plantar aspect of the heel |

31. lateral malleolus
32. inferior lateral malleolus
33. middle aspect of plantar arch of foot
34. plantar aspect of the first metatarsal head
35. flexor fold, plantar aspect, second toe
36. dorsal aspect, great toe at interphalangeal joint
37. anterior leg just inferior to patella
38. anterior aspect of the middle ankle
39. dorsal mid arch of the foot
40. lateral upper arm dorsal to deltoid muscle
41. inner arm
42. outer elbow
43. inner wrist
44. dorsal hand
45. volar aspect of hand at grooved region
46. knuckle, second digit of the hand
47. dorsal aspect of the proximal interphalangeal joint of the hand
48. volar aspect of the proximal interphalangeal joint of the hand
49. distal finger
50. interdigital web of second finger of the hand

In addition, a strip of skin measuring 0.6 x 6.0 cm was excised from both dorsal and volar aspects of the second digit of the hand for epidermal-dermal interface study only.

The samples from the various locations of cases 1, 2 and 3 were subjected to histological work only since they were embalmed at the time of dissection. Cases 4, 5, 6 and 7 were not embalmed and were suitable for both histological and epidermal-dermal interface studies.

A classification according to skin function on a mechanical basis, namely, covering, special wrinkling types, anchoring, rounded covering, weight bearing (or sites receiving pressure), and surfaces involved with flexing and extending was made from the 50 sites originally selected. The six functional subdivisions may be overlapping, but are reasonable.

The classification follows with the skin site indicated by the parenthesis:

Sites where the skin serves mainly to cover

scalp (1)
cheek (3)
mid chest (8)
buttox (14)
upper lateral back (15)
posterior thigh (22)
anterior thigh (24)
lateral thigh (26)
medial thigh (27)
posterior leg (29)
lateral malleolus (31)
dorsal middle arch of the foot (39)
inner arm (41)
dorsal hand (44)

Sites at which the skin had a special wrinkling function

eyelid (2)
shaft of the penis (17)

Sites at which the skin firmly affixes to structures below

chest at body mid line (7)
linea alba (10)
back at body mid line at level of clavicle (12)
back at body mid line at level of lumbar v. 4/5 (13)
tibial crest (28)

Sites at which skin covers well rounded structures

chin (5)
middle portion of the lateral margin of the ear (18)
ear lobe (19)

Sites at which skin was exposed to pressure and weight bearing

plantar heel (30)
middle aspect of the plantar arch of the foot (33)
plantar aspect of the first metatarsal head (34)
flexor fold of plantar aspect of the second toe (35)

Sites at which skin was involved with active flexion and extension

posterior fold of the neck (3)
anterior neck fold below larynx (6)
axilla of the arm (9)
groin (11)

gluteal fold (16)
inner elbow (20)
posterior ankle above insertion of achilles tendon (21)
popliteal space (23)
knee, anterior to patella (25)
inferior lateral malleolus (32)
dorsal aspect of the great toe at interphalangeal joint (36)
anterior leg just inferior to patella (37)
anterior aspect of middle ankle (38)
lateral upper arm at belly of deltoid muscle (40)
elbow (42)
wrist (43)
volar aspect of the hand about volar grooves (45)
knuckle (46)
dorsal aspect, proximal interphalangeal joint, finger (47)
volar aspect, proximal interphalangeal joint of finger (48)
interdigital web of the finger (50)

A hemisection was made of the specimen, one half for light microscopic evaluation, the remainder for epidermal-dermal interface preparation and study.

Histology

Skin samples were excised by eliptical and conjoined incisions measuring about 1.5 x 0.8 cm. After fixation in 10% neutral formalin overnight, the tissue was dehydrated, cleared, infiltrated with paraffin *in vacuo* and embedded (Pearse, 1961). The material was sectioned at 7 μ and affixed to glass slides with albumen.

Staining - Hematoxylin and eosin were employed to study the morphological features of all skin and standard methods for staining were followed (Pearse, 1961).

Measurement technique

Thickness Measurements - All slides were examined with an Olympus microscope, Model EH. Measurements were made from an enlarged image (X 30) projected by a Leitz Watzlar Prado slide projector. The thicknesses of the stratum corneum and the supra-papillary stratum Malpighii together with total epidermis were determined. The relative amount of total thickness of the epidermis that the epidermal features under study (stratum corneum and suprapapillary stratum Malpighii) were calculated. In addition, the number of rete pegs in 1 mm section of each specimen was determined and the length measured. Results of these determinations are listed in Tables I, II and III in terms of the mean measurement of the six cases studied at each of the fifty functional sites.

Technical Note - The importance of properly embedding skin specimens for reliable measurements is acknowledged. Care must be taken to ensure that the free surface of skin be at right angles to the microtome knife. Specimens mounted at an angle would give exaggerated measurements. It is also necessary to view many sections in order to be sure that the rete pegs are fully formed since it is possible that sections could have been cut at a point along the curvature of the structure before the structure attained its greatest dimension. Despite all precautions, the possibility of error can exist. It should be pointed out, however, that the same methodology was employed throughout this study and comparisons are, in all likelihood, valid.

Area Determinations - The area of the epidermal features studied was determined by the indirect method of comparative weights of stratum corneum and the stratum Malpighii (including the rete ridges). In thickness measurements, only thicknesses of the strata were involved. In this approach, both thickness and increased area resulting from rete ridges for a given cross sectional length are taken into account.

Enlarged projections were traced on paper of known constant weight. Each of the six cases studied were included and all fifty sites analysed. A 2 mm length of epidermis in cross section was enlarged (x35) and cut from the paper. The stratum corneum was then separated from the stratum Malpighii and each weighed. The weights provided an arbitrary number and were useful only in comparing one skin type with another along with their respective epidermal component parts. A tabulation of tissues in terms of relative area as reflected by weight allowed the fifty epidermal sites to be listed in order of greatest to smallest area (Table V). A percentage value could also be obtained comparing the stratum corneum area to the stratum Malpighii as these strata related to the total epidermis. The tabulation according to area proved to be essentially similar to Table IV which listed functional sites from the greatest to least thickness of the total epidermis. The area determination, however, made possible a somewhat finer separation of sites that had identical thickness measurements.

Statistics

Standard statistical methods commonly used in evaluating body measurements were applied (Garn, 1958). The epidermal features of thickness and area for stratum corneum, stratum Malpighii, and number and length of rete ridges were considered. Formulae for the "t" test and correlation coefficients are given in Appendix E.

Scattergrams - Mean values for the six cases studied were used in plots comparing epidermal features such as stratum corneum, stratum Malpighii, total epidermis, number and length of the rete Malpighii.

Histograms - Observed values for thickness of stratum corneum, suprapapillary stratum Malpighii and total epidermis in each of the six cases dissected were grouped according to the functional classifications of skin. The frequency or actual number of occurrences for each unit of thickness from .01 to 1.10 mm were tabulated and grouped for the preparation of histograms. This provided a representation of range of observed values and the points at which greatest and least thickness for a given functional skin group were noted.

Similar histograms were prepared from data concerning length in .01 mm and number per mm of rete ridges occurring among the six functional classifications of skin.

Maceration Technique for Examination of Epidermal-Dermal Interface

Biopsied skin was placed in aqueous 1 N sodium bromide solution for 24 hours. Using fine forceps, the free epidermal surface was placed on firm flat discs of cork. The epidermis was held firmly against the cork surface and the dermal portion separated in a rolling motion and mounted on the adjacent portion of the disc using fine non-corrosive pins. The interface of dermis and epidermis was oriented upward.

The mounted tissue was fixed in 10% formalin for 24 hours. With the pins in place and the bottles filled with solution and capped, the tissue was kept fully immersed. Efforts to fix, dehydrate, clear and impregnate the tissues with resin en masse proved impractical because of occasional exposure of tissue to air and the tendency for the formation of a precipitate. Instead, the mounted specimens were individually dehydrated and cleared (Appendix A). Finally, each tissue was immersed for 12 hours in a 1% solution of beeswax in turpentine (Pinkus, 1969) which renders the dermis and epidermis opaque with a resinous material. The cork discs with tissues mounted were removed from their individual bottles and allowed to dry for 3 days taking care to shield them from dust of the air. The tissues were removed from the cork discs, transferred to glass slides and affixed using "Elmer's Glue" (Borden Co.).

All specimen were examined microscopically under incident light. Photomicrographs were prepared using Kodak Panatomic X film and enlarged X 40 on Agfa paper.

## RESULTS

### GENERAL CONSIDERATIONS

This study is directed toward an understanding of epidermal morphology in relationship to its interactions with the external environment, particularly as it interacts on a mechanical basis. The epidermal features which lend themselves to measurement are the stratum corneum (the end product of the process of differentiation called keratinization) and the suprapapillary stratum Malpighii (the nucleated cellular mass undergoing differentiation). The two layers are easily discerned by their staining and morphological characteristics and lend themselves to measurements of thickness and relative area as reflected by weight determinations (see page 16). Number and length of rete Malpighii reflect an increase in cell mass and anchoring ability of the epidermis on the dermis (McCarthy and Habowsky, 1972b). These parameters also lend themselves to analysis which is further reinforced by the photomicrographs of the epidermal-dermal interface demonstrated in the following chapter.

### MEASUREMENT OF EPIDERMAL FEATURES

Tables I, II and III report the data as mean values for each site studied and reported by number as they occurred anatomically. In all cases column identification is as follows:

C = stratum corneum
M = stratum Malpighii
E = total epidermis, the sum of stratum corneum, Malpighii.

%C is the percentage that the stratum corneum represents of the total thickness (or area) of the total epidermis.

%M is the percent represented by the suprapapillary stratum Malpighii in terms of thickness (Table 1) or the percent represented by the total area of the stratum Malpighii as reflected by relative weight determination (Table II).

Table III provides a listing of the observed length of the rete pegs in cross section as they interdigitate and bind with the underlying dermis. The basis for the determination was the length measured below the suprapapillary plate (see glossary). The number of pegs of the rete Malpighii occurring along a .1 mm section of each skin site examined was counted as well and listed as to mean number of occurrences and the range.

The three parameters investigated (thickness, area of the respective epidermal strata and the length of rete pegs) have been rearranged in tables IV, V and VI. Table IV lists the site of greatest total epidermal thickness at the top to the thinnest at the bottom with those intermediate in sequence. Table V indicates the site of greatest area as reflected by relative weight (see page 16) at the top and the least at the bottom. From these two tables, a statement can be made as to how the particular site under study related to the whole such as being in the upper 1/3 of all sites studied, or among the lower 1/2 of all sites analysed etc.

Table VI places the rete peg length calculations in order of the greatest length to the shortest (see technical note, page 14).

It is interesting to note that the plantar of the heel occurs first in terms of thickness, area and length of rete pegs, and the plantar region of the first metatarsal occurs second with respect to these epidermal features. Both sites are primary weight bearing surfaces. Conversely,

TABLE I
MEAN THICKNESS MEASUREMENTS (.01 mm) FROM FIFTY ANATOMICAL SITES MY NUMERICAL OCCURRENCES: TOTAL EPIDERMIS AND STRATA

| ANATOMIC LOCATION | C* | M* | E* | %C* | %M* |
|---|---|---|---|---|---|
| 1 scalp | .03 | .03 | .06 | 50 | 50 |
| 2 eyelid | .01 | .03 | .04 | 27 | 73 |
| 3 post. neck | .02 | .03 | .05 | 43 | 57 |
| 4 cheek | .02 | .03 | .05 | 39 | 61 |
| 5 chin | .03 | .03 | .06 | 47 | 53 |
| 6 ant. neck | .03 | .03 | .06 | 54 | 46 |
| 7 chest, mid line | .02 | .02 | .04 | 46 | 54 |
| 8 chest, middle | .02 | .03 | .05 | 40 | 60 |
| 9 axillar arm | .05 | .02 | .07 | 65 | 35 |
| 10 linea alba | .02 | .03 | .05 | 43 | 57 |
| 11 groin | .02 | .03 | .05 | 45 | 55 |
| 12 mid line, back | .02 | .02 | .04 | 48 | 52 |
| 13 mid line, back-L4/5 | .02 | .02 | .04 | 50 | 50 |
| 14 buttox | .02 | .02 | .04 | 50 | 50 |
| 15 upper lat back | .02 | .02 | .04 | 50 | 50 |
| 16 gluteal fold | .02 | .02 | .04 | 50 | 50 |
| 17 penile shaft | .02 | .02 | .04 | 50 | 50 |
| 18 mid lat. ear | .03 | .04 | .07 | 33 | 67 |
| 19 ear lobe | .01 | .02 | .03 | 33 | 67 |
| 20 inner elbow | .03 | .03 | .06 | 50 | 50 |
| 21 achilles tendon | .21 | .09 | .30 | 63 | 27 |
| 22 post. thigh | .03 | .02 | .05 | 60 | 40 |
| 23 popliteal space | .02 | .03 | .05 | 50 | 50 |
| 24 ant. thigh | .03 | .03 | .06 | 50 | 50 |
| 25 superior patella | .05 | .03 | .08 | 62 | 38 |
| 26 lateral thigh | .03 | .03 | .06 | 50 | 50 |
| 27 medial thigh | .02 | .02 | .04 | 50 | 50 |
| 28 tibial crest | .02 | .02 | .04 | 50 | 50 |
| 29 posterior leg | .03 | .03 | .06 | 50 | 50 |
| 30 plantar heel | .56 | .07 | .63 | 89 | 11 |
| 31 malleolus | .03 | .03 | .06 | 50 | 50 |
| 32 infra malleolus | .05 | .03 | .08 | 55 | 45 |
| 33 mid pl. arch | .22 | .04 | .26 | 76 | 24 |
| 34 pl. met head I | .34 | .05 | .39 | 87 | 13 |
| 35 toe fold | .11 | .05 | .16 | 65 | 35 |
| 36 d. great toe | .06 | .03 | .09 | 67 | 33 |
| 37 infra patella | .05 | .03 | .08 | 62 | 38 |
| 38 mid ankle | .03 | .03 | .06 | 50 | 50 |
| 39 dorsal arch | .04 | .03 | .07 | 67 | 33 |
| 40 supra-deltoid | .02 | .03 | .06 | 45 | 55 |
| 41 inner elbow | .03 | .03 | .06 | 50 | 50 |
| 42 elbow | .06 | .05 | .11 | 55 | 45 |
| 43 wrist | .09 | .03 | .12 | 70 | 30 |
| 44 dorsal hand | .04 | .04 | .08 | 50 | 50 |
| 45 volar hand | .16 | .05 | .21 | 75 | 25 |
| 46 knuckle | .09 | .04 | .13 | 65 | 35 |
| 47 d. interphalangeal | .14 | .05 | .19 | 75 | 25 |
| 48 v. interphalangeal | .12 | .06 | .18 | 70 | 30 |
| 49 distil finger | .25 | .05 | .30 | 80 | 20 |
| 50 interdigital finger | .14 | .05 | .19 | 75 | 25 |

*Legend on pages 18 and 19

TABLE II

RELATIONSHIP OF STRATUM CORNEUM AND STRATUM MALPIGHII AS PERCENT (%m OR %C) AS A FUNCTION OF AREA**-E (total) C (corneum) m (malpighii)

| ANATOMIC LOCATION | %m* | %C* | E* | C* | m* |
|---|---|---|---|---|---|
| 1 scalp | 59 | 41 | .3800 | .1575 | .2225 |
| 2 eyelid | 77 | 23 | .3306 | .0774 | .2532 |
| 3 post. neck | 55 | 45 | .3726 | .1651 | .2075 |
| 4 cheek | 62 | 38 | .3667 | .1374 | .2233 |
| 5 chin | 70 | 30 | .4482 | .1332 | .3150 |
| 6 ant. neck | 53 | 47 | .5411 | .2540 | .2871 |
| 7 chest, mid line | 62 | 38 | .3100 | .1184 | .1917 |
| 8 mid chest | 63 | 37 | .5490 | .2010 | .3480 |
| 9 axillar arm | 42 | 58 | .6958 | .4007 | .2951 |
| 10 linea alba | 65 | 35 | .3321 | .1171 | .2150 |
| 11 groin | 64 | 36 | .5199 | .1849 | .3350 |
| 12 mid line, back | 49 | 51 | .2559 | .1297 | .1260 |
| 13 mid line, back-L | 63 | 37 | .3425 | .1260 | .2165 |
| 14 buttox | 69 | 31 | .3651 | .1130 | .2521 |
| 15 u.l. back | 57 | 43 | .2829 | .1229 | .1600 |
| 16 gluteal fold | 59 | 41 | .4335 | .1752 | .2485 |
| 17 penile shaft | 71 | 29 | .4038 | .1173 | .2865 |
| 18 mid lat. ear | 70 | 30 | .6351 | .1915 | .4436 |
| 19 ear lobe | 69 | 31 | .3095 | .0955 | .2140 |
| 20 inner elbow | 52 | 48 | .5570 | .2674 | .2896 |
| 21 achilles tendon | 31 | 69 | .1932 | .1333 | .5996 |
| 22 post. thigh | 52 | 48 | .4234 | .2044 | .2190 |
| 23 popliteal space | 59 | 41 | .3710 | .1500 | .2210 |
| 24 ant. thigh | 43 | 57 | .3954 | .2261 | .1693 |
| 25 superior patella | 45 | 55 | .6195 | .3368 | .2827 |
| 26 lat. thigh | 58 | 42 | .4448 | .1848 | .2600 |
| 27 med. thigh | 55 | 45 | .3806 | .1699 | .2107 |
| 28 tibial crest | 51 | 49 | .3394 | .1673 | .1721 |
| 29 post. leg | 55 | 45 | .4518 | .2029 | .2489 |
| 30 plantar heel | 33 | 67 | 4.503 | 3.3033 | 1.23 |
| 31 malleolus | 49 | 51 | .5331 | .2705 | .2625 |
| 32 infra malleolus | 49 | 51 | .6750 | .3463 | .3287 |
| 33 mid p. arch | 39 | 61 | .3110 | .8060 | .5050 |
| 34 p. met head I | 29 | 71 | 2.007 | 1.447 | .5610 |
| 35 toe fold | 41 | 59 | 1.309 | .7682 | .5391 |
| 36 d. great toe | 50 | 50 | .6094 | .3050 | .3044 |
| 37 infra patella | 43 | 57 | .5880 | .3368 | .2512 |
| 38 mid ankle | 63 | 37 | .5861 | .2189 | .3672 |
| 39 d. arch | 43 | 57 | .5147 | .2945 | .2202 |
| 40 supra-deltoid | 56 | 44 | .4130 | .1829 | .2301 |
| 41 inner arm | 52 | 48 | .3815 | .1847 | .1968 |
| 42 elbow | 52 | 48 | 1.040 | .4954 | .5449 |
| 43 wrist | 38 | 62 | 1.174 | .7283 | .4500 |
| 44 dorsal hand | 54 | 46 | .7168 | .3310 | .3858 |
| 45 volar hand | 36 | 64 | 1.856 | 1.188 | .6683 |
| 46 knuckle | 39 | 61 | 1.2038 | .7360 | .4676 |
| 47 d. interphalangeal | 39 | 61 | 1.4914 | 9144 | .5170 |
| 48 v. interphalangeal | 40 | 60 | 1.7029 | 1.014 | .6886 |
| 49 distil finger | 38 | 62 | 1.8368 | 1.135 | .7018 |
| 50 interdigital finger | 32 | 68 | 1.8569 | 1.263 | .5936 |

* Legend on pages 18 and 19. **As reflected by weight (page14 )

TABLE III

NUMBER AND LENGTH OF RETE RIDGES FROM FIFTY ANATOMICAL SITES BY NUMERICAL OCCURRENCE (BOTH MEAN VALUES AND RANGE)

| ANATOMIC LOCATION | Mean Number per .1 mm | Mean Length (.01 mm) | Observed Range Number | Observed Range Length |
|---|---|---|---|---|
| 1 scalp | 2 | .03 | 0-8 | .01-.11 |
| 2 eyelid | 2 | .02 | 0-6 | .02-.03 |
| 3 post. neck | 2 | .03 | 0-3 | .03-.04 |
| 4 cheek | 1 | .01 | 0.7 | .01-.04 |
| 5 chin | 3 | .03 | 0-5 | .01-.04 |
| 6 ant. neck | 5 | .04 | 2-12 | .02-.08 |
| 7 chest, mid line | 4 | .03 | 0-6 | .02-.05 |
| 8 mid chest | 8 | .06 | 4-11 | .03-.10 |
| 9 axillar arm | 6 | .05 | 1-14 | .02-.06 |
| 10 linea alba | 5 | .03 | 0-10 | .02-.06 |
| 11 groin | 6 | .04 | 0-9 | .02-.08 |
| 12 mid line, back | 6 | .04 | 0.7 | .01-.09 |
| 13 mid line, back-L | 7 | .03 | 2-11 | .01-.06 |
| 14 buttox | 6 | .05 | 5.8 | .03-.07 |
| 15 u.l. back | 4 | .02 | 2-5 | .02-.03 |
| 16 gluteal fold | 6 | .04 | 2-10 | .02-.08 |
| 17 penile shaft | 5 | .04 | 3-9 | .02-.05 |
| 18 mid lat. ear | 7 | .05 | 2-10 | .03-.06 |
| 19 ear lobe | 6 | .03 | 0-8 | .03-.05 |
| 20 inner elbow | 2 | .01 | 0-6 | .02-.04 |
| 21 achilles tendon | 8 | .07 | 5-10 | .02-.10 |
| 22 post. thigh | 3 | .02 | 0-7 | .02-.07 |
| 23 popliteal space | 3 | .02 | 0-7 | .02-.06 |
| 24 ant. thigh | 2 | .02 | 0-5 | .03-.04 |
| 25 superior patella | 5 | .04 | 2-7 | .02-.06 |
| 26 lat. thigh | 3 | .03 | 0-11 | .02-.08 |
| 27 med. thigh | 2 | .02 | 0-4 | .02-.03 |
| 28 tibial crest | 3 | .03 | 0-8 | .02-.05 |
| 29 post. leg | 3 | .03 | 0-8 | .02-.08 |
| 30 plantar heel | 7 | .23 | 7-9 | .12-.30 |
| 31 malleolus | 5 | .03 | 1-7 | .01-.07 |
| 32 infra malleolus | 5 | .05 | 3-8 | .03-.10 |
| 33 mid p. arch | 8 | .09 | 6-10 | .07-.14 |
| 34 p. met head I | 9 | .12 | 6-12 | .08-.14 |
| 35 toe fold | 9 | .10 | 8-10 | .09-.12 |
| 36 d. great toe | 7 | .06 | 3-9 | .03-.09 |
| 37 infra patella | 5 | .04 | 4-7 | .03-.05 |
| 38 mid ankle | 6 | .04 | 5-7 | .03-.05 |
| 39 d. arch | 5 | .04 | 2-9 | .02-.06 |
| 40 supra-deltoid | 5 | .03 | 0-11 | .02-.06 |
| 41 inner arm | 1 | .01 | 0-4 | .01-.03 |
| 42 elbow | 7 | .06 | 5-10 | .05-.07 |
| 43 wrist | 8 | .06 | 6-15 | .05-.07 |
| 44 dorsal hand | 4 | .03 | 1-8 | .02-.05 |
| 45 volar hand | 9 | .07 | 7-11 | .06-.10 |
| 46 knuckle | 9 | .07 | 8-10 | .05-.13 |
| 47 d. interphalangeal | 9 | .09 | 7-11 | .04-.12 |
| 48 v. interphalangeal | 10 | .10 | 9-12 | .07-.16 |
| 49 distil finger | 10 | .08 | 9-11 | .07-.09 |
| 50 interdigital finger | 8 | .07 | 8-12 | .04-.10 |

TABLE IV

FIFTY SELECTED ANATOMIC SITES ARRANGED IN ORDER OF THICKNESS OF TOTAL EPIDERMIS (MEAN LINER MEASUREMENTS $\bar{X}$ IN mm)

| ANATOMIC LOCATION | stratum corneum $\bar{X}$ | stratum corneum $S^2$ | stratum corneum S | stratum Malpighii $\bar{X}$ | stratum Malpighii $S^2$ | stratum Malpighii S | total epidermis $\bar{X}$ | total epidermis $S^2$ | total epidermis S |
|---|---|---|---|---|---|---|---|---|---|
| plantar heel | .564 | .0118 | .1088 | .074 | .0013 | .0361 | .638 | .0138 | .1176 |
| plantar metatarsal head I | .340 | .1130 | .3360 | .045 | .0007 | .0268 | .385 | .1301 | .3607 |
| distil finger | .246 | .0298 | .1726 | .054 | .0003 | .0182 | .300 | .0359 | .1895 |
| achilles tendon | .210 | .0100 | .1015 | .090 | .0043 | .0655 | .300 | .0081 | .0902 |
| mid plantar arch | .218 | .0367 | .1915 | .038 | .0001 | .0109 | .256 | .0344 | .1856 |
| volar hand | .163 | .0064 | .0799 | .047 | .0005 | .0242 | .210 | .0092 | .0961 |
| interdigital finger | .144 | .0129 | .1135 | .049 | .0003 | .0160 | .193 | .0055 | .0747 |
| dorsal interphalangeal finger joint | .143 | .0053 | .0728 | .050 | .0009 | .0297 | .193 | .0094 | .0969 |
| volar interphalangeal finger joint | .121 | .0049 | .0698 | .059 | .0015 | .0387 | .175 | .0089 | .0943 |
| plantar toe fold | .114 | .0015 | .0383 | .049 | .0003 | .0186 | .153 | .0022 | .0472 |
| knuckle | .092 | .0039 | .0631 | .042 | .0003 | .0173 | .134 | .0050 | .0709 |
| wrist, dorsally | .092 | .0033 | .0578 | .033 | .0002 | .0134 | .125 | .0032 | .0568 |
| elbow, outer aspect | .064 | .0010 | .0319 | .045 | .0001 | .0105 | .109 | .0008 | .0288 |
| great toe, dorsally | .062 | .0023 | .0487 | .033 | .0002 | .0136 | .095 | .0035 | .0592 |
| superior to patella | .053 | .0003 | .0167 | .030 | .0001 | .0103 | .083 | .0004 | .0207 |
| inferior to malleolus | .051 | .0006 | .0242 | .032 | .0001 | .0133 | .083 | .0008 | .0294 |
| dorsal hand | .043 | .0004 | .0194 | .040 | .0002 | .0141 | .081 | .0005 | .0232 |
| beneath patella | .054 | .0011 | .0337 | .029 | .0003 | .0160 | .075 | .0022 | .0476 |
| axilla of arm | .052 | .0004 | .0204 | .021 | .0001 | .0084 | .073 | .0004 | .0207 |
| mid lateral ear | .032 | .0011 | .0337 | .038 | .0003 | .0172 | .070 | .0022 | .0473 |
| dorsal arch of foot | .042 | .0005 | .0213 | .027 | .0001 | .0136 | .069 | .0011 | .0331 |
| anterior mid ankle | .032 | .0001 | .0109 | .034 | .0001 | .0089 | .066 | .0004 | .0195 |
| malleolar prominence | .033 | .0004 | .0196 | .030 | .0001 | .0109 | .063 | .0004 | .0197 |
| inner elbow | .030 | .0002 | .0126 | .032 | .0003 | .0160 | .062 | .0007 | .0279 |
| anterior neck | .034 | .0002 | .0152 | .028 | .0001 | .0084 | .062 | .0005 | .0228 |
| anterior thigh | .030 | .0001 | .0082 | .030 | .0002 | .0141 | .060 | .0004 | .0216 |

TABLE IV (CONTINUED)

FIFTY SELECTED ANATOMIC SITES ARRANGED IN ORDER OF THICKNESS (MEAN LINEAR MEASUREMENTS IN mm) OF TOTAL EPIDERMIS

| ANATOMIC LOCATION | stratum corneum | | | stratum Malpighii | | | total epidermis | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\bar{X}$ | $S^2$ | S | $\bar{X}$ | $S^2$ | S | $\bar{X}$ | $S^2$ | S |
| chin | .027 | .0001 | .0103 | .030 | .0002 | .0126 | .057 | .0004 | .0197 |
| scalp | .027 | .0002 | .0137 | .028 | .0001 | .0075 | .055 | .0002 | .0134 |
| posterior leg | .027 | .0001 | .0082 | .028 | .0001 | .0121 | .055 | .0003 | .0163 |
| inner arm | .027 | .0001 | .0121 | .025 | .0001 | .0084 | .052 | .0003 | .0172 |
| superior to deltoid | .024 | .0003 | .0163 | .027 | .0000 | .0055 | .051 | .0002 | .0147 |
| groin | .022 | .0001 | .0075 | .028 | .0001 | .0017 | .050 | .0003 | .0167 |
| lateral thigh | .025 | .0004 | .0187 | .025 | .0002 | .0152 | .050 | .0010 | .0322 |
| posterior thigh | .028 | .0001 | .0075 | .022 | .0001 | .0082 | .050 | .0002 | .0141 |
| cheek | .020 | .0001 | .0089 | .030 | .0000 | .0063 | .050 | .0002 | .0126 |
| mid chest | .022 | .0001 | .0117 | .025 | .0001 | .0055 | .047 | .0001 | .0121 |
| linea alba | .018 | .0000 | .0041 | .028 | .0002 | .0133 | .047 | .0002 | .0141 |
| mid thigh | .022 | .0000 | .0045 | .024 | .0002 | .0134 | .046 | .0001 | .0114 |
| popliteal space | .020 | .0000 | .0063 | .025 | .0001 | .0122 | .045 | .0002 | .0122 |
| posterior neck | .018 | .0000 | .0040 | .025 | .0001 | .0084 | .043 | .0001 | .0103 |
| mid line of back | .020 | .0000 | .0063 | .023 | .0001 | .0103 | .043 | .0002 | .0137 |
| shaft of penis | .018 | .0001 | .0075 | .023 | .0001 | .0082 | .042 | .0002 | .0147 |
| crest of the tibia | .023 | .0002 | .0137 | .020 | .0000 | .0063 | .043 | .0003 | .0186 |
| eyelid | .014 | .0000 | .0041 | .029 | .0001 | .0075 | .043 | .0000 | .0051 |
| chest at mid line | .018 | .0000 | .0041 | .022 | .0000 | .0041 | .040 | .0000 | .0000 |
| upper lateral back | .020 | .0002 | .0155 | .020 | .0001 | .0089 | .040 | .0004 | .0219 |
| buttox | .017 | .0000 | .0052 | .022 | .0002 | .0147 | .040 | .0003 | .0167 |
| gluteal fold | .018 | .0000 | .0045 | .018 | .0001 | .0084 | .036 | .0001 | .0114 |
| ear lobe | .013 | .0000 | .0052 | .020 | .0000 | .0000 | .033 | .0000 | .0052 |
| back at mid line | .018 | .0001 | .0096 | .017 | .0000 | .0050 | .035 | .0002 | .0129 |

TABLE V

FIFTY SELECTED ANATOMIC SITES ARRANGED IN ORDER OF RELATIVE AREA AS DETERMINED BY WEIGHT

| ANATOMIC LOCATION | %M* | %C* | E* | C* | M* |
|---|---|---|---|---|---|
| plantar heel (30) | 33 | 67 | 4.503 | 3.303 | 1.2370 |
| p.met head I (34) | 29 | 71 | 2.007 | 1.447 | .5610 |
| achilles tendon (21) | 31 | 69 | 1.9322 | 1.3326 | .5996 |
| interdigital finger(50) | 32 | 68 | 1.857 | 1.263 | .5936 |
| volar hand (45) | 36 | 64 | 1.8560 | 1.188 | .6683 |
| distil finger (49) | 38 | 62 | 1.8368 | 1.135 | .7018 |
| v. interphalangeal (48) | 40 | 60 | 1.7029 | 1.014 | .6886 |
| d. interphalangeal (47) | 39 | 61 | 1.4914 | .9144 | .5170 |
| mid p arch (33) | 39 | 61 | 1.3110 | .8060 | .5050 |
| toe fold (35) | 41 | 59 | 1.309 | .7682 | .5391 |
| knuckle (46) | 39 | 61 | 1.2038 | .7360 | .4676 |
| wrist (43) | 38 | 62 | 1.174 | .7283 | .4500 |
| elbow (42) | 52 | 48 | 1.040 | .4954 | .5449 |
| dorsal hand (44) | 54 | 46 | .7168 | .3310 | .3858 |
| axillar arm (9) | 42 | 58 | .6958 | .4007 | .2951 |
| infra malleolus (32) | 49 | 51 | .6750 | .3463 | .3287 |
| mid lat. ear (18) | 70 | 30 | .6351 | .1915 | .4436 |
| superior patella (25) | 45 | 55 | .6195 | .3368 | .2827 |
| d. great toe (36) | 50 | 50 | .6094 | .3050 | .3044 |
| infra patella (37) | 43 | 57 | .5880 | .3368 | .2512 |
| mid ankle (38) | 63 | 37 | .5861 | .2189 | .3672 |
| inner elbow (20) | 52 | 48 | .5570 | .2674 | .2896 |
| mid chest (8) | 63 | 37 | .5490 | .2010 | .3480 |
| ant. neck (6) | 53 | 47 | .5411 | .2540 | .2871 |
| malleolus (31) | 49 | 51 | .5331 | .2705 | .2625 |
| groin (11) | 64 | 36 | .5199 | .1849 | .3350 |
| d. arch (39) | 43 | 57 | .5147 | .2945 | .2202 |
| post. leg (29) | 55 | 45 | .4518 | .2029 | .2489 |
| chin (5) | 70 | 30 | .4482 | .1332 | .3150 |
| lat. thigh (26) | 58 | 42 | .4448 | .1848 | .2600 |
| gluteal fold (16) | 59 | 41 | .4335 | .1752 | .2485 |
| post. thigh (22) | 52 | 48 | .4234 | .2044 | .2190 |
| supra-deltoid (40) | 56 | 44 | .4130 | .1829 | .2301 |
| penile shaft (17) | 71 | 29 | .4038 | .1173 | .2865 |
| ant. thigh (24) | 43 | 57 | .3954 | .2261 | .1693 |
| inner elbow (41) | 52 | 48 | .3815 | .1847 | .1968 |
| mid thigh (27) | 55 | 45 | .3806 | .1699 | .2107 |
| scalp (1) | 59 | 41 | .3800 | .1575 | .2225 |
| popliteal space (23) | 59 | 41 | .3710 | .1500 | .2210 |
| post. neck (3) | 55 | 45 | .3726 | .1651 | .2075 |
| cheek (4) | 62 | 38 | .3667 | .1374 | .2233 |
| buttox (14) | 69 | 31 | .3651 | .1130 | .2521 |
| mid line back-L (13) | 63 | 37 | .3425 | .1260 | .2165 |
| tibial crest (28) | 51 | 49 | .3394 | .1673 | .1721 |
| linea alba (10) | 65 | 35 | .3321 | .1171 | .2150 |
| eyelid (2) | 77 | 23 | .3306 | .0774 | .2532 |
| chest,mid line (7) | 62 | 38 | .3100 | .1184 | .1917 |
| ear lobe (19) | 69 | 31 | .3095 | .0955 | .2140 |
| u.l. back (15) | 57 | 43 | .2829 | .1229 | .1600 |
| mid line,back (12) | 49 | 51 | .2559 | .1297 | .1260 |

*Legend on pages 18 and 19

TABLE VI

FIFTY SELECTED ANATOMIC SITES ARRANGED IN ORDER OF MEAN LINEAR MEASUREMENTS OF RETE RIDGES

| ANATOMIC LOCATION | (MEAN) NUMBER per .1mm | (MEAN) LENGTH (mm) | RANGE OF LENGTH |
|---|---|---|---|
| plantar heel (30) | 7 | .23 | .12 - .30 |
| p.met head I (34) | 9 | .12 | .08 - .14 |
| toe fold (35) | 9 | .10 | .09 - .12 |
| v.interphalangeal (48) | 10 | .10 | .07 - .16 |
| d.interphalangeal (47) | 9 | .09 | .04 - .12 |
| mid p arch (33) | 8 | .09 | .07 - .14 |
| distil finger (49) | 10 | .08 | .07 - .09 |
| interdigital finger(50) | 8 | .07 | .04 - .10 |
| knuckle (46) | 9 | .07 | .05 - .13 |
| volar hand (45) | 9 | .07 | .06 - .10 |
| achilles tendon (21) | 8 | .07 | .02 - .10 |
| wrist (43) | 8 | .06 | .05 - .07 |
| elbow (42) | 7 | .06 | .05 - .07 |
| d.great toe (36) | 7 | .06 | .03 - .09 |
| infra malleolus (32) | 5 | .05 | .03 - .10 |
| mid lat ear (18) | 7 | .05 | .03 - .06 |
| buttox (14) | 6 | .05 | .03 - .07 |
| axillar arm (9) | 6 | .05 | .02 - .06 |
| d.arch (39) | 5 | .04 | .02 - .06 |
| mid ankle (38) | 6 | .04 | .03 - .05 |
| infra patella (37) | 5 | .04 | .03 - .05 |
| supra patella (25) | 5 | .04 | .02 - .06 |
| penile shaft (17) | 5 | .04 | .02 - .05 |
| gluteal fold (16) | 6 | .04 | .02 - .08 |
| mid line,back (12) | 6 | .04 | .01 - .09 |
| groin (11) | 6 | .04 | .02 - .08 |
| ant. neck (6) | 5 | .04 | .02 - .08 |
| dorsal hand (44) | 4 | .03 | .02 - .05 |
| supra deltoid (40) | 5 | .03 | .02 - .06 |
| malleolus (31) | 5 | .03 | .01 - .67 |
| post. leg (29) | 3 | .03 | .02 - .08 |
| tibial crest (28) | 3 | .03 | .02 - .05 |
| lat. thigh (26) | 3 | .03 | .02 - .08 |
| ear lobe (19) | 6 | .03 | .03 - .05 |
| mid line,back L (13) | 7 | .03 | .01 - .06 |
| linea alba (10) | 5 | .03 | .02 - .06 |
| chest,mid line (7) | 4 | .03 | .02 - .05 |
| chin (5) | 3 | .03 | .01 - .04 |
| post. neck (3) | 2 | .03 | .03 - .04 |
| scalp (1) | 2 | .03 | .00 - .11 |
| mid thigh (27) | 2 | .02 | .02 - .03 |
| ant. thigh (24) | 2 | .02 | .03 - .04 |
| popliteal space (23) | 3 | .02 | .02 - .06 |
| post. thigh (22) | 3 | .02 | .02 - .07 |
| u.l. back (15) | 4 | .02 | .02 - .03 |
| eyelid (2) | 2 | .02 | .02 - .03 |
| inner arm (41) | 1 | .01 | .01 - .03 |
| inner elbow (20) | 2 | .01 | .01 - .04 |
| cheek (4) | 1 | .01 | .00 - .04 |

the eyelid is consistently found at the bottom of the sequentially ordered lists. Generally, all sites examined tended to be placed in essentially the same order regardless of which epidermal feature was under analysis. The apparent trends required the data be subjected to statistical evaluation.

STATISTICAL METHODOLOGY

An Overall Appraisal of Human Epidermal Measurements: Analysis by Correlation Coefficient and Scattergram.

Correlation Coefficient - An increase in total epidermal thickness is usually accompanied by an increase in the length of the rete ridges. The thickness of the stratum corneum appears frequently to increase directly with total epidermal thickness. The suprapapillary stratum Malpighii exhibits similar, but less pronounced trends. In order to evaluate the significance of these findings, standard methods of determining correlation coefficients were applied (Garn, 1958). All of the available data from the fifty sites in the six bodies studies were compiled. The individual epidermal features studied (thickness of stratum corneum, suprapapillary stratum Malpighii and total epidermis together with the length of rete ridges) were tested one against the other. In each instance, a significant positive correlation was demonstrated (Table VII). While the table speaks for itself, attention is drawn to the strong correlation of total epidermal thickness and/or stratum corneum with the length of the rete pegs of the stratum Malpighii. This observation provides a mechanism for increasing the number of cells involved in the process of differentiation (keratinization) within the stratum Malpighii.

TABLE VII

| Portion of Epidermis Under Study | Stratum Corneum (C) | Stratum Malpighii (M) | Total Epidermis (E) | Length of Rete Pegs |
|---|---|---|---|---|
| Stratum Corneum (C) | ---- | 0.687 (r)* ** | 0.993* (r) ** | 0.883 (r)* ** |
| Stratum Malpighii (M) | | ---- | 0.755 (r)* ** | 0.693 (r)* ** |
| Total Epidermis (E) | | | ---- | 0.918 (r)* ** |
| Length of Rete Pegs | | | | ---- |

* Correlation Coefficients Between Epidermal Components

** Significance at 1% level

Thickness modulations of the stratum corneum are directed by rete peg length and suprapapillary stratum Malpighii dimensions. Thickness of the total epidermis reflects the overall efficiency of keratinization activity. Thus, correlation coefficients, as they apply to the several epidermal features, reflect their developmental interdependence.

Scattergram Analysis - Additional insight into the overall characteristics of human epidermis are provided by the scattergrams (Figs. 1 and 2). The mean values of the measurements of the epidermal features studied from sites 1 through 50 were calculated (Table 1). The range of the observed means and the areas of greatest occurrence for any given measurement now become apparent. Fig. 1 tests the length of rete ridges which may vary from 0.01 to 0.23 mm against stratum corneum and total epidermal thickness as they vary from less than 0.05 mm to 0.60 mm. The broad spread of the thickness of stratum corneum and total epidermis related to the length of rete pegs in Fig. 1 approaches linearity and for reasons cited earlier may be cautiously interpreted as one of causation. The range of thickness of suprapapillary stratum Malpighii is limited to .05 mm ranging from .02 to .07 mm and the correlation is not as strong as for the total epidermis or stratum corneum related to the rete peg length. Using the scattergram, however, it is possible to estimate the thickness of the epidermal stratum from the length of the rete pegs.

Fig. 2 considers the mean thicknesses of stratum corneum, suprapapillary stratum Malpighii and total epidermis, testing one against the other. As with the preceding study, correlations approaching linearity can be observed. The total epidermis and stratum corneum exhibit wide

Fig. 1

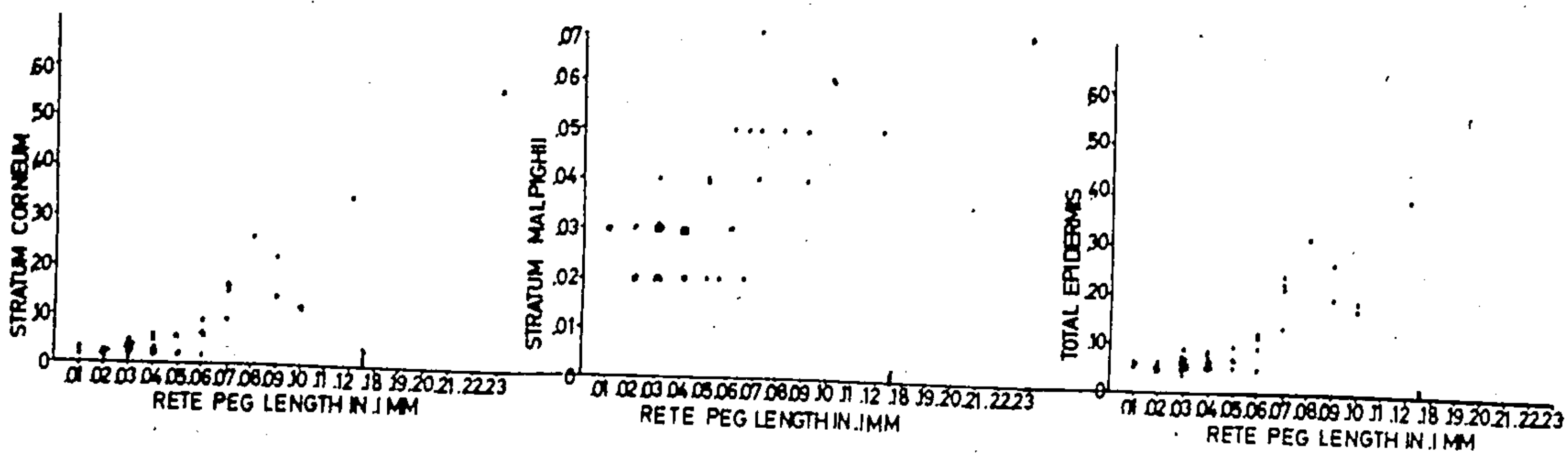
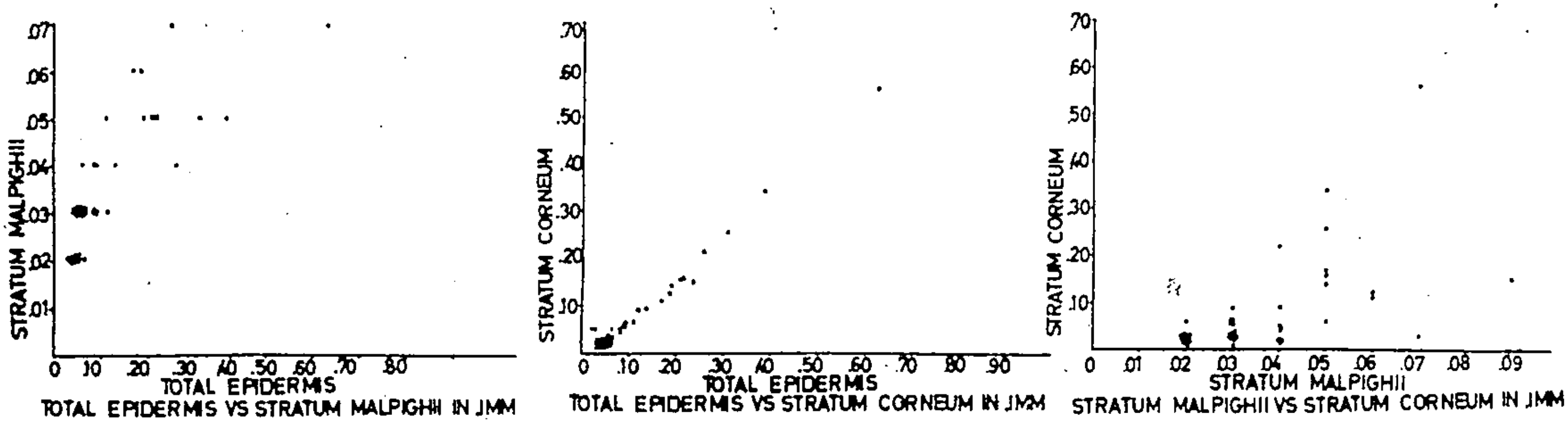

STRATUM CORNEUM
RETE PEG LENGTH IN .1 MM
STRATUM MALPIGHII
RETE PEG LENGTH IN .1MM
TOTAL EPIDERMIS
RETE PEG LENGTH IN .1 MM

Fig. 2


STRATUM MALPIGHII
TOTAL EPIDERMIS
TOTAL EPIDERMIS VS STRATUM MALPIGHII IN JMM
STRATUM CORNEUM
TOTAL EPIDERMIS
TOTAL EPIDERMIS VS STRATUM CORNEUM IN JMM
STRATUM CORNEUM
STRATUM MALPIGHII
STRATUM MALPIGHII VS STRATUM CORNEUM IN JMM

dispersion of points from less the .05 mm to .60 mm. The scattergrams demonstrate a heavy clustering towards the lower part of the range of mean measurements representing all fifty sites studied. The norm for epidermis or its component parts is .10 mm or less total thickness. About 25% of the mean values for fifty sites studied, however, lie beyond this range. They constitute the harder working tissues involved in flexion and extension or weight bearing. These points, none the less, lie predictably along a linear path of the graph and it remains possible to predict the thickness of total epidermis or its component strata only if one of the variable epidermal features is known.

The stratum Malpighii above the papillary plate is about .07 mm at its greatest thickness as compared with .70 mm for the stratum corneum (mean measurements). The narrower spread of values for the suprapapillary stratum Malpighii exhibits a significant positive (though less pronounced) correlation in the scattergram allowing estimation of total epidermis or stratum corneum thickness if the dimension of the suprapapillary stratum Malpighii is known.

Thus far the analysis of the fifty sites studied has involved observed individual or mean measurements applied to epidermis as a generalized entity. It now becomes necessary to analyse the epidermis as it functions mechanically to test the hypothesis that skin morphology varies in response to these external demands.

## Analysis of Epidermal Features Restricted to Functional Groups and Expressed as Histograms

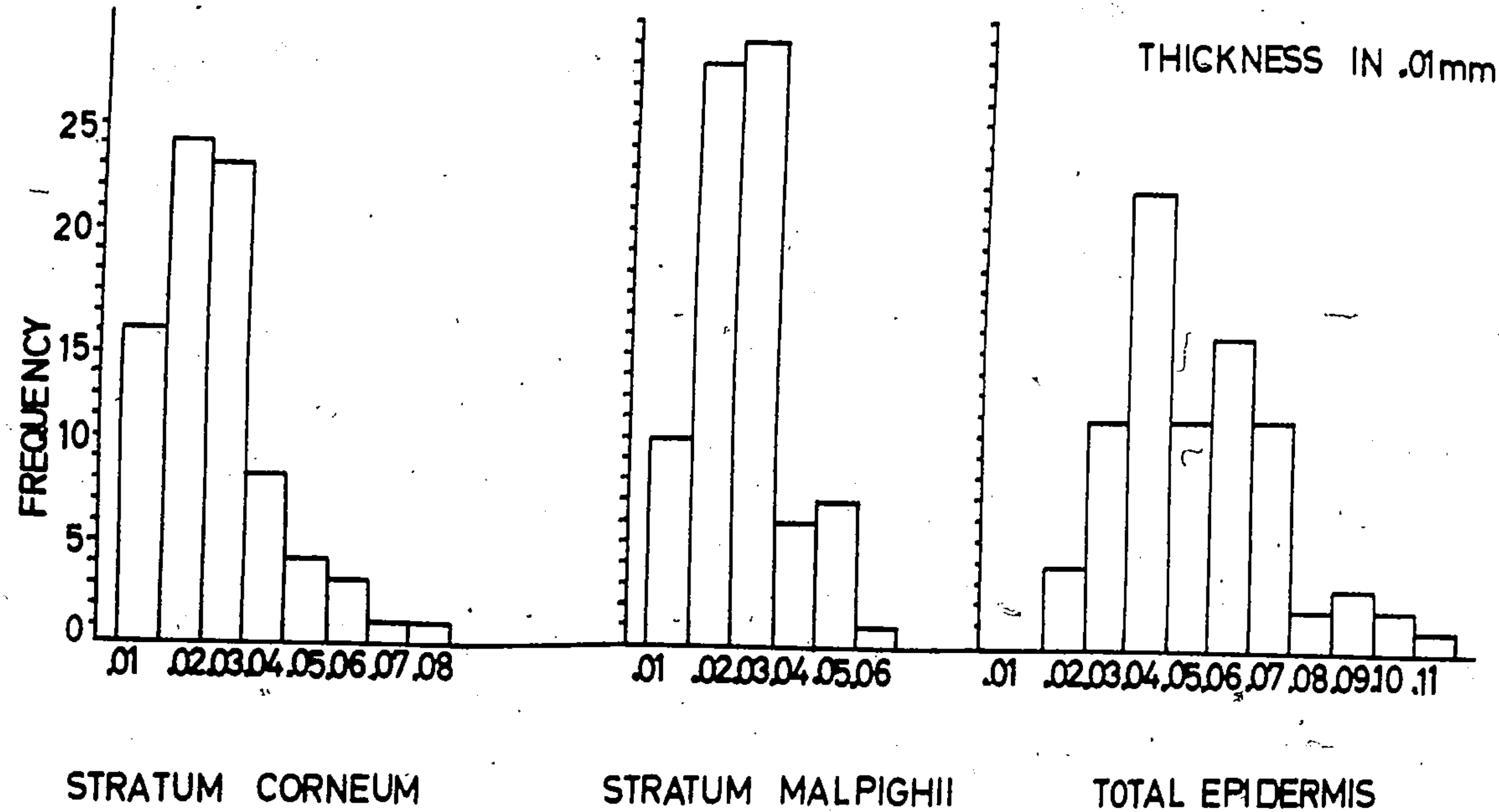
It is likely that the morphology of the epidermis reflects its functional characteristics (McCarthy and Habowsky, 1972). In order to logically study this premise, skin from various body regions was divided into six groups according to their mechanical roles. They were; coverings (flat and rounded), anchoring, special (penis and eyelid), flexing and weight bearing. Histograms were prepared comparing stratum corneum, suprapapillary stratum Malpighii and total epidermal thickness to the frequency at which each epidermal feature occurred. A similar study was made involving rete peg length and number per mm as to their frequency of occurrence. The frequency took into account each individual measurement of the several epidermal features from each of the six bodies under study for each anatomical site assigned to a particular functional classification. For example, in Fig. 3, the histogram comparing the epidermal features in those sites described as covering, there were 16 measurements (occurrences) of the stratum corneum at the .01 mm level, 24 at the .02 mm thickness and so on.

Figs. 3 through 8 compare the range and peaks of occurrence (frequency) of the thicknesses of epidermal features within the six different skin functional groups. Where coverings (flat and rounded), anchoring and the special types (penis and eyelid) were involved, the thickness of the total epidermis seemed to huddle in a narrow range (Figs. 3 - 6). The stratum corneum grouped about .02 mm values (Figs 3 through 6) but the weight bearing surfaces (Fig. 7) had its greatest frequency of occurrence at the thickness level of .31 mm and the flexion surface grouped about the .06 mm thickness (Fig. 8). Apparently, the work of weight bearing increases the stratum corneum 10 to 15 times that of more "passive" skin,and flexion and/or extension activity requires a lesser but still noticeable 3 fold expansion of the stratum corneum as compared with less active skin surfaces. The stratum Malpighii showed a similar increase, but to a lesser degree (about two fold increase for weight bearing and flexing types of skin as opposed to the more passive types).

Figs. 9 through 14 compare the number and length of the rete pegs by the histogram method identifying the range and peaks of occurrences (frequency) of these two variable among the six functional groupings. The same trends observed in the measurement of epidermal strata continue to be reflected in this study. Again, weight bearing epidermis showed the most marked shift toward increased length of rete Malpighii (Fig. 13) making it necessary to employ a scale extended to .30 mm. Rete length in epidermis involved in flexion and extension showed the second widest range as occurrences of up to .15 mm were reached. The more passive skin types again huddled in a range under .10 mm length of rete pegs with the greatest frequency of occurrence being in the .03 to .06 mm range.

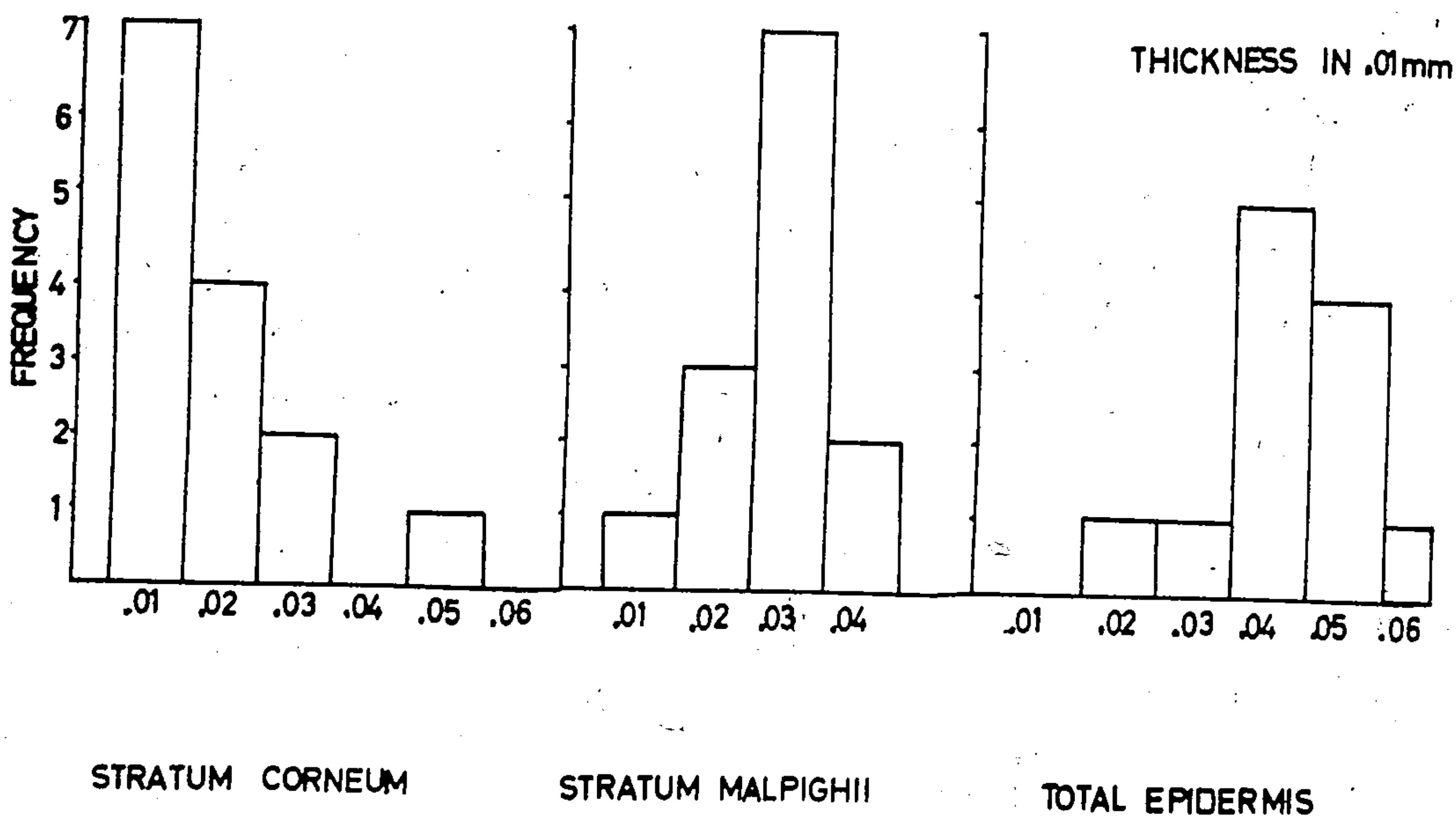
Histograms reflect overall range and peaks of occurrence (frequency) for measured values on individual cases (Appendix B compilation). It is possible to generalize from the data. Mean values calculated from individual measurements of the epidermal features under study and functionally grouped are summarized in Table VIII. This defines central tendencies within the groups as a whole, but of course tends to mask some of the extreme values. Weight bearing and flexion groupings of epidermis

Fig. 3



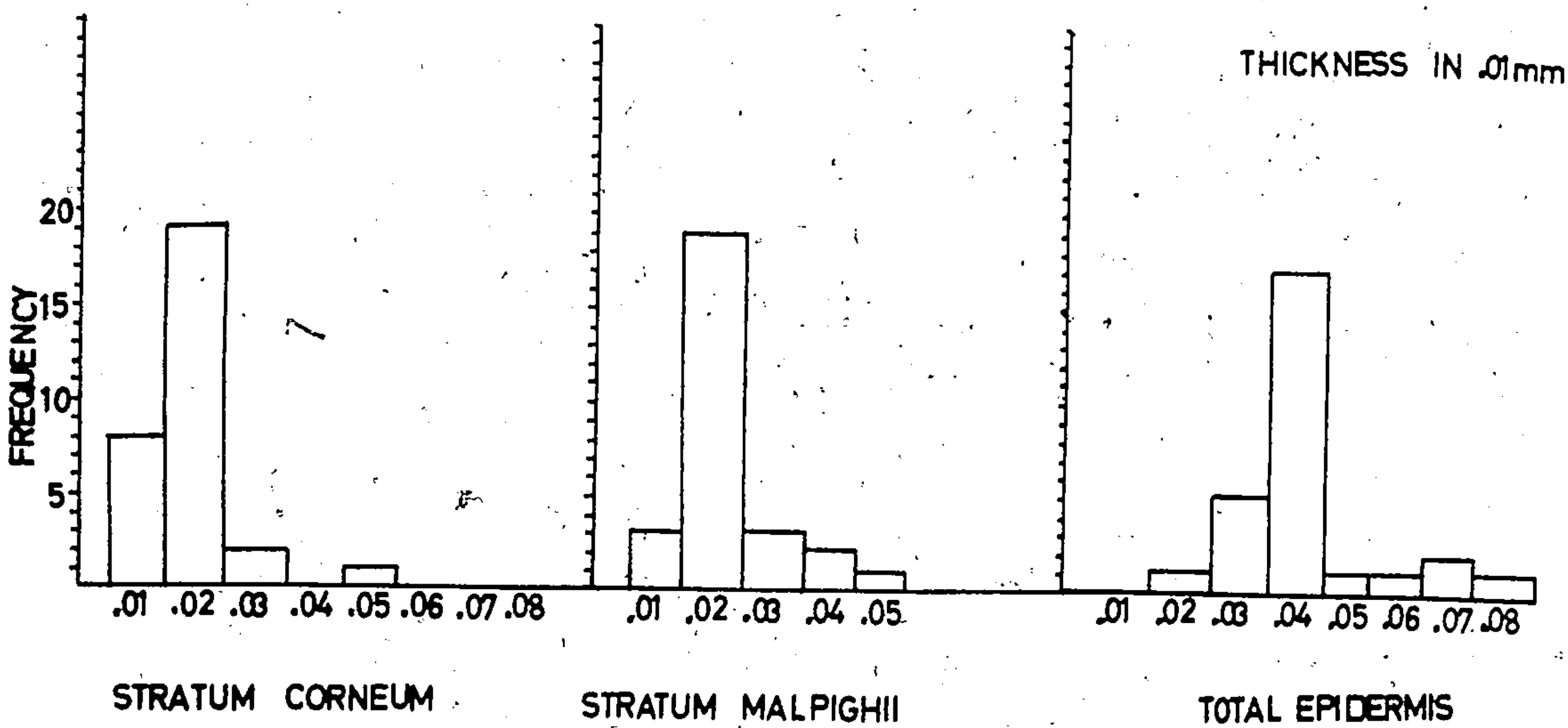

SKIN INVOLVED IN COVERING

Fig. 4



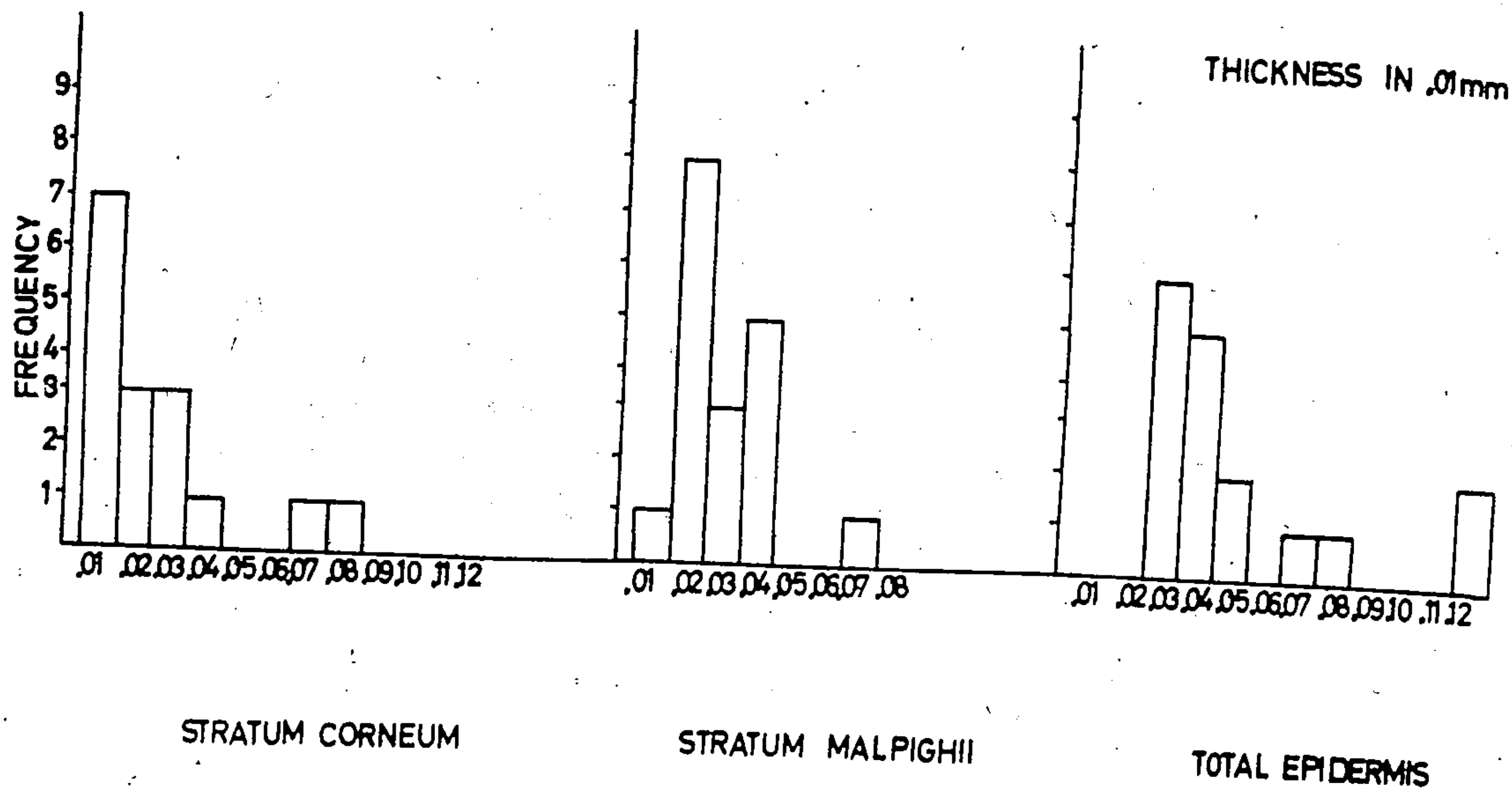

SPECIAL SKIN TYPES

Fig. 5



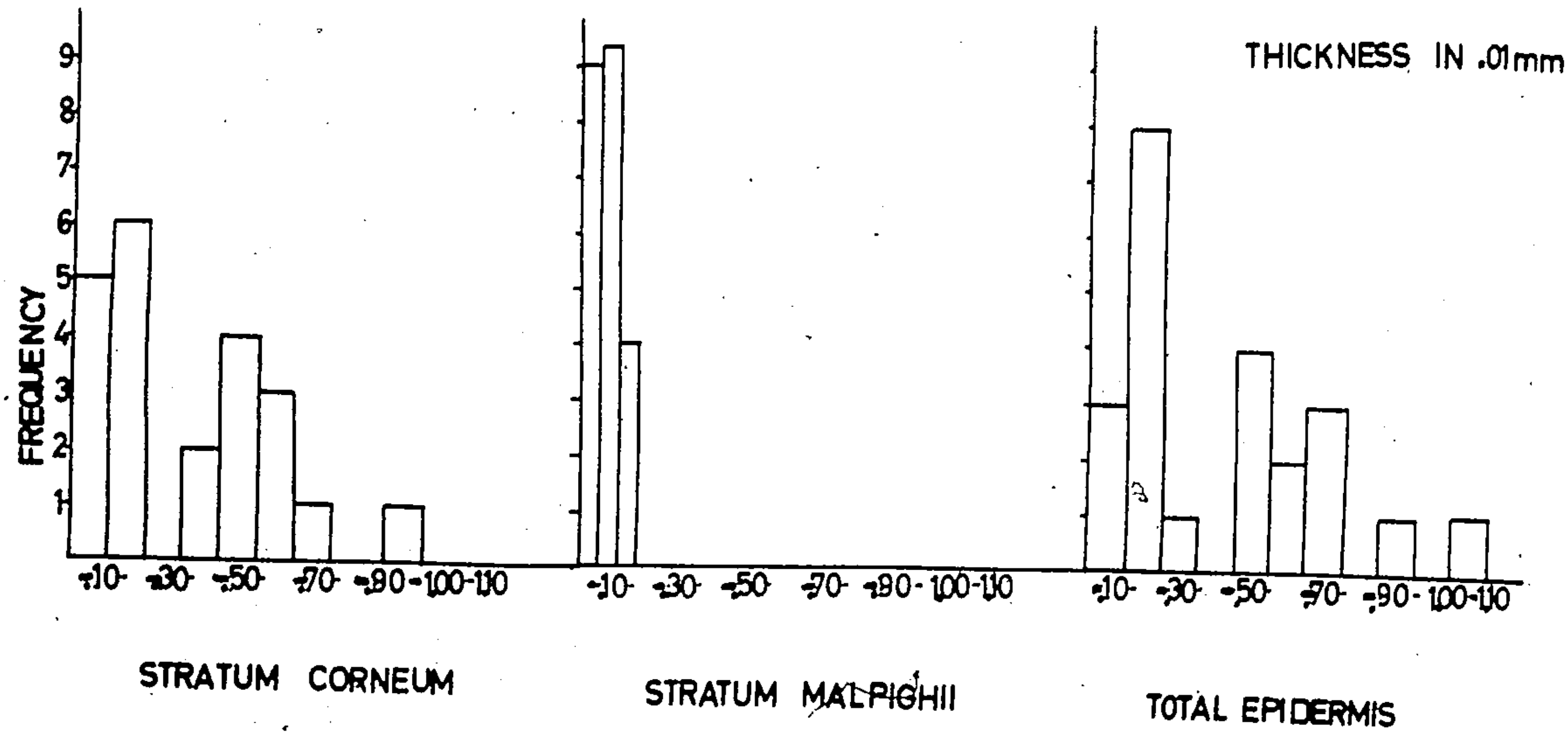

FIRMLY FIXED OR ANCHORING SKIN TYPES

Fig. 6



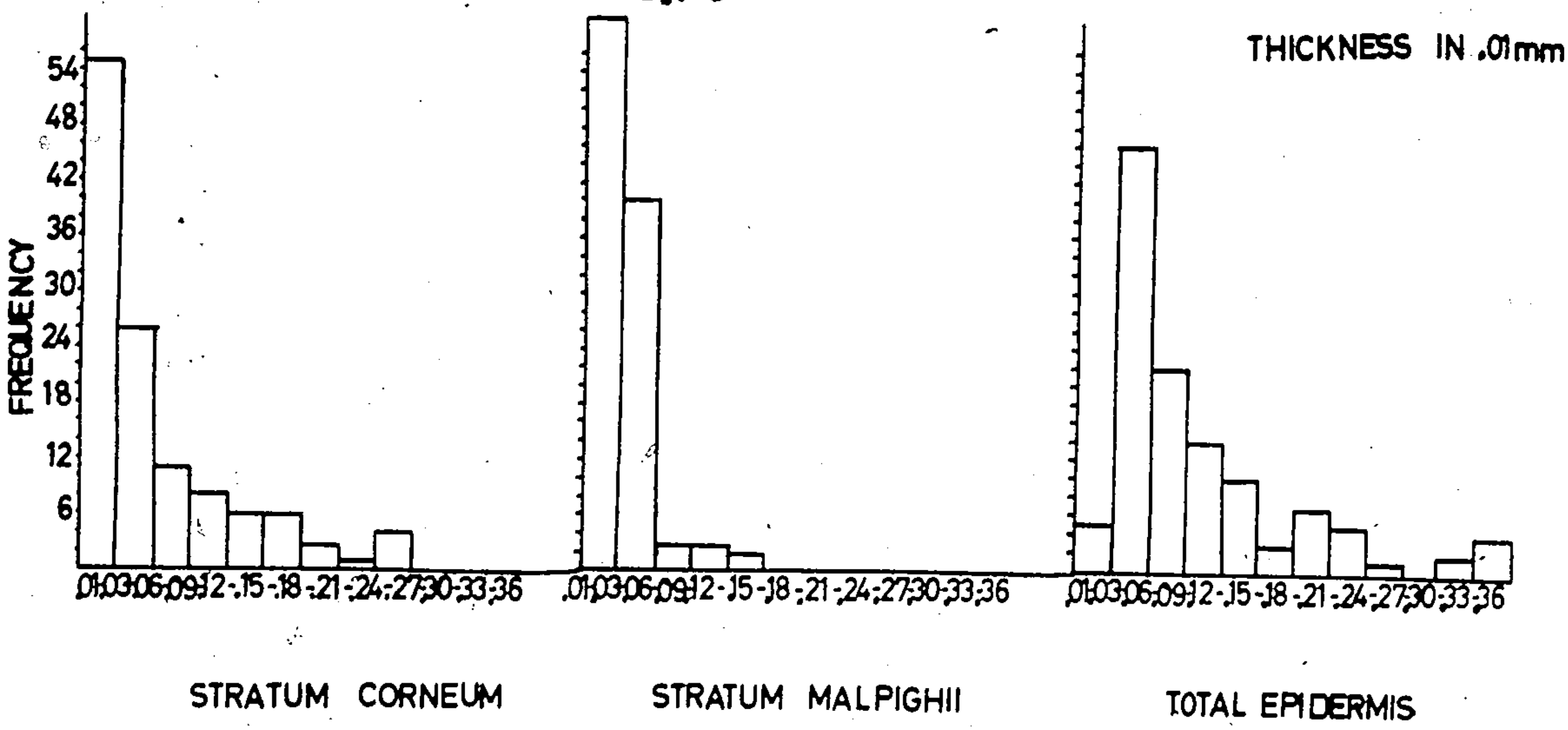

SKIN COVERING ROUNDED SURFACES

Fig. 7




SKIN INVOLVED IN WEIGHT BEARING

Fig. 8




SKIN WITH FLEXING FUNCTION

Fig. 9

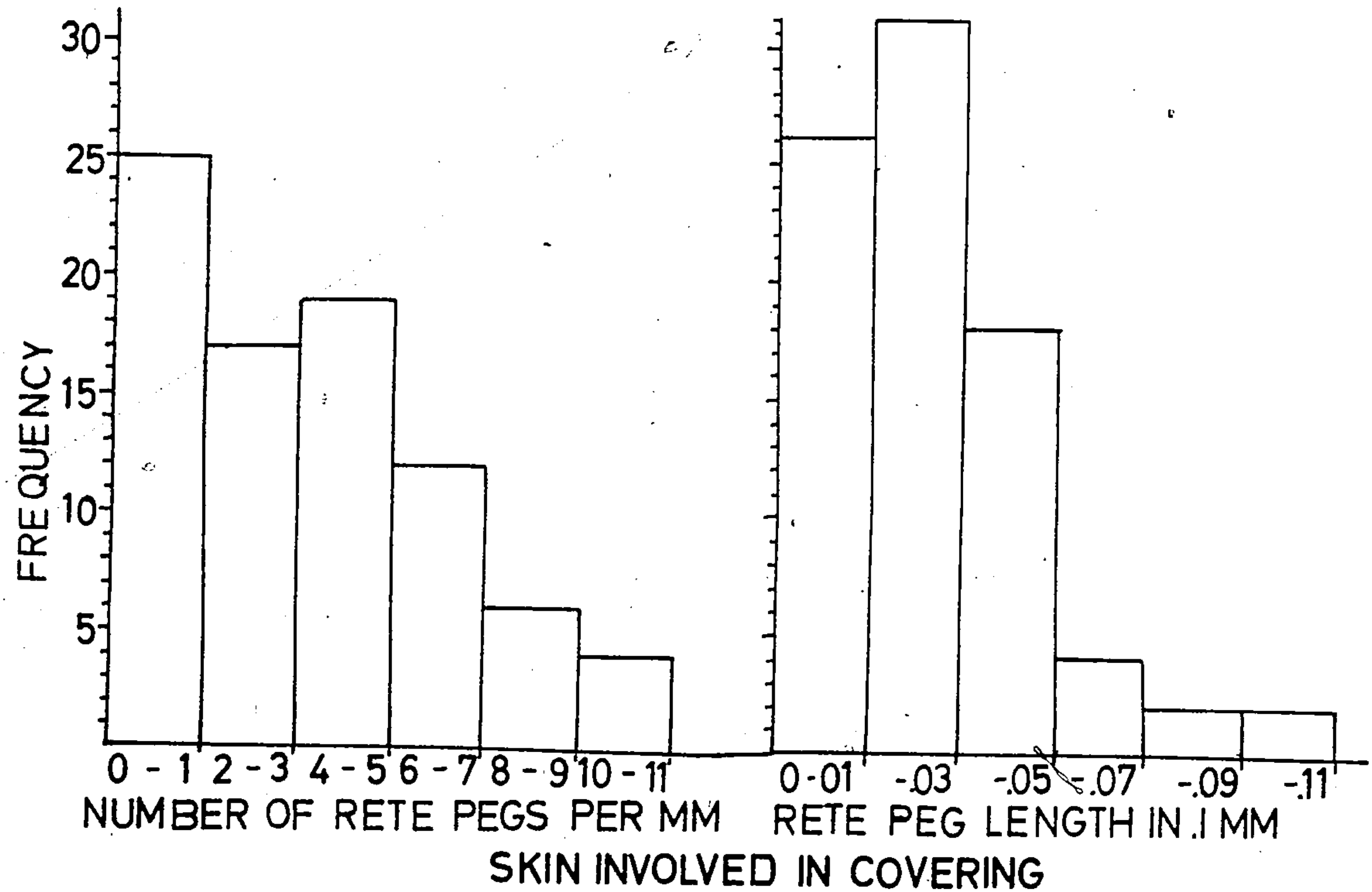
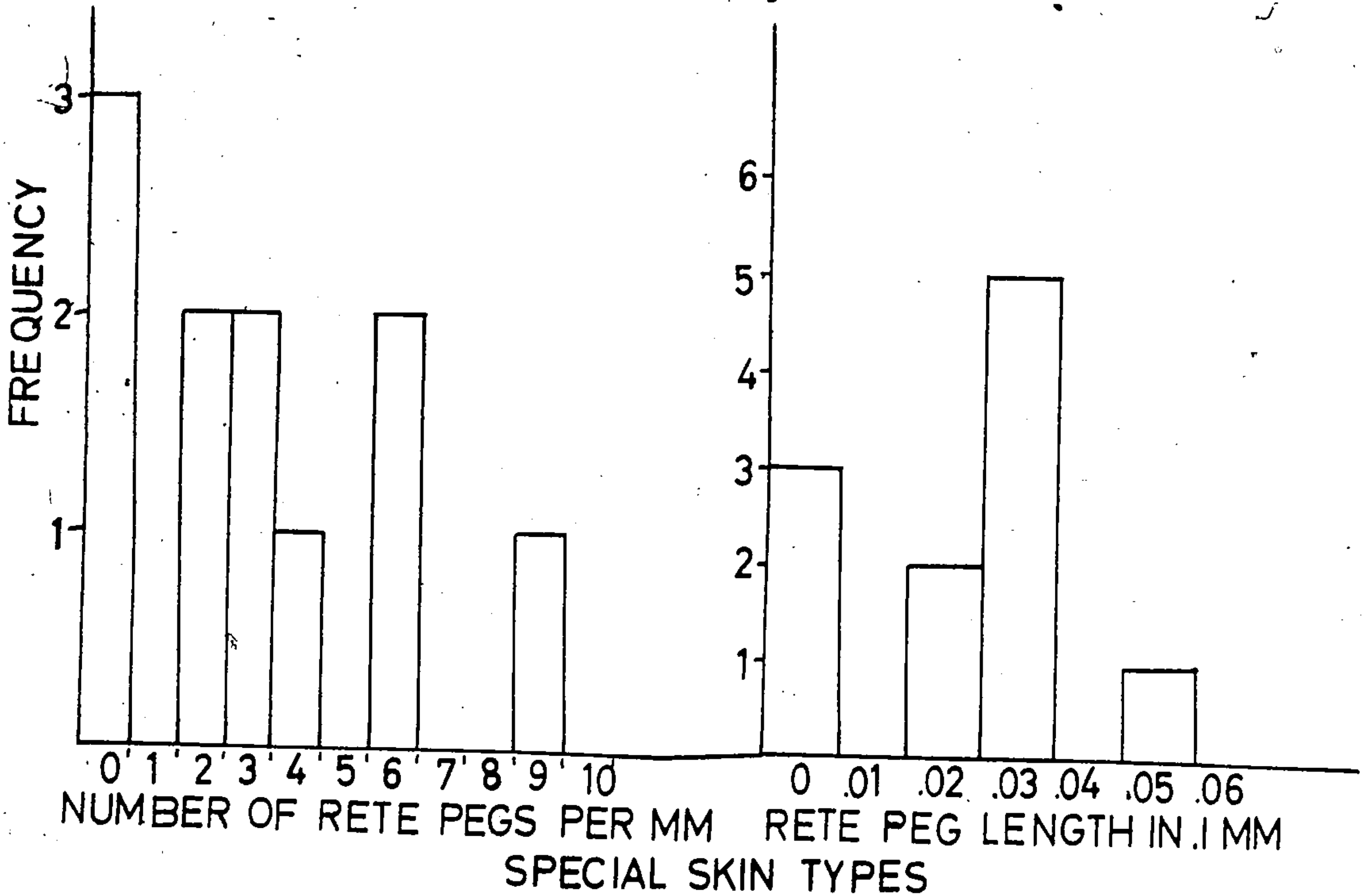

30
25
20
15
10
5
FREQUENCY
0 - 1
2 - 3
4 - 5
6 - 7
8 - 9
10 - 11
NUMBER OF RETE PEGS PER MM
0-01
-.03
-.05
-.07
-.09
-.11
RETE PEG LENGTH IN .1 MM
SKIN INVOLVED IN COVERING

Fig. 10



FREQUENCY
3
2
1
0 1 2 3 4 5 6 7 8 9 10
NUMBER OF RETE PEGS PER MM
6
5
4
3
2
1
0 .01 .02 .03 .04 .05 .06
RETE PEG LENGTH IN .I MM
SPECIAL SKIN TYPES

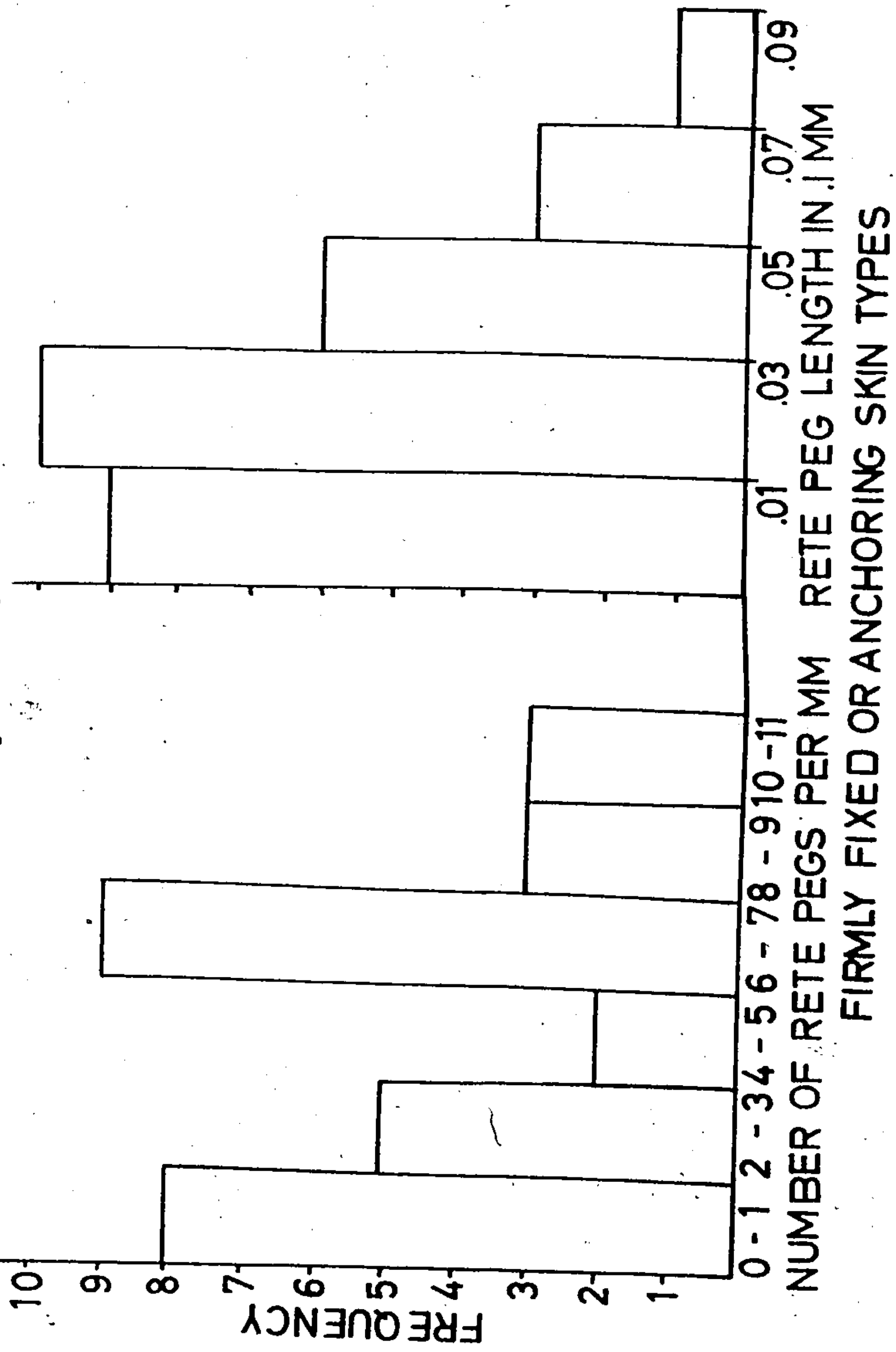
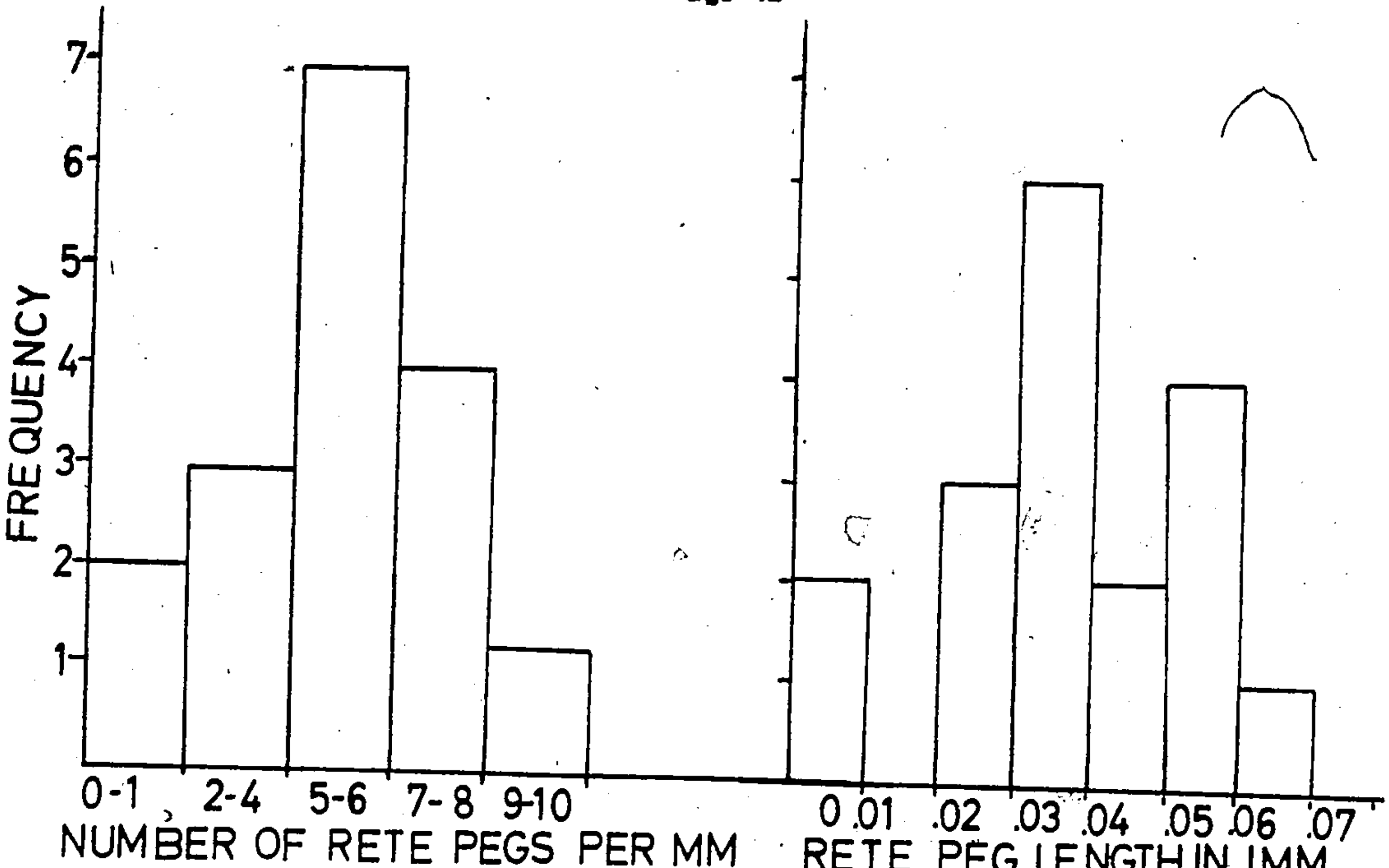

FREQUENCY
10
9
8
7
6
5
4
3
2
1
0-1 2-3 4-5 6-7 8-9 10-11
NUMBER OF RETE PEGS PER MM
.01 .03 .05 .07 .09
RETE PEG LENGTH IN .1 MM
FIRMLY FIXED OR ANCHORING SKIN TYPES

Fig. 11

Fig. 12




SKIN COVERING ROUNDED SURFACES

Fig. 13

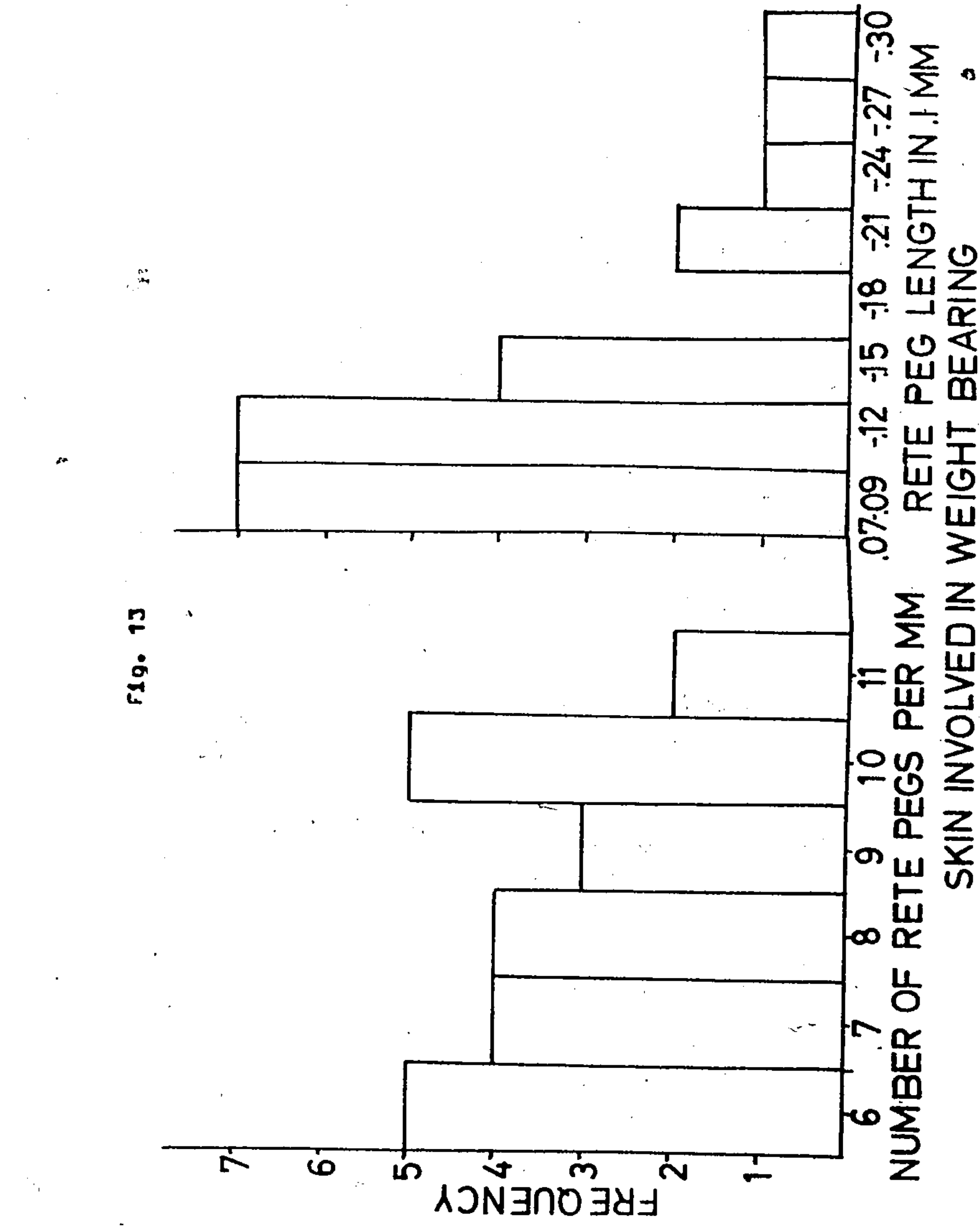
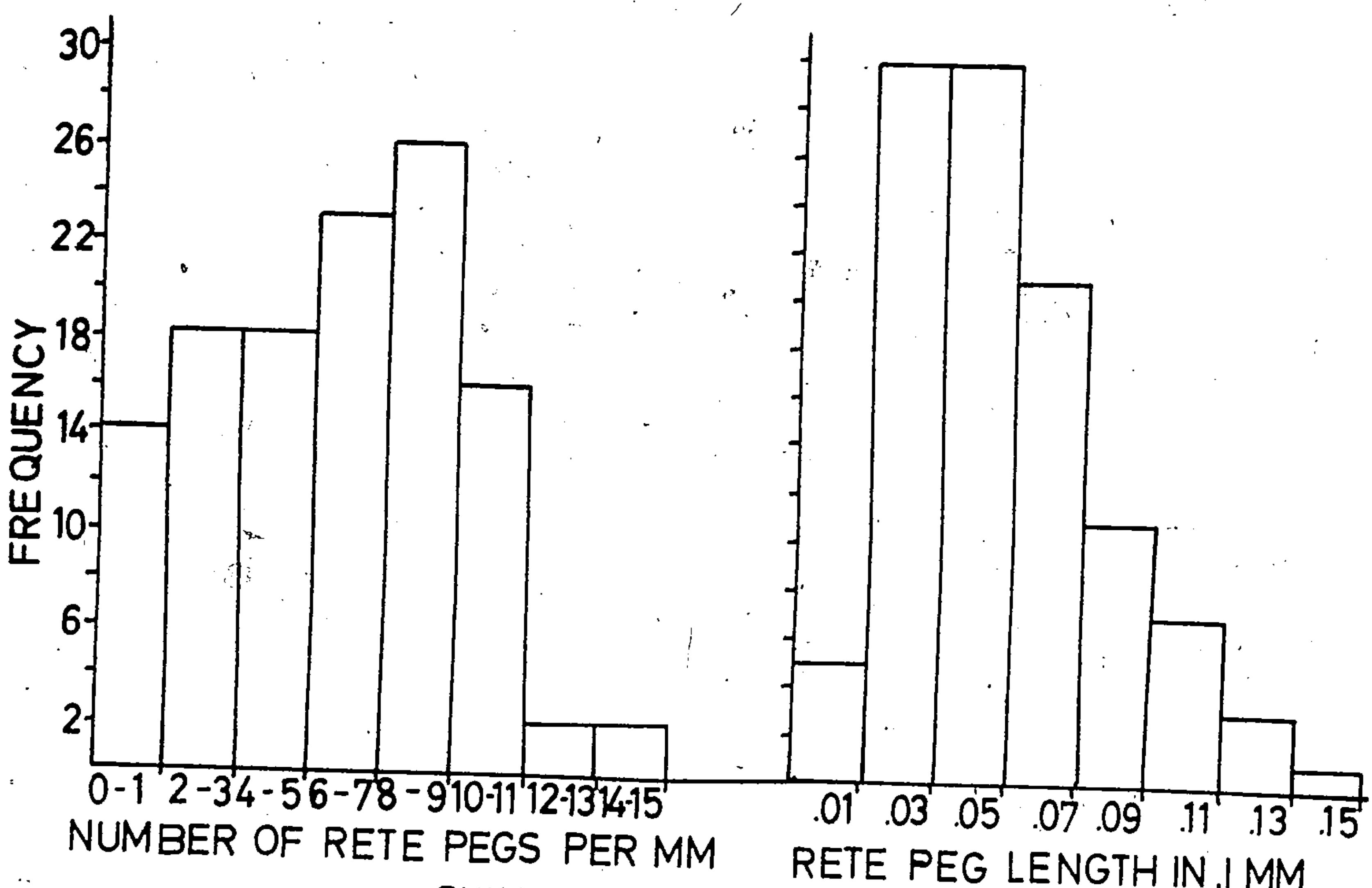

FREQUENCY
1
2
3
4
5
6
7
6 7 8 9 10 11
NUMBER OF RETE PEGS PER MM
.07 .09 .12 .15 .18 .21 .24 .27 .30
RETE PEG LENGTH IN .1 MM
SKIN INVOLVED IN WEIGHT BEARING

Fig. 14




SKIN WITH FLEXING FUNCTION

TABLE VIII

| Skin Types / MEASURED VALUES | Weight Bearing | Coverings | Special | Anchoring | Rounded Coverings | Flexor Surfaces |
|---|---|---|---|---|---|---|
| **Stratum Corneum** | | | | | | |
| $\bar{X}$ | .31 | .027 | .015 | .020 | .024 | .067 |
| $S^2$ | .0658 | .000214 | .0000455 | .0000628 | .00437 | .00388 |
| $S$ | .2565 | .0146 | .00674 | .007927 | .0209 | .0623 |
| **Stratum Malpighii** | | | | | | |
| $\bar{X}$ | .0522 | .0269 | .0275 | .0225 | .0294 | .039 |
| $S^2$ | .000727 | .000129 | .0000568 | .0000787 | .000194 | .000486 |
| $S$ | .0270 | .01136 | .0075 | .00887 | .0139 | .0220 |
| **Total Epidermis** | | | | | | |
| $\bar{X}$ | .364 | .0518 | .043 | .042 | .053 | .103 |
| $S^2$ | .07518 | .000388 | .000111 | .000173 | .00102 | .00583 |
| $S$ | .2742 | .01969 | .0106 | .01315 | .03199 | .0763 |
| **Number of Rete Pegs** | | | | | | |
| $\bar{X}$ | 8.26 | 3.602 | 3.182 | 4.467 | | 6.008 |
| $S^2$ | 3.202 | 9.608 | 8.3636 | 12.740 | | 11.598 |
| $S$ | 1.789 | 3.099 | 2.892 | 3.509 | | 3.406 |
| **Length of Rete Pegs** | | | | | | |
| $\bar{X}$ | .133 | .027 | .0218 | .028 | | .052 |
| $S^2$ | .00371 | .000586 | .000256 | .000566 | | .000848 |
| $S$ | .0609 | .0242 | .0160 | .0238 | | .0291 |

Measured Values of Epidermal Components in the Various Skin Types: Means and Standard Deviations again show distinct departure from the other more passive groups. If the stratum corneum is considered, weight bearing sites are 15 to 20 times greater in thickness than passive sites. Flexion sites are about 3 times thicker.

The stratum Malpighii presents a mean thickness of .05 mm, twice that of the passive epidermal types, when compared to weight bearing. Flexion surfaces demonstrate an increased thickness of stratum Malpighii of .04 mm compared to .03 mm average for the passive types overall.

Mean total epidermal thickness of weight bearing skin types is 7 or 8 times as thick as the passive groups while flexion surfaces are twice as thick.

The mean number of rete pegs in weight bearing surfaces is twice that of the passive group. The mean occurrence of pegs in flexion surfaces is 6 compared with 4 for the surfaces involved in coverings (flat and rounded) special and anchoring types.

Rete peg length in weight bearing sites averages .13 mm compared with .03 mm in passive groups, a four fold increase. Length of flexor surfaces is double that of the passive skin types (.05 mm) but only 1/3 the length average for weight bearing surfaces.

Thus, the observed data indicate that regardless of which of the several epidermal features are considered, the external demands occasioned by weight bearing or flexion produce an increased thickness all dimensions (total epidermis or its component strata and/or number and length of rete ridges). These alterations are all the more noticeable when individual variations are considered within the particular cases individually

A Comparison of Variability of Epidermal Feature Thickness in Different Sites

From Regions of Varying Function

| Location | stratum corneum thickness $\bar{X}$ | stratum corneum thickness $s^2$ | stratum corneum thickness s | stratum Malpighii thickness $\bar{X}$ | stratum Malpighii thickness $s^2$ | stratum Malpighii thickness s | total epidermial thickness $\bar{X}$ | total epidermial thickness $s^2$ | total epidermial thickness s |
|---|---|---|---|---|---|---|---|---|---|
| A **Weight Bearing** | | | | | | | | | |
| plantar heel | .56 | .0118 | .1088 | .073 | .0013 | .0361 | .630 | .0138 | .1176 |
| 1st m.p. | .34 | .1129 | .3360 | .050 | .0007 | .0026 | .388 | .1301 | .3607 |
| arch | .22 | .0367 | .1915 | .038 | .0001 | .0109 | .256 | .0344 | .1856 |
| plantar toe | .11 | .0014 | .0380 | .047 | .0003 | .0186 | .153 | .0020 | .0470 |
| B **Neck** | | | | | | | | | |
| post. neck | .022 | .00097 | .0098 | .025 | .00007 | .00837 | .043 | .00011 | .0103 |
| ant. neck | .034 | .00023 | .0152 | .028 | .00007 | .00837 | .062 | .00052 | .0228 |
| C **Upper Extremity Flexion** | .093 | .00503 | .0708 | .041 | .00048 | .022 | .134 | .0068 | .0830 |
| grasping | .148 | .00497 | .0704 | .053 | .00072 | .026 | .198 | .0069 | .0835 |
| thumb web | .163 | .0044 | .0662 | .048 | .00026 | .016 | .212 | .0056 | .0746 |
| D **Lower Extremity flexion** | .045 | .00168 | .0410 | .034 | .00053 | .0230 | .070 | .0033 | .0574 |
| post. ankle | .153 | .0046 | .068 | .090 | .0043 | .0656 | .243 | .0081 | .0902 |
| gluteal fold | .018 | .00002 | .0045 | .018 | .00087 | .0083 | .036 | .00013 | .011 |

E

Significant Differences as Demonstrated by "t" Testing Among Functional Groups

| | stratum corneum | stratum Malpighii | total epidermis | rete length |
|---|---|---|---|---|
| wt.bearing vs covering | 9.5714 | 6.5609 | 10.053 | 12.434 |
| wt.bearing vs flexion | 8.8548 | 2.511 | 8.751 | 9.786 |
| flexion vs covering | 5.5466 | 4.5233 | 5.865 | 6.2639 |

Table IX

(Appendix B) or among the differences between sites collectively making up a particular functional group. It must be observed that the standard deviations accompanying the mean values (Table VIII) for the several epidermal features under study as they occur among the six functional skin categories are of considerable magnitude. This suggests that the means might not be significantly different. Results of a "t" test showed, however, that the differences were statistically reliable (Table IXE). P for all values then was .001 except for weight bearing vs. flexion test of 2.511 where it was .05, still statistically different, however.

At the same time, no statistical difference between even the most different values among the passive skin types was observeable.

stratum corneum of covering vs special: "t" = 2.8629 (n.s.)
Stratum Malpighii of anchoring vs special "t"= 1.663 (n.s.)
Rete Length of special vs anchoring "t" = .8053 (n.s.)

It was on this basis that covering skin types were tested as representative of passive skin types against the active flexing and weight bearing groups. Weight bearing skin sites revealed marked heterogeneity, but the means observed from the various sites within this functional group are consistent with what is to be expected for the degree to which the site is involved in the weight bearing activity. It is obvious that the plantar heel, for example, bears more weight than the plantar aspect of the toe. (Table IXA). It can be said in general that weight bearing skin surfaces have much greater thickness of total epidermis and stratum corneum than passive skin groups. Within the weight bearing group itself significant difference predictably occurs (Table IX). Results of "t" tests show the plantar aspect of the toe (site 35) $\bar{X}$=.11 mm, differs significantly from the plantar aspect of the heel (site 30) $\bar{X}$=.56 mm (8.758 p=.001).

Differences among the six cases dissected provide the greatest degree of heterogeneity among each of the four functional weight bearing sites selected when compared to the passive skin sites where less variability is the rule. It is reasonable to expect that in each individual the four weight bearing sites were subjected to varying degrees of use in terms of body weight, activity, etc. with the result that observed thicknesses are especially variable at this point.

A similar analysis can be made with the flexion-extension data in which the mean epidermal thickness is .103 mm, more than twice the thickness of the passive epidermal types. The standard deviation of .0763 indicates considerable heterogeneity as well. The data was subdivided into head and neck, upper and lower extremities for a more particular analysis. The head and neck showed thin values of epidermal components (Table IX,B). No significant differences between the anterior and posterior flexing surfaces of the neck is evident ("t" =1.655 (n.s.)).

If the flexing surfaces of the upper extremity are tabulated it is again clear that variable functioning of parts results in a predictable heterogeneity of the data. Among the ten sites, it is immediately clear that those surfaces involved in grasping activity are responsible for the skew, and that the thickest measurements are found in the interdigital web of the apposable thumb. (Table IX, C). Significant difference is demonstrable between grasping and non grasping flexor surfaces: ("t" = 4.208 p = .001).

The lower extremity data demonstrates a skew largely due to high values for the flexing surface of the posterior ankle at the insertion of the tendon of Achilles. At this site, the part is involved with transmission of weight in walking and standing and varying degrees of irritation from shoe counter as well as in the act of flexing. Again, the increased thickness is predictable and is significantly different from less mechanically pressured regions such as the flexing surfaces of groin or gluteal fold. The total epidermal thickness of gluteal fold is significantly different from that of the posterior ankle although both flex members of the lower extremity where "t" = 4.342 p= .001.

The foregoing data demonstrate a predictable heterogeneity within the functional groups themselves as well as between different bodies at the same point. It is to this variation that the present study is addressed. The mean values for a given site and for the functional groups are useful to indicate certain central tendencies. Weight bearing does significantly increase the thicknesses of the component epidermal strata in direct relationship to the amount of weight born. Similarly, flexing surfaces increase their thickness of component epidermal features in response to the amount of work demanded of the part. Grasping regions of the hand and the much used posterior ankle place the skew to the mean data for flexion surfaces as a whole by their noticeably increased thickness values.

Individuality of Human Epidermis from Site to Site Demonstrated by <u>Pattern Analysis</u>

The statistical analysis of epidermis thus far has considered first the skin in its entirety; correlation coefficients and scattergram distribution. Secondly, a comparison of six different functional skin groups employing histograms and means (Table VIII) of the epidermal features of importance to the present study was made. In general, an increase in thickness of epidermal strata, number and length in rete ridges was noted as functional demands of weight bearing, flexing and extending were made upon skin sites. It must be reasoned, however, that no two skin sites operate identically, and if the assumption is made that function influences morphology of the epidermis it follows that variation within certain limits should, indeed, be the norm. Most data are complicated by a degree of variability, and this study is no exception. Fifty sites are under study and each site has a range of observed thickness values. In order that these problem be resolved or accommodated, the use of pattern analysis (Garn, 1955) has been employed. This method permits comparison of measurements of numerous unrelated variables by fixing the respective data on the abscissa axis of a graph with site location positioned on the ordinate. When the numerous points are joined by lines, a pattern is formed enabling comparison of the variables (total site thickness or relationship of the component strata within). Mean values for each of the fifty sites studied have been used in the preparation of the patterns to follow. Biological interrelationships between the epidermal features being studied could be suspected if patterns were strikingly similar. Subsequent graphs will demonstrate noticeably corresponding patterns. Figs. 15, 16 17 and 18 demonstrate by the respective patterns formed the extremely variable nature of epidermis from site to site. The sites are indicated numerically on the abscissa of the graph and may be identified by number from the map provided in the section on materials and methods. At the same time, certain similarities are in evidence.

Fig. 15 demonstrates the number and length of the rete pegs to be a highly variable feature among the fifty different sites plotted. The number of rete,however, seems to be directly proportional to length since the patterns follow one another very closely. It should be recalled that the increase in both number and length of rete reflects an increase in cell number by increasing area which permits additional differentiation activity within the Malpighian layer which ultimately produces an increased thickness of stratum corneum. If patterns of Fig. 16 (thickness measurement) are visually compared with or superimposed upon Fig. 15 it is clear that the patterns are remarkably similar. Fig. 16 further relates thickness of Stratum Malpighii and stratum corneum with total epidermis. It is clear in the tabulation of mean values provided in Table VIII that tissues towards the thinner limits of total epidermis have relatively greater amounts of stratum Malpighii than of stratum corneum. The ratio reverses in favor of stratum corneum as total epidermis increases and this is graphically illustrated in Figs. 16 and 17. Pattern analysis reveals a great degree of variability in comparisons of each functionally different site. The total epidermis and/or the component Malpighian and cornified layer thickness ratio also is subject to variation from site to site.

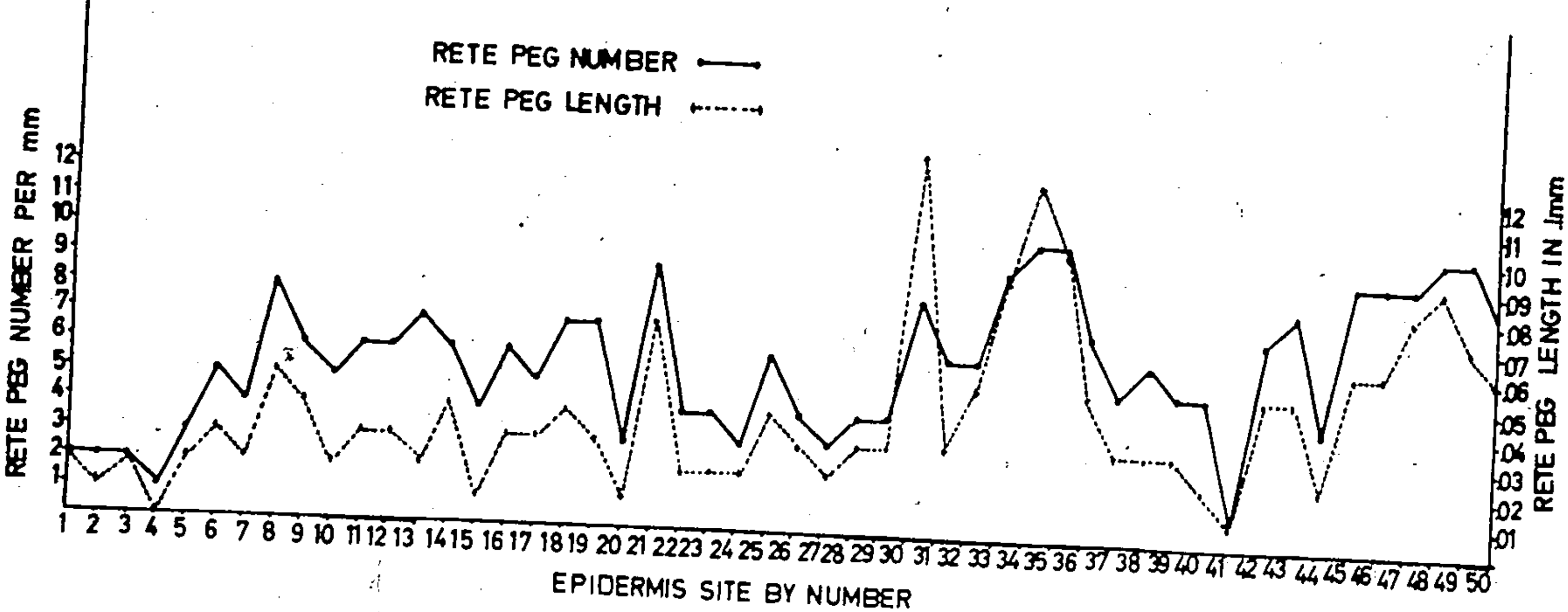
A pattern analysis was made comparing relative areas of total epidermis and component portions of stratum Malpighii (including rete pegs) and stratum corneum according to weight as described in the section on Materials and Methods. With only minor alterations, the pattern of the relative area proved almost identical to the thickness plot (Fig. 16). It may be reasoned from this that thickness measurements are as reliable as indicator as the laborious area determination by relative weights of strata for comparison of the activity of differentiation of the stratum Malpighii and the net result of that activity, the cornified stratum corneum.

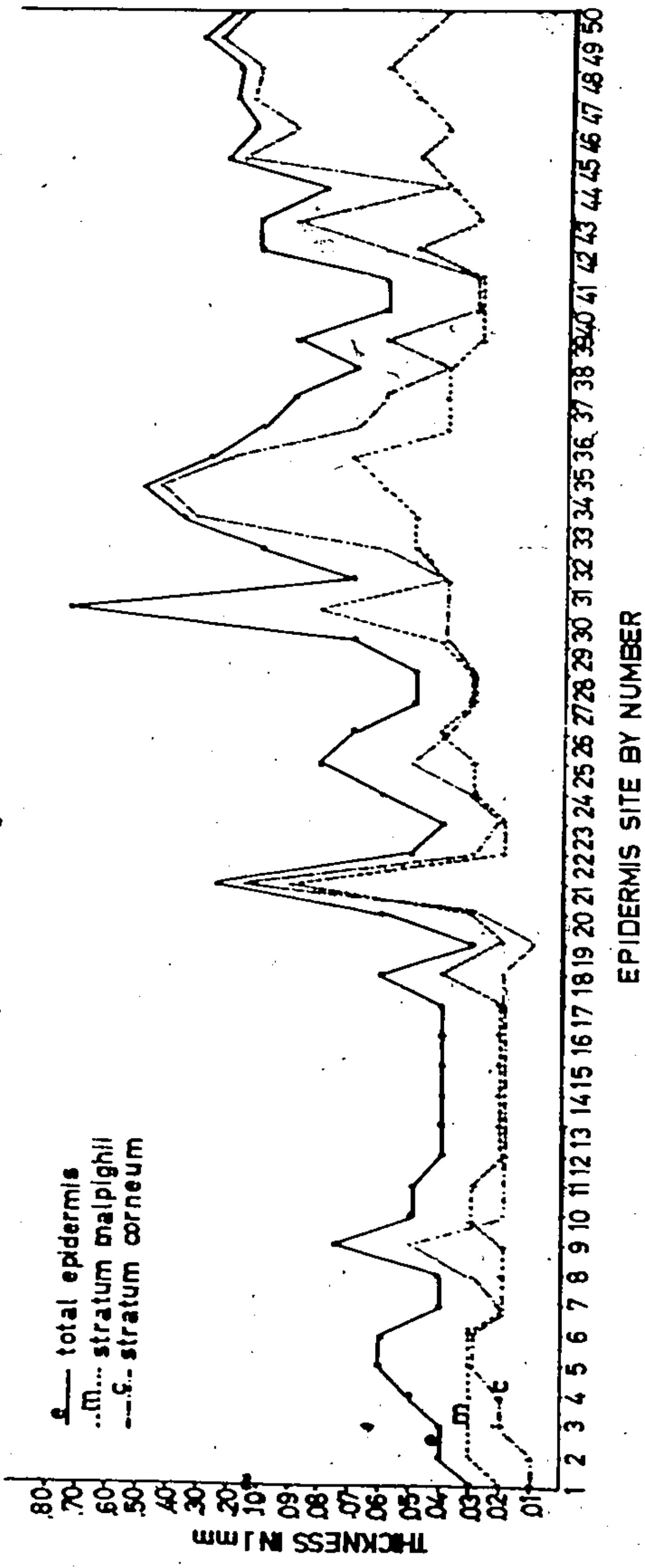
Percentage values calculated for stratum Malpighii on the left ordinate and stratum corneum on the right with site identification by number on the abscissa indicated essentially similar patterns for values derived from thickness measurement or area determinations based on comparative weights.

Analysis of Epidermal Features for Significant Difference

Irrespective of thickness involved from place to place in human epidermis, an analysis for statistically significant variation employing standard "t" testing can be made. Several approaches to such testing can be drawn from the data at hand. Comparisons of mean values for stratum corneum, suprapapillary stratum Malpighii and total epidermis along with length of rete pegs have already been discussed for the functionally different skin groups. Equally meaningful testing between different sites within the groups could be made, as well as comparisons between individual cases at the same anatomical location. It is felt, however, for purposes of this discussion that the most meaningful selection for "t" testing of

Fig. 15

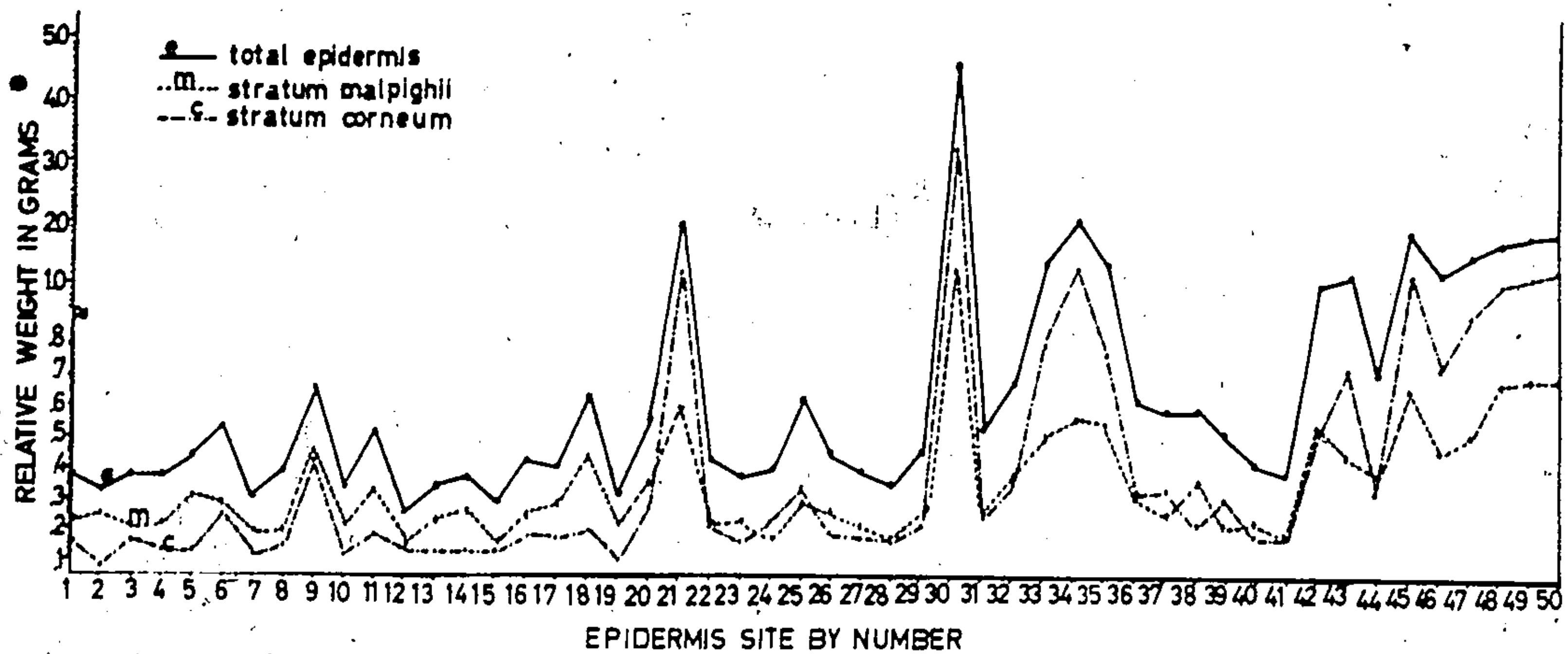

RETE PEG NUMBER
RETE PEG LENGTH
RETE PEG NUMBER PER mm
12
11
10
9
8
7
6
5
4
3
2
1
RETE PEG LENGTH IN mm
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
EPIDERMIS SITE BY NUMBER



e total epidermis
..m... stratum malpighii
---c.. stratum corneum
THICKNESS IN 1 mm
EPIDERMIS SITE BY NUMBER

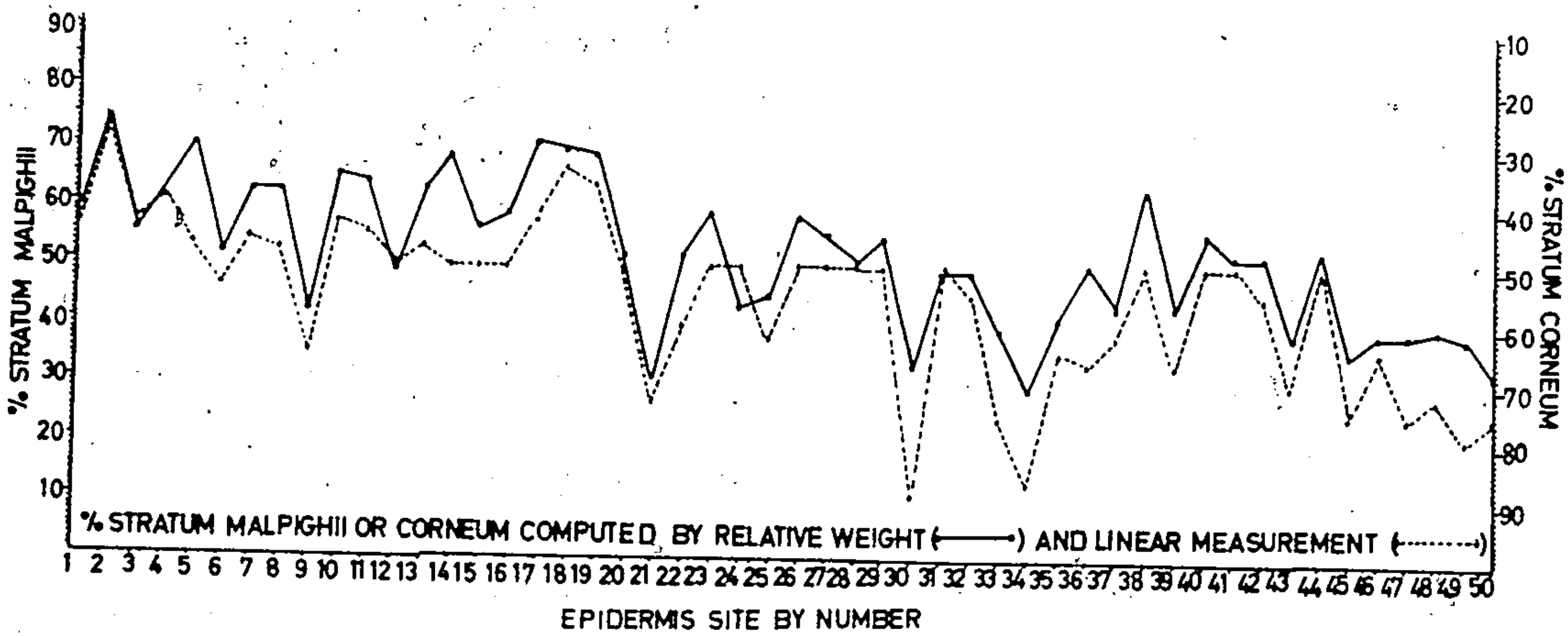

Fig. 16

fig. 17




* Reflects cross section area

Fig. 18


% STRATUM MALPIGHII
% STRATUM CORNEUM
% STRATUM MALPIGHII OR CORNEUM COMPUTED BY RELATIVE WEIGHT (———) AND LINEAR MEASUREMENT (--------)
EPIDERMIS SITE BY NUMBER

the data would relate significant shifts of the relative thickness of the several epidermal features within the functional group. The premise put forth in this thesis is that the morphology of epidermis varies in response to external functional demands. It has been observed that most of the sites observed (75%, Figs. 1 and 2) have total epidermal thickness in the narrow range of .04 to .08 mm thickness with the stratum Malpighii and stratum corneum about equally divided. These strata, as they constitute the total epidermis along with the rete pegs reflect an essentially even distribution between the differentiating stratum (Malpighian layer) and the totally differentiated stratum corneum in the orderly developmental process of keratinization. It is at the alteration of this balance as the different sites respond to external mechanical function, that the "t" test is directed. The stratum corneum, then, is tested against stratum Malpighii and total epidermis and length of rete pegs, and stratum Malpighii is tested against total epidermis and rete peg length. (Table X).

Significant differences between stratum corneum and the stratum Malpighii are found in the active weight bearing and flexion-extension skin groups ($p = <.05$). Skin grouped as covering (flat and rounded) and fixed or anchoring had "t" values in the range not statistically significant. The special tissues (eyelid and penis) characterized by flexibility showed significant difference, but evidenced a shift in favor of the stratum Malpighii since a reduction in thickness of stratum corneum would be desirable for this function.

In testing stratum corneum against total epidermis, significant differences were found as expected in the thinner tissues where stratum

TABLE X

| Skin Type / TEST | Coverings | Special | Anchoring | Rounded Coverings | Weight Bearing | Flexor Surfaces |
|---|---|---|---|---|---|---|
| S. Corneum vs S. Malpighii | t=.241 p= n.s. | t=4.0989 p=.001 | t=-1.2668 p= n.s. | t =-.3357 p= n.s. | t =+4.6881 p=.001 | t=+4.5539 p=.001 |
| S. Corneum vs Total Epithelium | t =-8.913 p=.001 | t=-7.291 p=.001 | t=-7.6136 p=.001 | t=-1.6511 p=n.s. | t=.6733 p= n.s. | t=-4.0016 p=.001 |
| S. Malpighii vs Total Epithelium | t=-9.815 p=.001 | t=-3.841 p=.001 | t=-6.4194 p=.001 | t=-2.8282 p=.01 | t =-5.306 p=.001 | t=-8.7478 p=.001 |
| S. Corneum vs Length of Rete Pegs | t=.1265 P= n.s. | t =1.2988 p= n.s. | t=1.7406 p=.10 | t =.4706 p= n.s. | t =3.149 p=.01 | t =2.370 p=.05 |
| S. Malpighii vs Length of Rete Pegs | t =.03345 p= n.s. | t =1.0689 p= n.s. | t =1.126 p= n.s. | t =-.4280 p= n.s. | t =-5.690 p=.001 | t =-3.777 p=.001 |

"t" Test For Comparison of Mean Values of Epidermal Components in the Various Skin Types

Malpighii was more prominent on a simple percentage basis. In the thick weight bearing tissues, "t" was not significant since the stratum corneum dominates the whole of the total epidermal thickness.

Stratum Malpighii showed significant differences with respect to total epidermis in all six functional skin types. This was to be expected since the stratum Malpighii, which is the layer involved in differentiation could not approach the mean value of epidermis reflecting the sum total of both strata. Again, the most significant values were for the more highly keratinized active tissues involved in weight bearing and flexion-extension of the skin.

Rete peg length reflects one method of increasing cell volume without increasing the area of the free surface of skin. It can, then, be an additional measure of the efficiency in the process of keratinization of a given epidermal site. Significant variations were sought for using rete peg length on one hand with respect to the stratum corneum (the completed cornified layer) and the stratum Malpighii (the layer undergoing differentiation) on the other (Table X).

The stratum corneum of coverings (flat and rounded) and the special skin types showed no significant differences when compared with their respective rete peg length. The stratum corneum of skin types grouped as weight bearing and flexion-extension demonstrated significant variation when compared with their respective rete peg length because of the especially marked increase of cornified layer. This thickness reflects the demands made on these tissues and the thickness is due in part to the increased number of cells contributed by the rete pegs.

No significant variation is noted between suprapapillary stratum Malpighii and rete pegs for any of the relatively thin epidermis involved with covering (rounded or flat) special and anchoring activity. This is not the case with the harder working epidermis of weight bearing or flexing skin types where the suprapapillary stratum Malpighii increases only slightly in thickness, but the rete pegs show marked elongation.

Significant variation can be established by "t" test, comparing stratum corneum and stratum Malpighii, total epidermis and papillary length one with another in the active weight bearing and flexing epidermal situations. This reflects the greater degree of differentiation required by the greater mechanical demands made on these two skin types. The exception is noted only where the stratum corneum is compared with total epidermis in weight bearing skin. The absence of significant variability is easily explained by the extreme keratinization making the stratum corneum predominant to an extreme in the total epidermis leaving minimal difference between the two measurements.

One principal biological role of the epidermis is keratinization, an orderly process involving differentiation in the cells of the stratum Malpighii and the completed process evidenced by the stratum corneum. Significant variability of epidermal features is consistent among the most active mechanically stimulated skin types.

## ANALYSIS OF HUMAN EPIDERMIS AND THE EPIDERMAL-DERMAL INTERFACE

### General Considerations in Evaluation of Tissues

Two principal methods, line drawings and photomicrographs, have been used in this thesis. The term "Site" refers by number to the anatomical location under study. "Case" designates the particular body being studied. Each site entails a study of anatomy, characteristics of the epidermis and the epidermal-dermal interface.

Functional Anatomy - The gross anatomy underlying the particular skin site under study as it relates to integumentary function precedes the descriptive part of the individual locations.

Epidermal Characteristics - Cases 1 through 6 are presented as light microscopic tracings and comparisons are made based on the thickness of stratum corneum and suprapapillary stratum Malpighii as well as length and occurrence of rete ridges (Table I&III)The particular site under study can be related to the study as a whole by its relative position in Tables IV, V and VI. The epidermal-dermal interface is seen in two dimensions as a sine curve. Reference to this structure is made as the sine interface.

Interface Characteristics - The epidermis and dermis are viewed in photomicrographs providing a three dimensional approach to the study of each site. Dermal papillae may be cone shaped or elongated ridges, both of which appear the same in cross section and so could lead to misinterpretation. This additional and novel approach eliminates this possibility. It is this three dimensional representation which is referred to as the interface. Throughout this thesis, the photomicrograph to the left of each site identified on the page is the epidermal portion of the interface. It is less subject to shrinkage and tends to remain flatter than the dermis. The photomicrograph on the right of each page throughout this thesis is the dermis, which is often quite revealing, but does not always provide a hand in glove relationship with the epidermis, due in part to artifact.

Site 1, Scalp

Functional Anatomy - The tissues examined were from the external occipital protruberance. The underlying musculature is sparse limited to the epicranius and the galea aponeurotica which allows only for a wrinkling effect.

Epidermal Characteristics - The scalp epidermis is found among the lower third in thickness of the 50 sites studied with the mean at .05 mm. Thickness ranged from .03 to .07 mm. Stratum Malpighii and stratum corneum are about equal in thickness. The rete peg range was 0 to 8 per mm with 2 per mm the mean. Mean length was .03 mm, but case 2, the bald individual exhibited an unusual .11 mm length.

Interface Characteristics - Scalp interface is characterized by a very low profile. This is not due to the absence of movement alone, but rather to the effect of hair follicles whose development requires most of the "diffusable dermal influencing factor." Hair follicles can be seen on the epidermal interface orienting in several directions. When hair is lost as was the situation in case 2 and to a lesser extent in case 6, rete pegs as shown by the sine interface are again strongly in evidence. The dermal interface was an almost flat sheet pitted occasionally for the reception of the numerous adnexa.

Site 2, Eyelid

Functional Anatomy - The firm underlying eyeball is protectively shielded by the eyelid which is thin and modified for rapid blinking movements governed by the levator palpebrae musculature below and aided by the orbicularis oculi about which allows for strong winking.

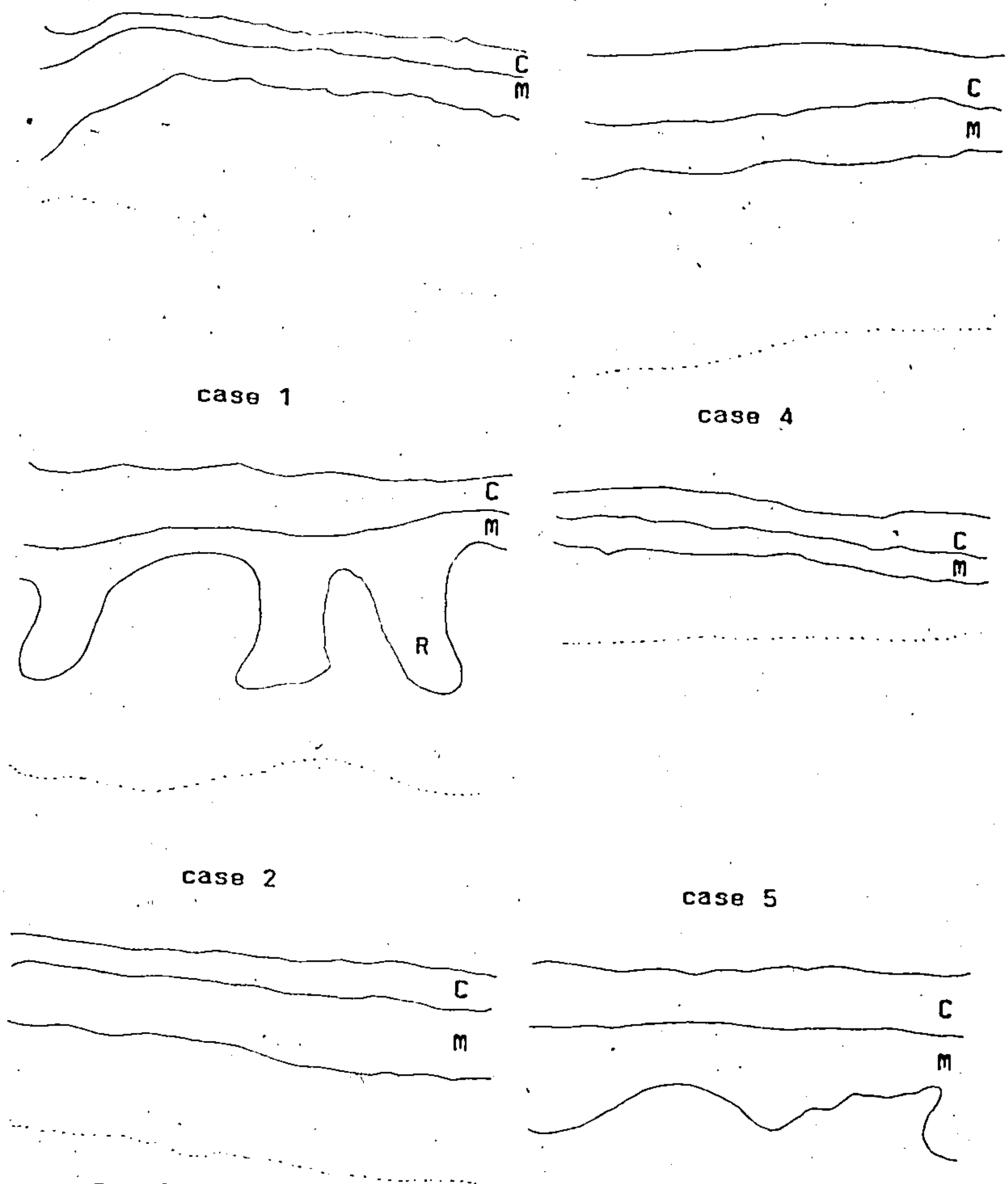
Epidermal Characteristics - The epidermis of the eyelid is found in the lower tenth in thickness of the 50 sites studies and ranged from .04 to .05 mm. There was a decided emphasis on the stratum Malpighii which constituted about 70% of the total thickness. It may be that the demands of rapidly blinking almost constantly during the waking hours requires that the epidermis be thin. The number of rete Malpighii ranged from 0 to 6 with a mean number of 2 per mm. The length of rete is small ranging from .02 to .03 mm when they did occur.

Interface Characteristics - Like the hairy surface of the scalp, the epidermal-dermal interface has an extremely low profile. Whereas a considerable amount of movement is characteristic, anchoring of the epidermis on the dermis is made by the numerous adnexa seen on the epidermal portion of the interface microphotograph. The sine interface of case 1 shows an infolding expected in this contractile and thin epidermis. The dermal interface is flat and is pitted for the reception of the numerous adnexa. There seems to be a tendency for microfolding as evidenced by numerous parallel striations.

Site 3, Posterior Neck Fold

Functional Anatomy - The specimen was from the deeply folded region where the odontoid process of the axis articulates with the atlas vertebrae. This site allows for strong dorsal and ventral flexion of the head and rotational movement as well. The skin section was from

Plate 1




C = Stratum corneum
M = Stratum Malpighii
R = Rete peg of the stratum Malpighii

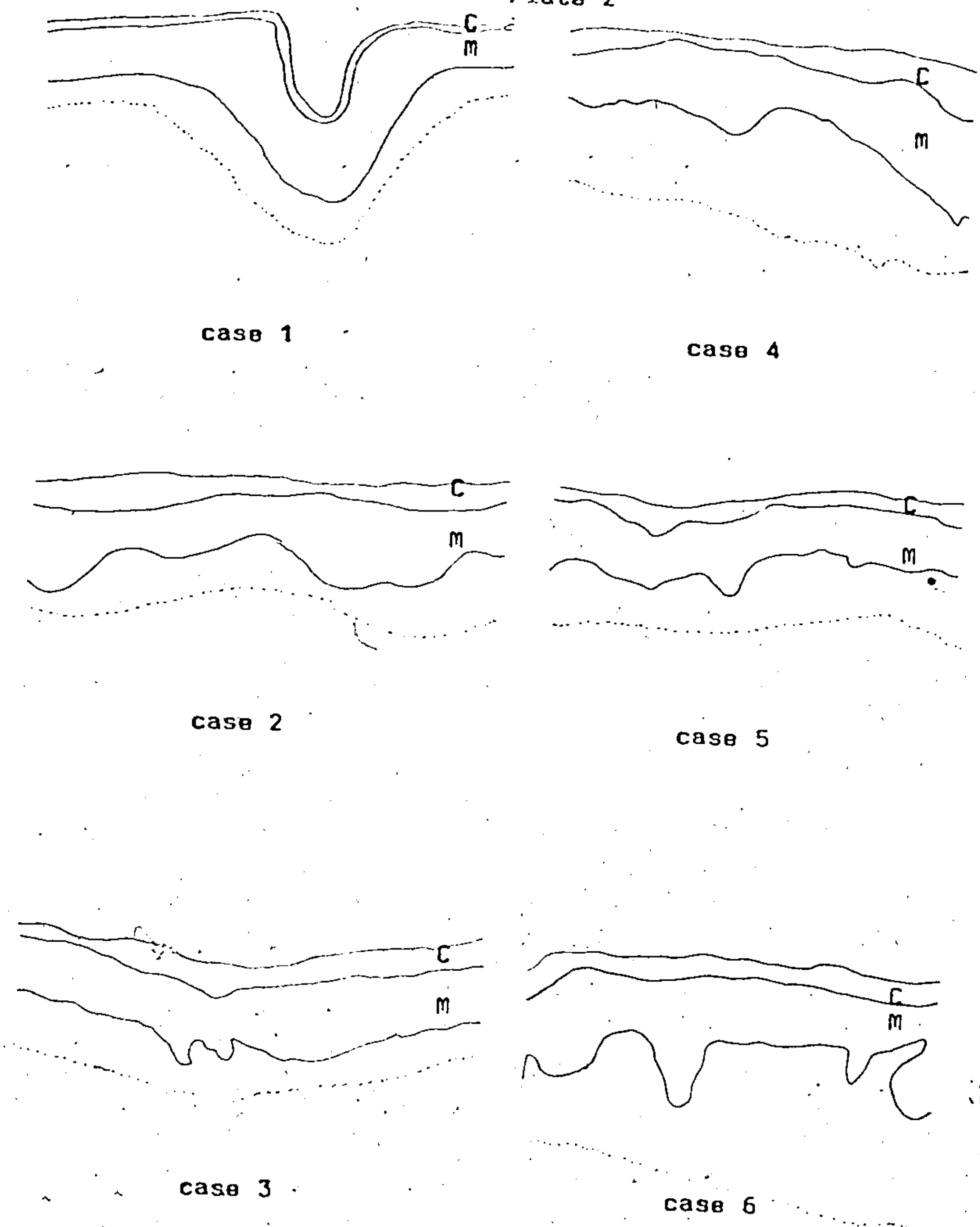
case 3

case 6

SITE 1, The Scalp

= .1 mm

Plate 2




Site 2, The Eyelid

SITE 1, THE SCALP

SITE 2, THE EYELID

between the ligamentum nuchae. The underlying splenius and trapezius muscles became fibrous as they approached their respective insertions on the occipital bone. This skin was surprisingly tough probably due to underlying connective tissue.

Epidermal Characteristics - Despite the apparent toughness on dissection, the thickness of epidermis itself is found in the lower third of epidermal sites studied. The range of .04 to .07 mm in thickness was observed, with an average of .06 mm. The stratum Malpighii tended to dominate (55%) the stratum corneum very slightly. The rete length ranged from .03 to .04 mm in length and the number of rete ranged from 0 to 3 per mm.

Interface Characteristics - The sine interface has a much folded appearance due in the main to the external folding. The interface structure is of low profile. The rete are seldom seen ranging from 0 to 3 per mm of sections examined. The length is correspondingly low with a mean length of .03 mm. The epidermal interface shows criss-cross striations with prominent girder-like ridges. The dermis is flat and pitted occasionally for reception of epidermal structures. Several cutaneous nerves lie obliquely on the section.

Site 4, Cheek

Functional Anatomy - Tissue from the cheek just inferior to the zygomatic bone is covering skin but has some slight movement from the action of the buccinator muscle principally used in mastication in concert with the zygomaticus major and minor musculature beneath. The bearded region of the face was avoided.

Epidermal Characteristics - The epidermis of the cheek was thin being among the lower third in thickness of all the sites examined. The total epidermis ranged in thickness from .04 to .07 mm with a mean value of .05 mm. The stratum Malpighii predominated representing 60% of the total thickness. The rete pegs were sparse with a mean occurrence of 1 per mm and were .01 mm in length. The range of occurrence was from 0 to 7 per mm, but the length never exceeded .04 mm.

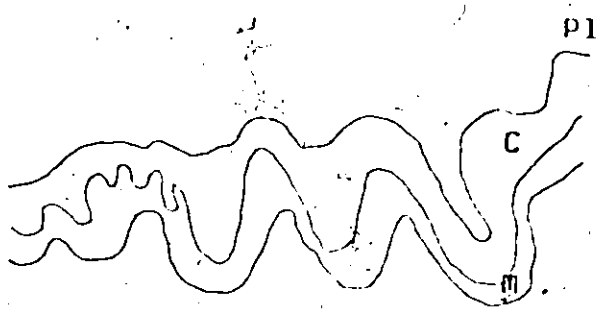
Interface Characteristics - The epidermal interface is flat with few rete pegs. Adnexa and hair follicles interrupt the otherwise unremarkable surface. The dermal interface is occasionally pitted for the reception of adnexa and several cross striations are seen which do not seem to have any counterpart with the epidermal interface. Little work other than covering is attributed to the portion of skin, and little structural individuality can be seen.

Site 5, Chin

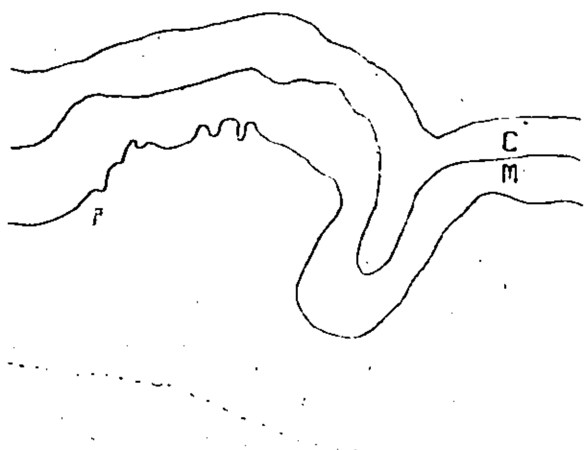
Functional Anatomy - Skin was excised from between the mental protruberances above the mandibular symphysis, below skin at this site is a rounded covering and has only slight movements. Contractions are from the small mentalis muscle and by the orbicularis oris in strong movement.

Epidermal Characteristics - The thickness of chin epidermis is found among the middle third of all skin sites examined. Total thickness ranges from .03 to .08 mm with the mean at .06 mm. The stratum Malpighii predominates in this relatively thin epidermal tissue where the stratum corneum is limited to about 40% of the total epidermal thickness. Rete pegs are relatively sparse and range from 0 to 5 in number per mm with

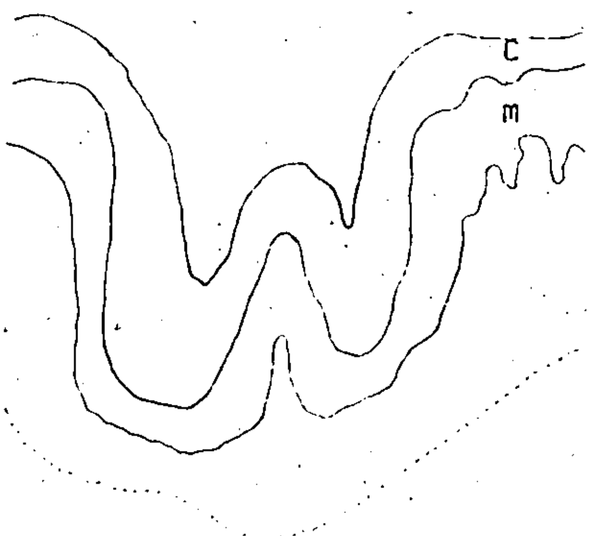
Plate 4



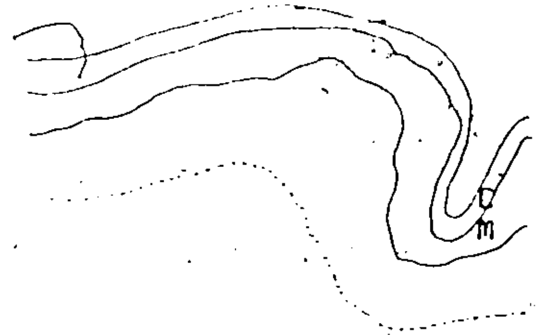

case 1



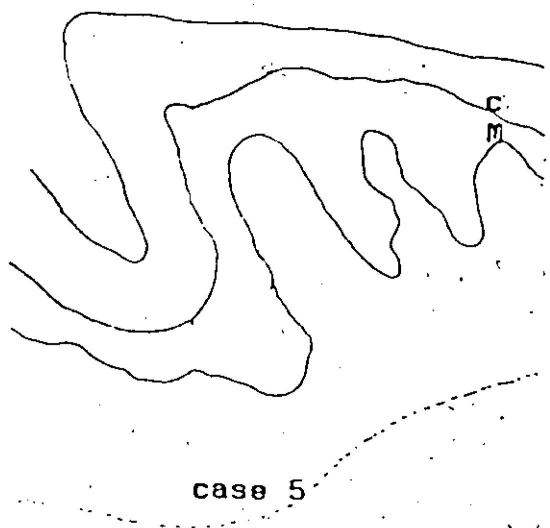

case 2



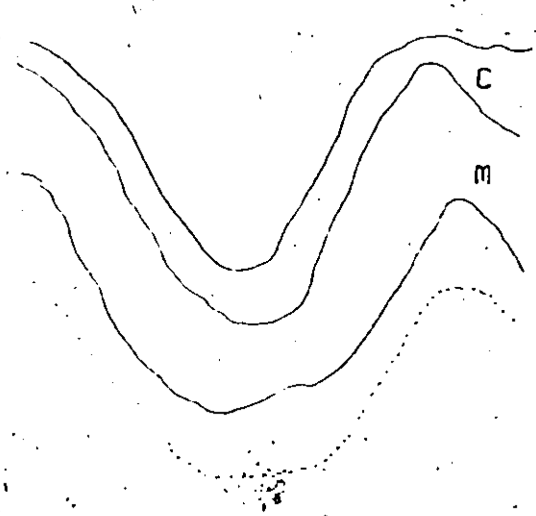

case 3




case 4



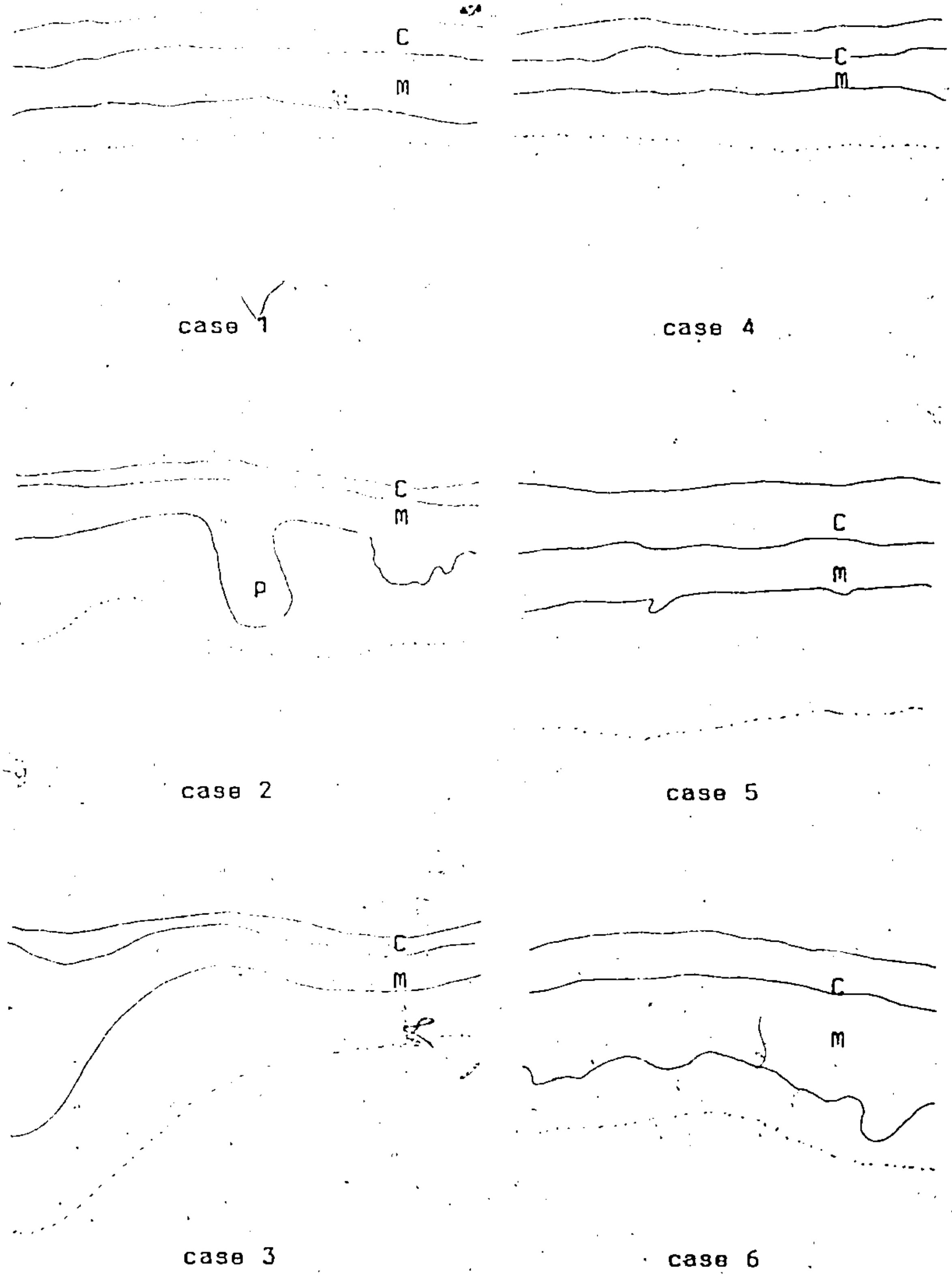

case 5




case 6

Site 3, Posterior Fold of the Neck

Plate 5




Site 4, The Cheek

SITE 3, THE POSTERIOR NECK FOLD

SITE 4, THE CHEEK

a length range of from .01 to .04 mm. The mean number is 3 and the average length is .03 mm.

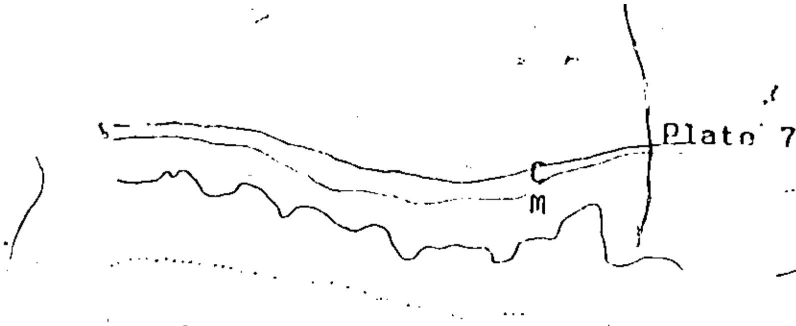
Interface Characteristics - The sine interface aré quite variable with case 1 presenting numerous but short rete pegs and case 5 showing a flat sine interface. The interface shown on the microphotograph is dominated by numerous hair follicles of the beard and some of the adenexa. The epidermal interface itself seems to be very flat. The dermal interface is correspondingly flat except for regularly placed pits for the reception of adnexa.

Site 6, Anterior Neck Fold

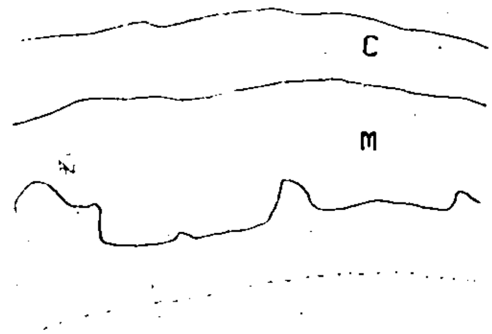
Functional Anatomy - Rotational movement provided by the odontoid process of the axis articulating with the atlas vertebrae with flexion of the head on vertebral column constitutes the activity of the skin excised from the anterior neck just below the hyoid bone and above the thyroid cartilage.

Epidermal Characteristics - Total thickness of the epidermis at the anterior neck fold ranges from .04 to .10 mm with .06 mm as the mean. The stratum corneum constitutes about half of the total thickness. Rete pegs in this moderately active skin are a bit more numerous than here-to-fore ranging from 2 to 12 with length varying from .02 to .08 mm. The average number of rete is 5 per mm with mean length of .04 mm.

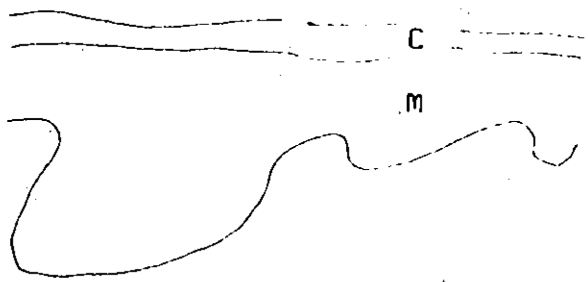
Interface Characteristics - The sine interface reveals little of the folding, but the photomicrograph shows a tendency toward low profile ridging both on epidermis and dermis. A few random papillae can be seen on the dermis with scattered concavities on the epidermis. Thread-



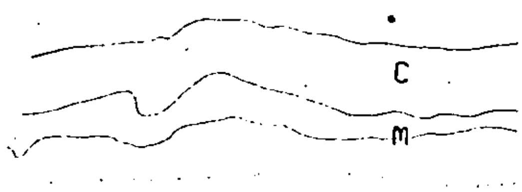

case 1



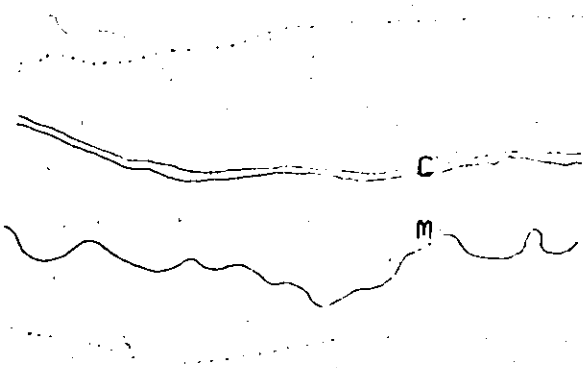

case 4



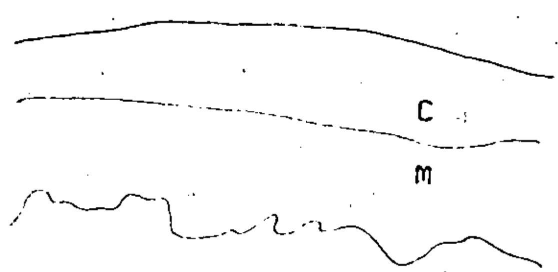

case 2




case 5



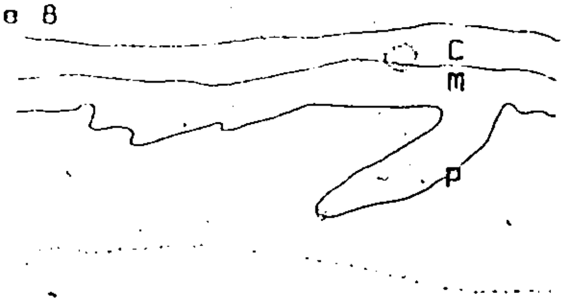

case 3



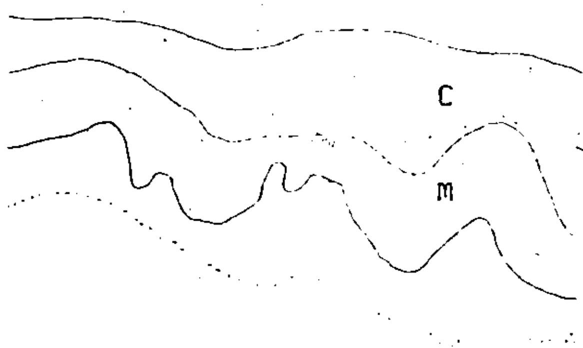

case 6

Site 5, The chin

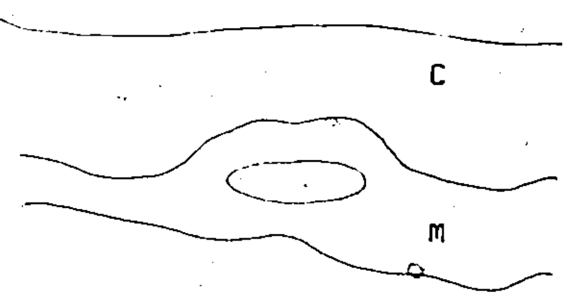
Plate 8



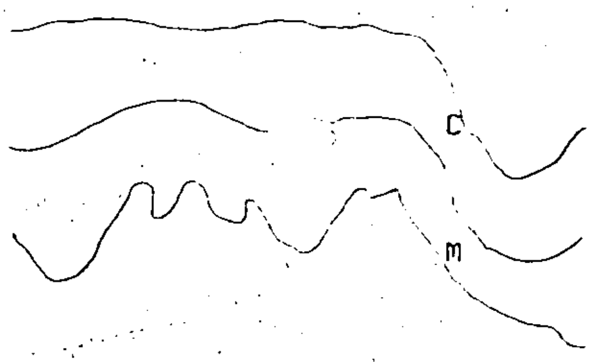

case 4



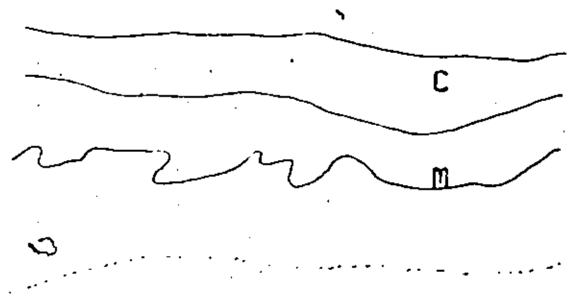

case 2




case 5

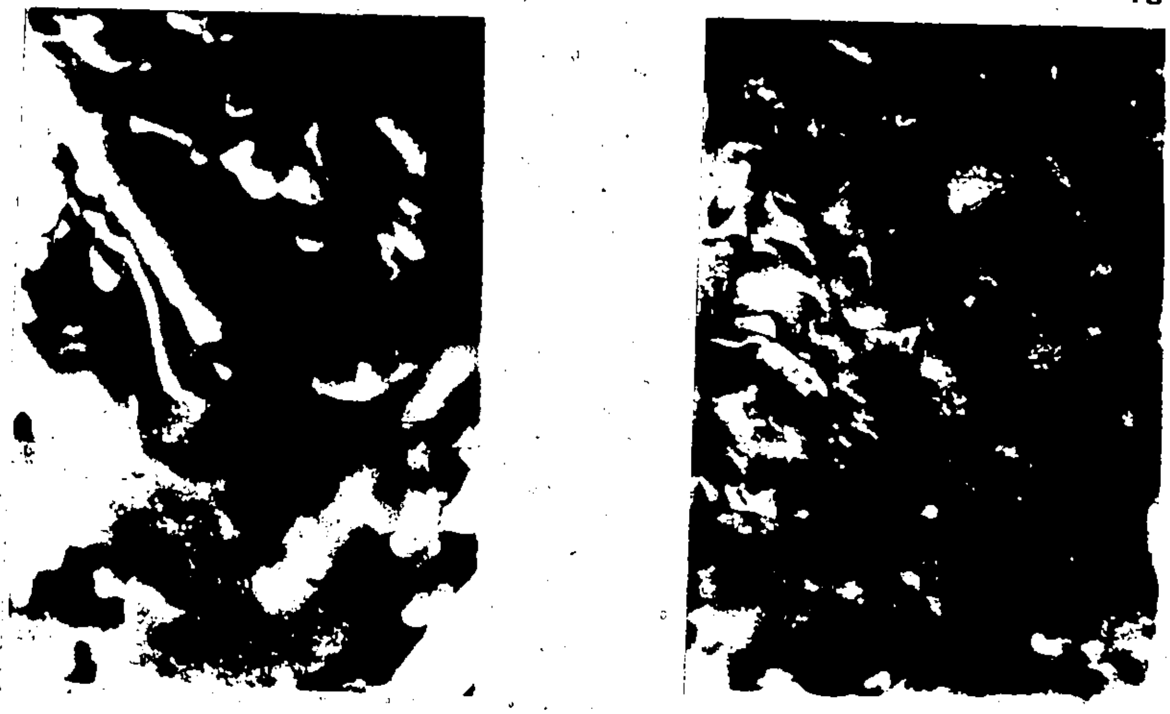



case 3

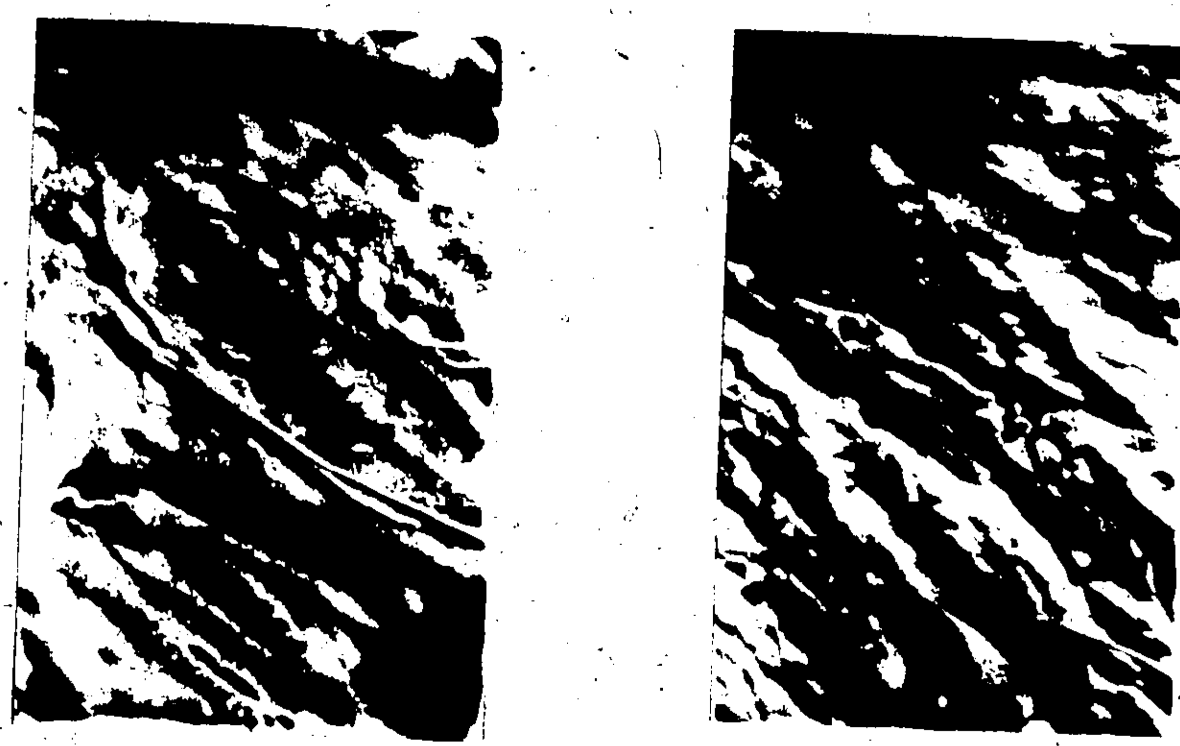



case 6

Site 6, Anterior Aspect of the Neck



SITE 5 THE CHIN



SITE 6 ANTERIOR NECK

like cutaneous nerves and scattered adnexa are visible on the epidermal interface.

Site 7 Chest at Mid-line

Functional Anatomy - Dense fibrous connective tissue of the membrana sterni, which gives rise to the powerful pectoralis major muscle, underlies the section of skin cut. Flexion and extension of the vertebral column and movements of the arms put some strain on this site.

Epidermal Characteristics - Total epidermal thickness of skin at the sterno-costal articulation is in the lower third of all skin studied and was found to have relative thickness of .04 mm with the stratum Malpighii tending to predominate (50 to 60% range). Moderate numbers of rete pegs can be seen (4 per mm), but of short dimension (mean length, .03 mm). A need for firmly anchoring the skin exists, but the dense subcutaneous tissue makes for much of the firmness here.

Interface Characteristics - Considerable variation of the sine interface is in evidence. Most cases show well developed rete pegs. Case 6, a female showed especially broad rete, but case 1 revealed few rete (none on the sine interface). The interface shown on the photomicrograph reveals numerous dermal papillae neatly arranged in rows with equally regular craters among the rete on the epidermal interface. Some adnexa is in evidence. It is reasonable to assume that the anchoring function of this site demands firm adhesion of dermis to epidermis without great thickness of the stratum corneum since the connective tissues beneath predominate.

Site 8, Mid Chest

Functional Anatomy - The massive pectoralis major muscle which covers the rib cage underlies the skin excised. The skin is essentially a covering, but some slight movement is experienced in respiration and strong movement of the arms.

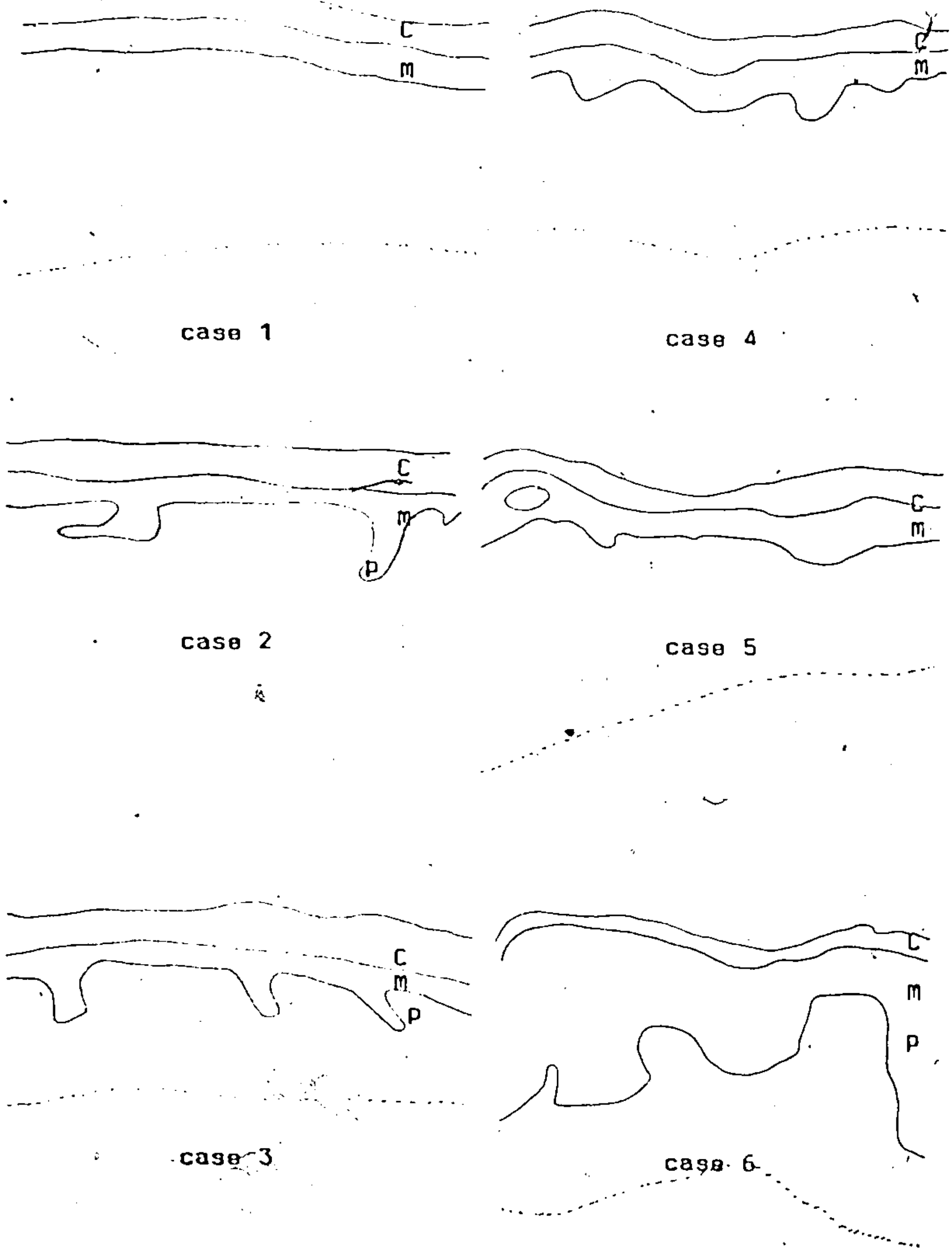
Epidermal Characteristics - The total thickness of the epidermis range from .03 to .06 mm with a mean of .04 mm and places the mid chest skin in the middle third of all skin examined. Rete pegs have an average number of 4 per mm and are relatively low with a mean length of .03 mm. The stratum Malpighii tends to dominate the total epidermis forming an average 60%.

Interface Characteristics - The sine interface reveals well developed rete pegs in all cases. The heavily muscled case 2 has an especially long peg. The rete of the mid chest are more numerous and distinct than those found at the mid line of the chest and may be a response to the greater movement associated with the arm despite the essential covering function of the skin. The epidermal interface reveals several hair follicles and cutaneous nerves. The dermal interface shows well formed papillae which are delicate and interdigitate with equally well formed rete ridges of the epidermis. The dermis appears to have folds.

Site 9, Axilla of the Arm

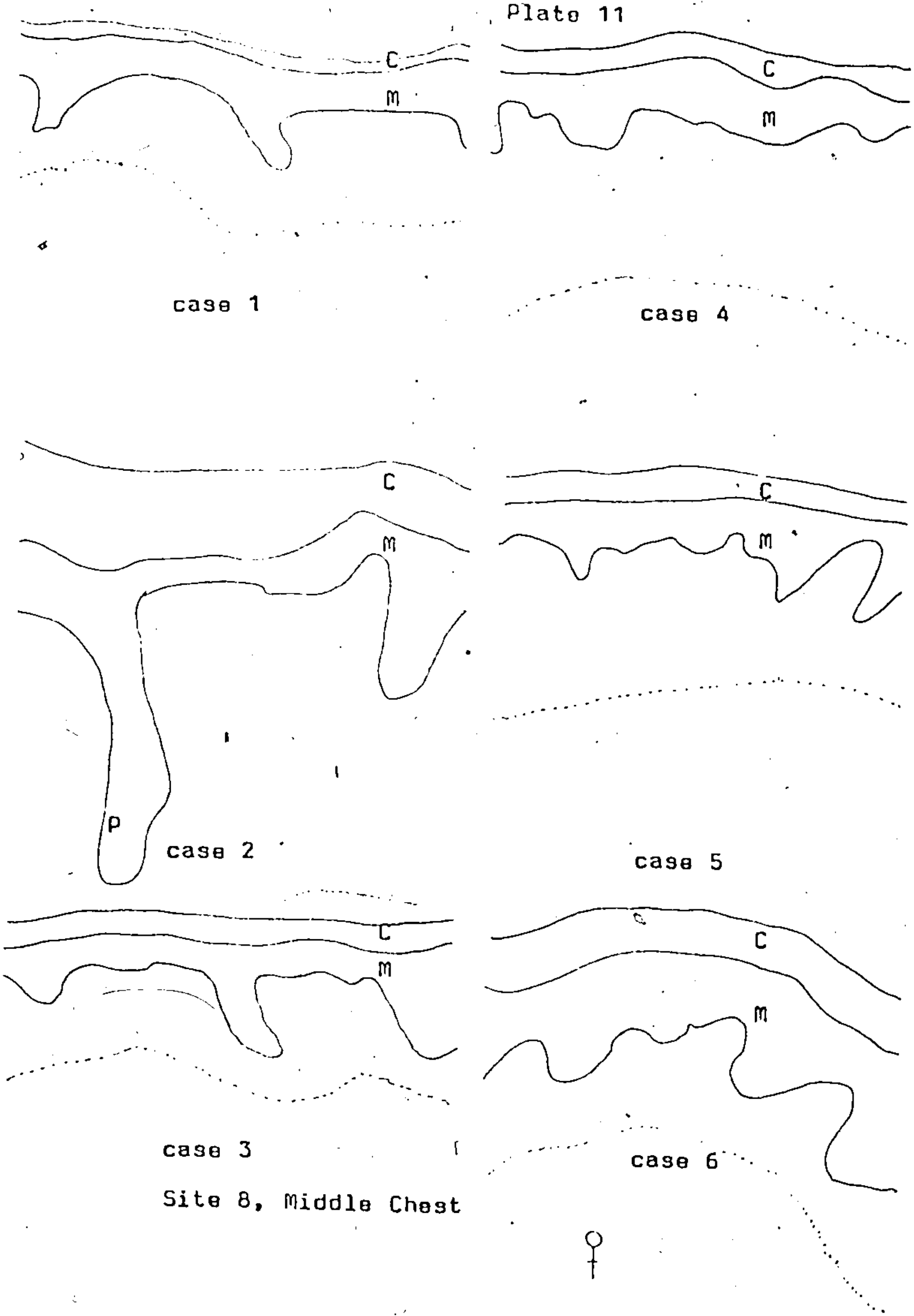
Functional Anatomy - The shoulder joint is enarthrotic and allows motion about an indefinite number of axes formed by the ball and socket of the head of the humerus articulating with the glenoid cavity of the

Plate 10

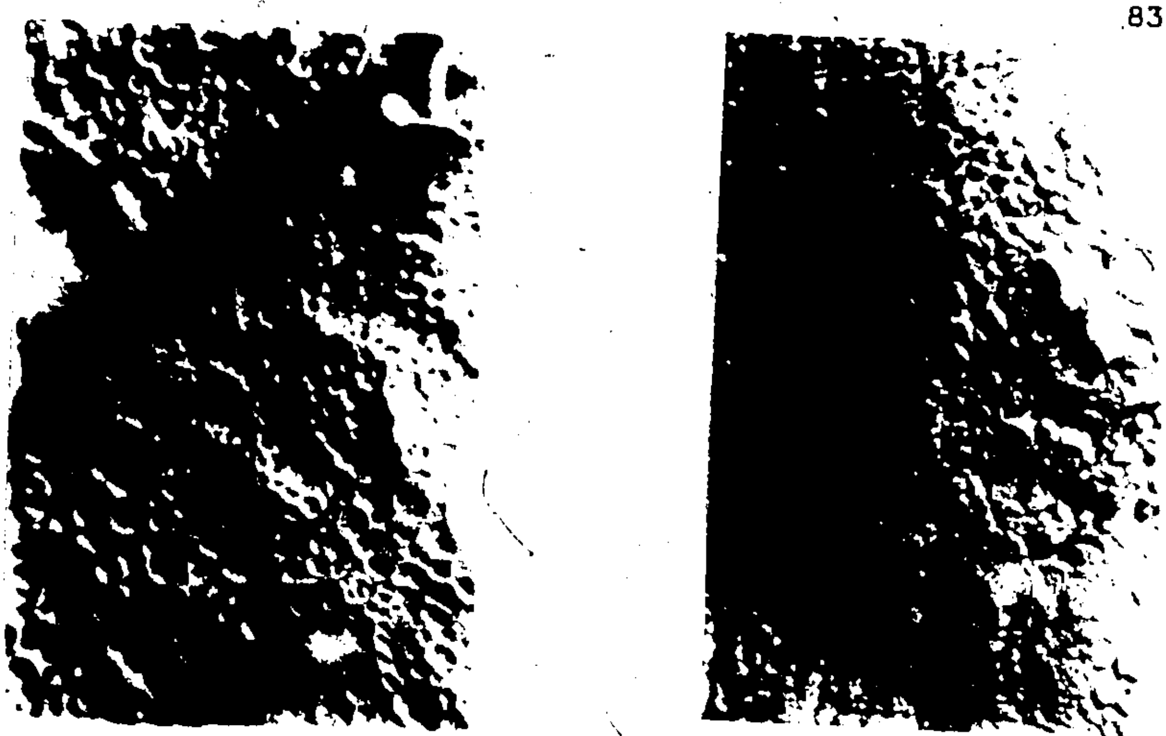



Site 7, The Chest at Mid-Line

Plate 11




Site 8, Middle Chest



SITE 7 CHEST AT MID LINE

SITE 8 MIDDLE CHEST

scapula. Numerous tendons approach either site of the axilla, but only axillary fascia and vessels lie beneath the region of skin excised. The skin appears much wrinkled and contains axillary hair.

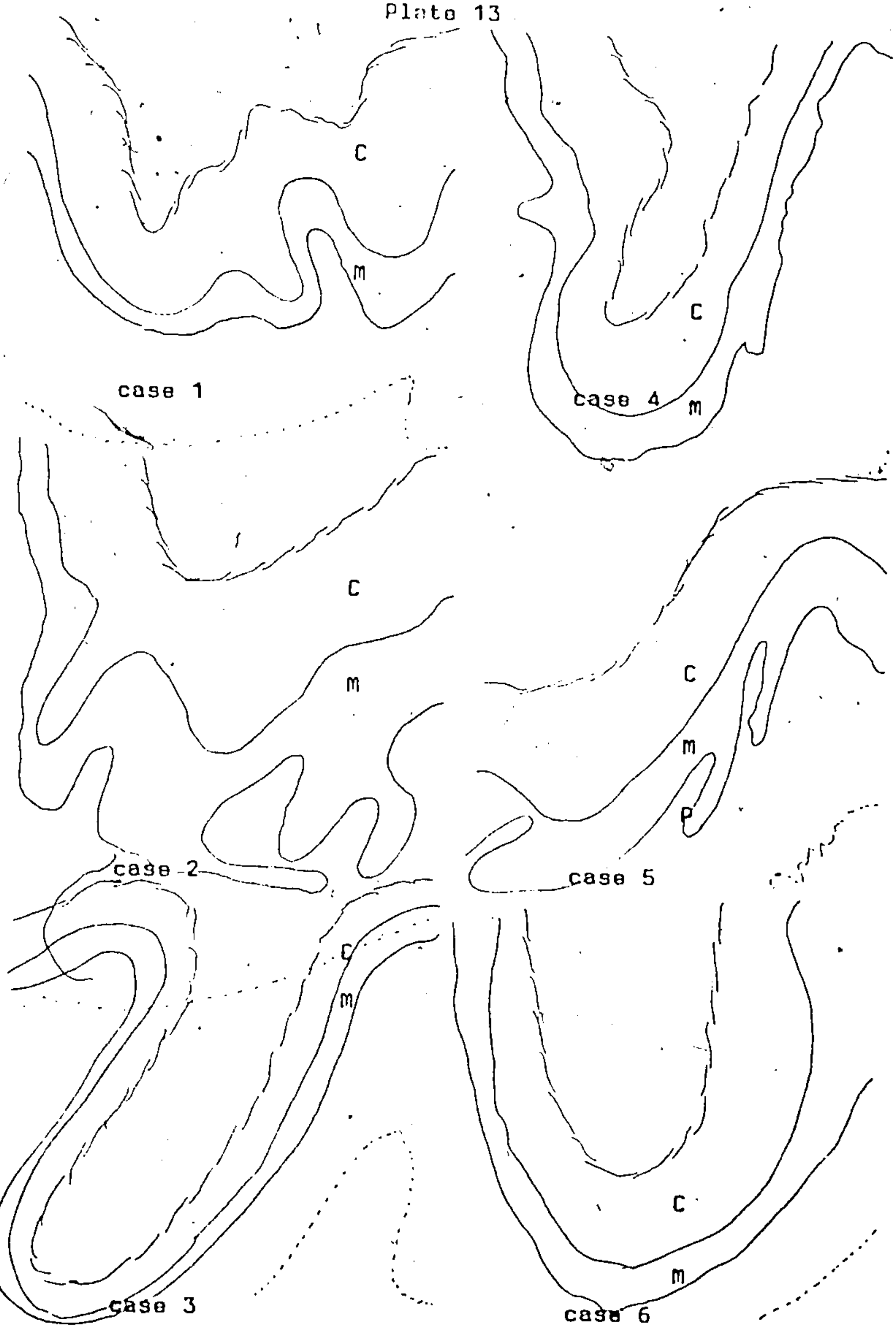
Epidermal Characteristics - The axillar skin is found among the upper third in epidermal thickness of all skin examined ranging from .04 to .10 mm thickness with .07 mm the mean. The stratum corneum predominates (60%). Rete pegs are fairly numerous averaging 6 with a range of 1 to 14 per mm in all cases examined. The average length of rete ridges observed in axillar skin is .05 mm and places this tissue in middle range with respect to rete measurement. The upper border of the stratum corneum tends to desquamate and is indicated on the line drawings as a broken line.

Interface Characteristics - The sine interface follows the much folded free surface of skin. The rete pegs, where they occur are somewhat bizarre orienting as they do in several directions. It is probable that this is due to the extreme range of motion this skin in put through. The epidermal interface is interesting in that the upper half appears almost flat except for some low profile ridges and sharply demarcated below are well formed through shallow rete ridges. A cutaneous nerve has been preserved in this specimen. The dermal interface has numerous papillae somewhat randomly placed along the apparent folds. The considerable motion this skin receives demands that the interface have considerable structural variation.

Site 10, Line Alba

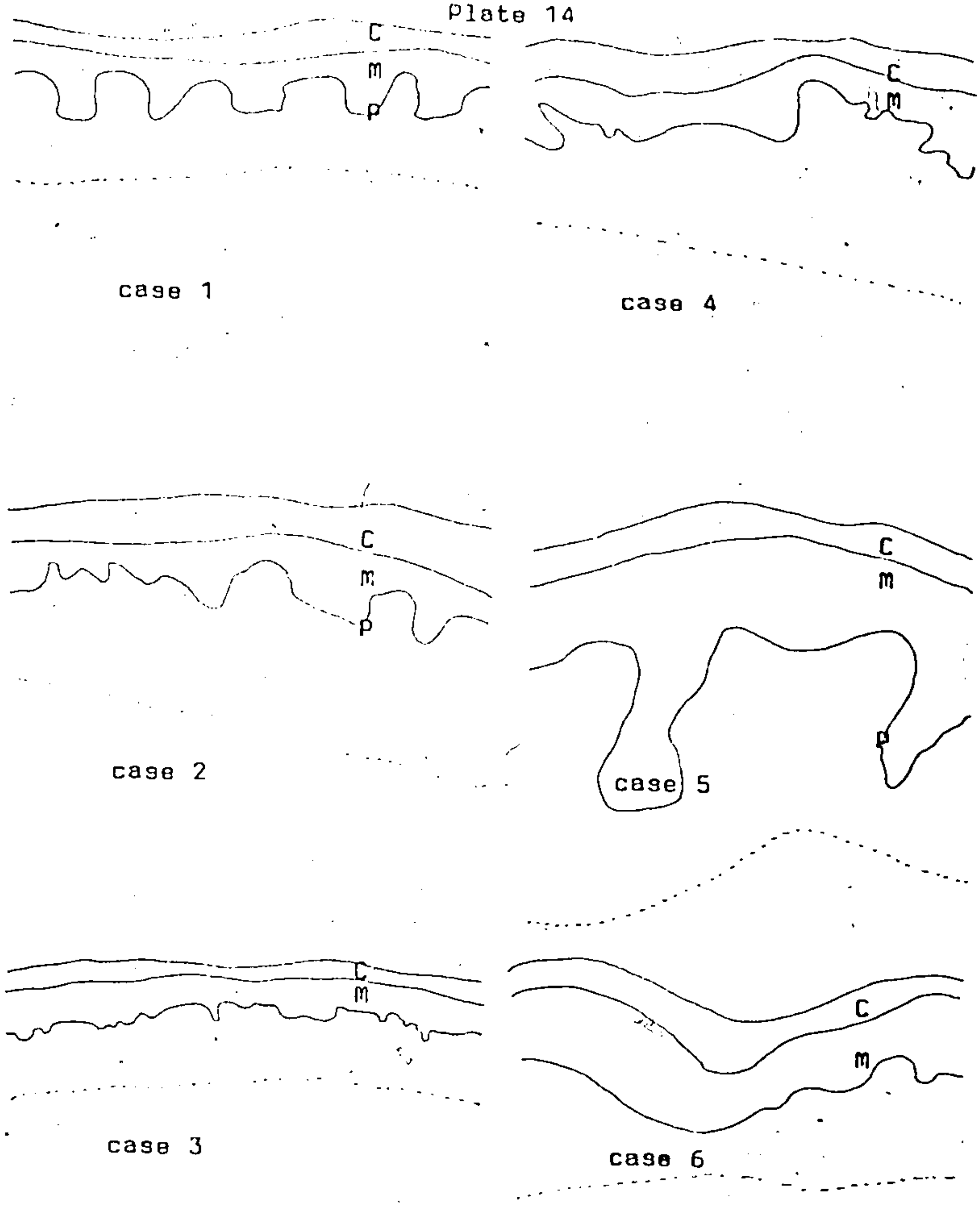
Functional Anatomy - At the mid line of the abdomen, the rectus abdomenus and oblique externus musculature joint in a fibrous aponeurosis.

Plate 13




Site 9, Axillar Fold of the Arm

Plate 14




Site 10, The Linea Alba


SITE 9 AXILLA OF THE ARM


SITE 10 THE LINEA ALBA

The skin reflects this rather firmly anchoring situation in a white line appropriately called the linea alba.

Epidermal Characteristics - The total epidermis of the linea alba is found among the lower third in thickness of all sites studied. The thickness range is from .03 to .07 mm with .05 mm the median. The stratum Malpighii predominates constituting 60% of the total epidermal thickness. Rete peg number varied from 0 to 10 per mm with 5 being average. Their length pattern ranged from .02 to .06 mm with .03 mm the mean.

Interface Characteristics - The sine interface usually shows a well ordered arrangement of rete pegs. Case 5 had an unusually long club-like peg. The requirement to firmly anchor the epidermis on the dermis is reflected by numerous well formed rete ridges on the epidermal interface. Further mechanical advantage may be obtained by the parallel ridges which can be seen. Several cutaneous nerves have been preserved along with some adnexa. The dermal interface presents numerous well formed papillae which seem to gather in clumps giving this rather unique anchoring tissue a cauliflower-like appearance.

Site 11, Groin

Functional Anatomy - The hip joint formed by the articulation of the head of the femur with the acetabulum provides an enarthrotic joint allowing rotational movement, but flexion and extension of the thigh in walking and flexion in sitting are the principal motions of the hip and the groin marks the line of greatest movement. The skin was excised from just below the inguinal ligament above the inguinal canal. The rectus femoris muscle and the origin of the fasca lata were adjacent.

Epidermal Characteristics - The epidermis of the groin is found among the lower half in thickness of all sites examined. Thickness ranged from .02 to .06 mm and .05 mm was the mean. The stratum Malpighii tended to predominate (60%). The number of rete pegs ranged from 0 to 9 with 6 the mean. Length of the rete ranged from .02 to .08 mm with .04 the mean making the groin an average tissue among the 50 sites.

Interface Characteristics - The sine interface was in most cases dominated by the fold of the groin. Rete pegs are usually absent at the fold itself but are found peripheral to it. The epidermal interface present some adnexa and a few cutaneous nerves are preserved. Numerous well formed but variably sized craters formed by the rete ridges for the reception of dermal papillae are seen centrally bordered by a flat epidermal sheet where the fold itself is approached. The dermal interface has numerous papillae of variable size and shape and direction responding to the variety of movement demanded. The dark area at the upper right of the dermal interface is the sharp fold further accentuated by tissue shrinkage during the preparation.

Site 12, Back (Mid Line at the Clavicle)

Functional Anatomy - The dense tissue of the back at the level of the clavicle is an anchoring type of skin just above the thoracic vertebrae. Underlying the skin at this point are portions of the lumbo-dorsal fascia and the aponeurosis of the trapezius musculature. Slight motion may be attributed to the skin of this region as the vertebral column is flexed or arched or the trunk of the body twisted.

Epidermal Characteristics - The epidermal thickness of the back at the mid line, clavicular level places this tissue in the lowest third of all tissues studied. Total thickness ranges from .02 to .05 mm with .04 mm the mean. The stratum Malpighii tends to predominate forming just over 50% of the total thickness. The rete peg count is average numbering from 0 to 7 per mm with 6 the mean. Rete peg length ranges from .01 to .09 mm with the mean at .04 mm.

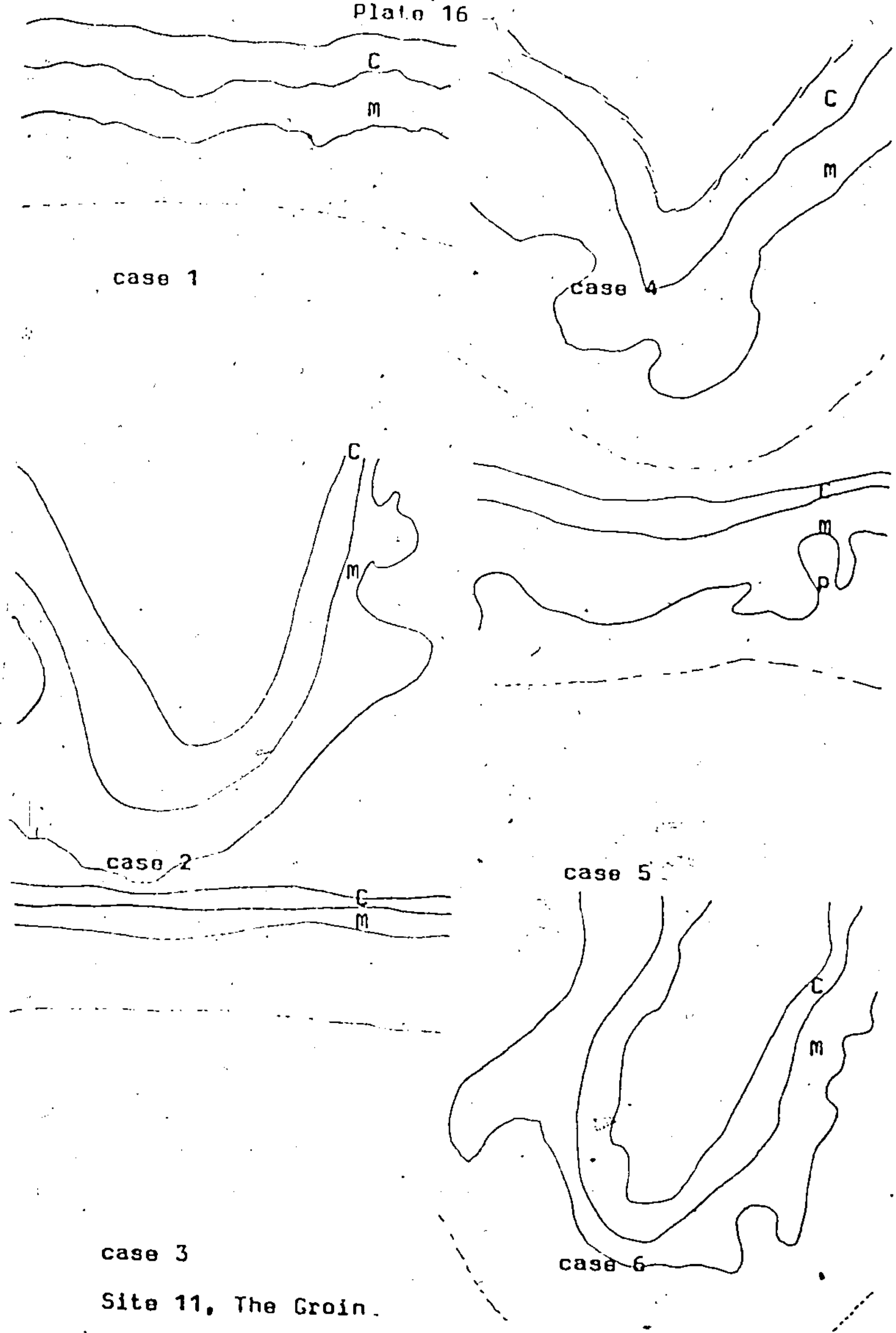
Interface Characteristics - The sine interface shows very low profile rete and case 1 shows none at all. The skin at the mid line of the back was very tough mainly due to the fibrous aponeurosis and dense connective tissue beneath. The epidermal interface, however, shows many well formed and fairly regular craters of the rete ridges to reinforce the anchoring function of the skin at the small of the back. The dermal interface shows many low profile papillae seemingly arranged in rows about the central fold. This seems characteristic of what, in this study, has been called anchoring skin types where rigidity is required in the absence of gross movements.

Site 13, Back at the level of the 4th Lumbar Vertebrae

Functional Anatomy - This site is characterized by strong motion in the twisting of the trunk and flexing as in the act of bending etc. Heavy musculature invests the vertebral column at this point, principally the latissimus dorsi, the the dense fibrous tissues of the lumbo-dorsal fascia blending in.

Epidermal Characteristics - The mid line of the back at the level of the 4th lumbar vertebrae has an epidermal thickness placing it in the lower third of all tissues studied. Total epidermal thickness ranges from .03 to .07 mm with .04 mm the mean. The stratum Malpighii predominates

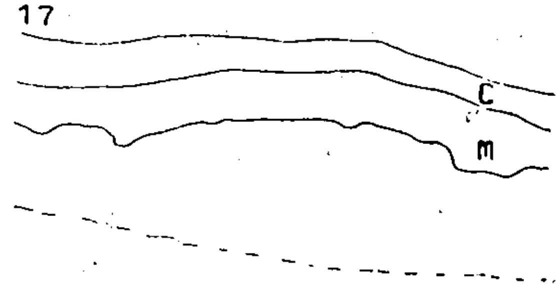
Plate 16



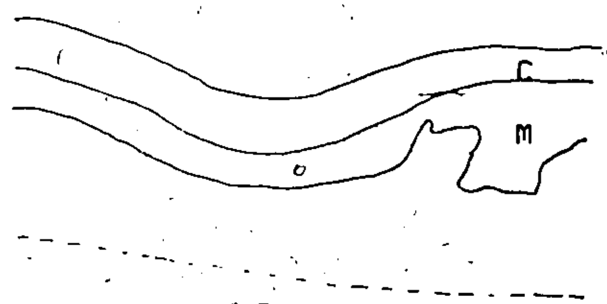

Site 11, The Groin.

Plate 17

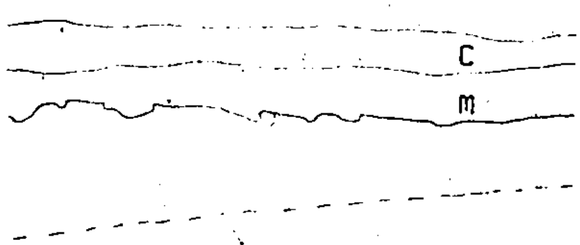

case 1




case 4

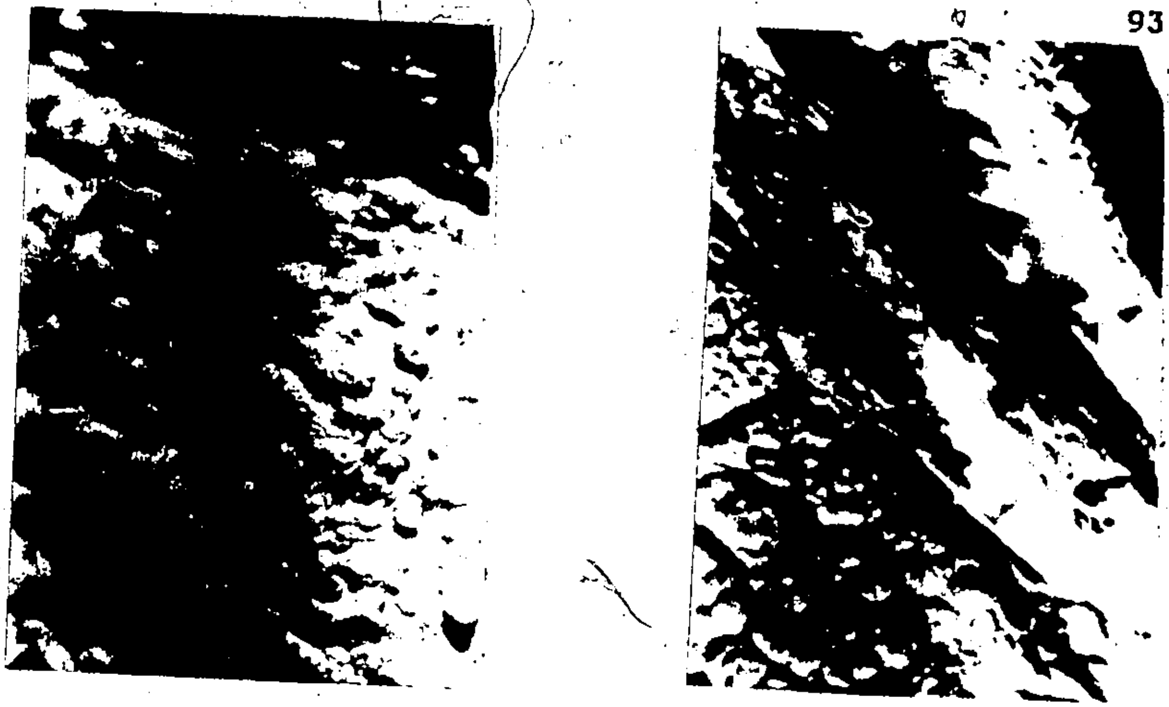



case 5

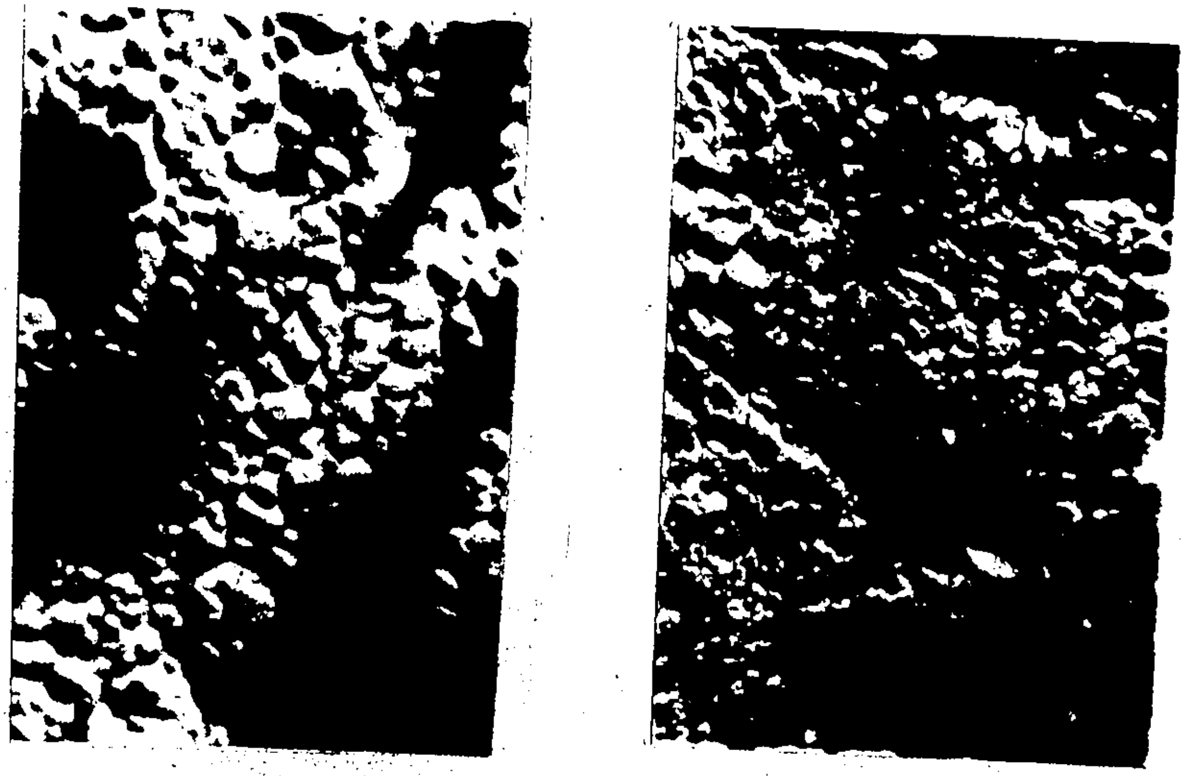



case 3

Site 12, The Back, Mid Line at the Clavicle



SITE 11 THE GROIN



SITE 12 BACK (MID LINE AT THE CLAVICLE)

forming 60% of the total thickness. Rete ridges are fairly numerous ranging from 2 to 11 per mm with a mean number of 7. The length is fairly low and ranges from .01 to .06 mm with the mean at .03 mm.

Interface Characteristics - Rete pegs were apparent in all sine interfaces, but considerable variation in morphology is in evidence. The epidermal interface shows a greater diameter of the craters formed by the rete ridges when compared with the mid line skin of the back at the level of the clavicle. It is felt that the greater work load placed on the lower level of the spine requires more definitely structures epidermal dermal interface. The dermal interface shows a fair degree of regularity to the occurrence of papillae which are well formed and seem to be perpendicularly oriented toward the free surface of the skin.

Site 14, Buttox

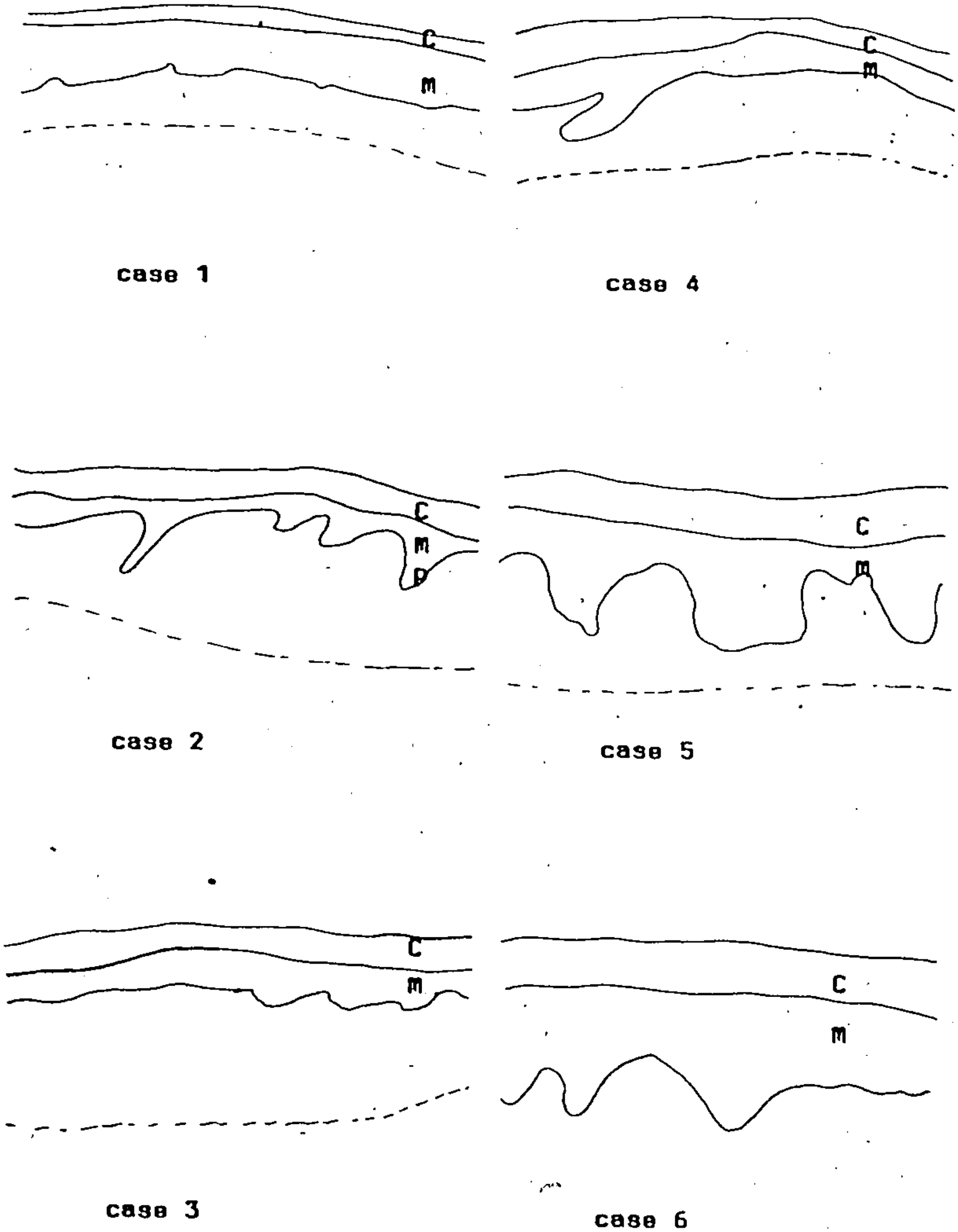
Functional Anatomy - The massive gluteal musculature, the gluteus maximus in particular arising from the ala of the ilium underlies the skin excised. This region is a covering, but is pressure receiving in the sitting position and receives indirect motion in rotational hip movements and in adduction and abduction of the femur.

Epidermal Characteristics - Epidermal thickness of the skin of the buttox is found in the lower third of all skin studied. The mean epidermal thickness is .04 mm with the range . 02 to .07 mm. The stratum Malpighii is predominant as it forms about 60% of the total epidermis.

The mean number of rete ridges is 6 per mm. The range of rete peg length is from .03 to .07 mm with .05 mm the mean.

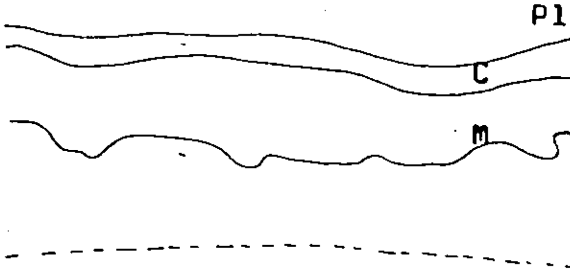
Interface Characteristics - This site is unusual in that it receives

Plate 19

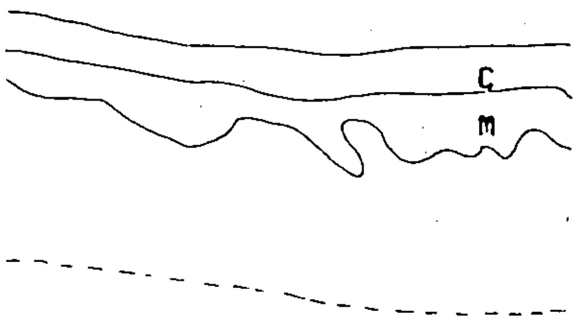



Site 13, The Back, Mid Line at Level of Lumbar 4/5

Plate 20

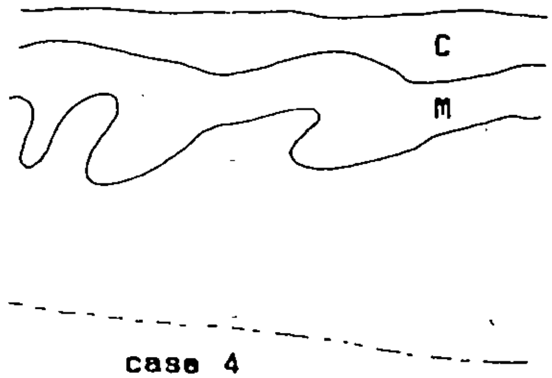



case 1

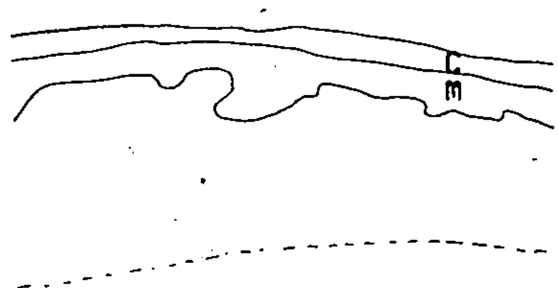



case 2

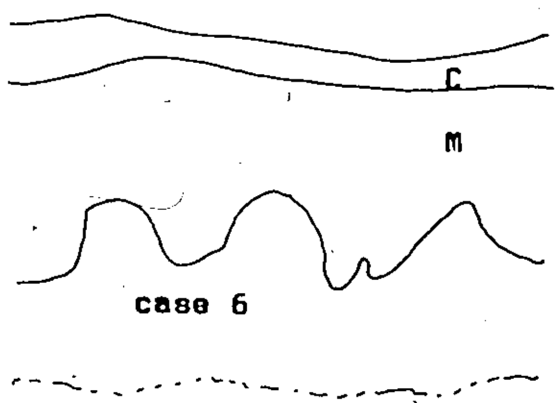

case 3




case 4




case 5




case 6

Site 14, The Buttox

SITE 13, BACK, LEVEL OF LUMBAR 4 and 5

SITE 14, THE BUTTOX

pressure and mild movement, but it is essentially a covering. This diversity suggests the reason for the numerous well formed crater-like depressions formed by the rete ridges. They are seen to orient along parallel ridges on the epidermal interface. Some adnexa and cutaneous nerves are in evidence. The dermal interface shows numerous well formed papillae which seem to have formed at a slight angulation, possibly as a result of pressure against the free surface of the skin.

Site 15, Back, Upper Lateral Portion

Functional Anatomy - The spine of the scapula is found at this site with the trapezius muscle overlaying the bone. This site is subject to movements of the sholder as a whole and the rotational and swinging movements of the arm. It is classified as a covering, however, since it is not actually at the position of flexion and extension and receives these motions in a peripheral way.

Epidermal Characteristics - The underlying musculature and connective tissues at this site are dense, but the overlying epidermis is thin and found among the lower third of all sites studied. The mean thickness is .04 mm with a range of .02 to .08 mm in upper lateral back epidermis. The stratum Malpighii was 55% of total epidermal thickness. The rete peg count was 4 per mm and the length of papillae was found to be fairly constant at .02 to .03 mm.

Interface Characteristics - The sine interface was for the most part of low profile except for the heavily muscled case 2 which revealed a few thin elongate pegs. The interface of the epidermal section showed parallel ridging between which were numerous craters formed by rete

Malpighii which were well formed and regular in size and shape. Some hair follicles are in evidence. The dermal interface shows numerous well formed small papillae which seem to slant slightly. The epidermis of the back, though thinly structured, is well anchored to the dermis by numerous rete and dermal papillae and provides flexibility to the part.

Site 16, Gluteal Fold

Functional Anatomy - The gluteal fold is deep and formed at the juncture of the transversly placed gluteal musculature above and the musculature of the posterior thigh, principally the semimembranosis and semitendinosis, below. The region receives heavy pressure on sitting as weight is transmitted through the conjoined rami of the ischium and pubis and reflects the rotational movement of the hip but is especially active in flexion and extension of the limb upon the trunk in walking.

Epidermal Characteristics - The skin from this site was especially tough in excision due to the dense underlying connective tissue. The epidermal thickness was thin and found in the lower third of all sites studied. The mean epidermal thickness was .04 mm and ranged from .02 to .05 mm. The stratum Malpighii formed 55% of the total thickness. The rete peg count was 6 per mm with their length ranging from .02 to .08 mm and .04 mm the mean.

Interface Characteristics - The interface reflected the sharp folding expected at this site. Rete pegs, usually of low profile, were noted on the sine interface, but not at the site of the actual fold. The rete pegs were sometimes at right angles to the skin, but often assumed a bizarre shape which could be expected considering the pressure transmitted through this part. The epidermal interface showed only a few depressions formed by the rete ridges. A generalized low profile with numerous ridges of parallel orientation is predominant. It is conceivable that cross section representations might give the appearance of rete pegs shown in the sine interface and a false impression on rete count and measurement. Several cutaneous nerves can be seen on the epidermal interface. The dermal interface shows parallel furrows with a few true dermal papillae irregularly placed and in a slanted position. It is clear that the papillary structure has been much modified due to pressure, and the continuous ridging and furrows reflect, in their parallel positions, the stress lines of flexion and extension.

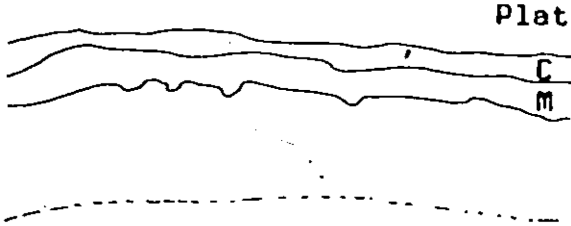
Site 17, Shaft of the Penis

Functional Anatomy - The skin of the shaft of the penis has been included in a special class and is unique in that alteration of size and shape occur as the cavernous sinuses fill with blood at erection. In passive states the shaft of the penis is quite flexible. The only underlying musculature is the cremaster muscle.

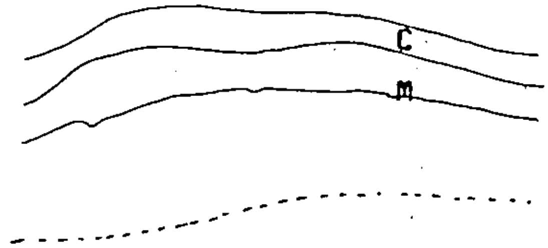
Epidermal Characteristics - Epidermal thickness found in the shaft of the penis places the tissue among the lower third of all skin examined. Epidermal thickness ranges from .02 to .06 mm in thickness with .04 mm the median. The stratum Malpighii is predominant and forms about 60% of total epidermal thickness. The rete peg count is average with 5 per mm the median. Length is of lower profile ranging from .02 to .05 mm with .04 mm the median.

Interface Characteristics - The sine interface demonstrates consid-

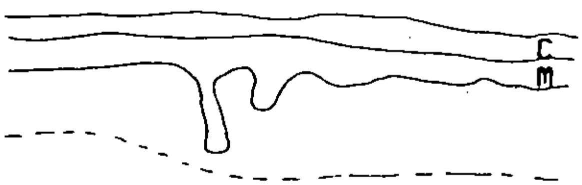
Plate 22



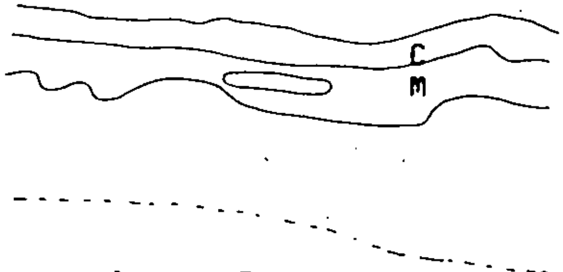

case 1



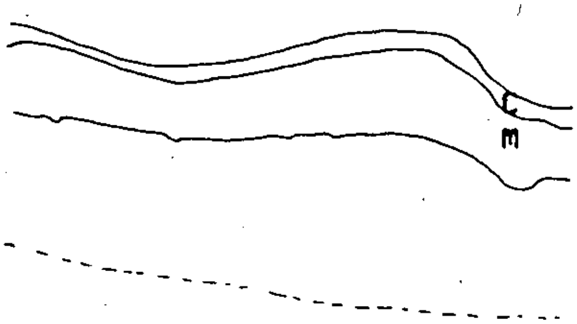

case 4



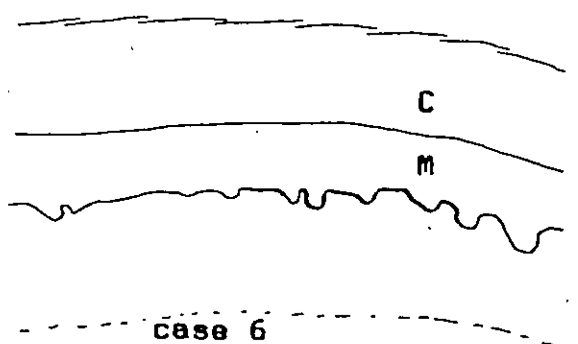

case 2




case 5



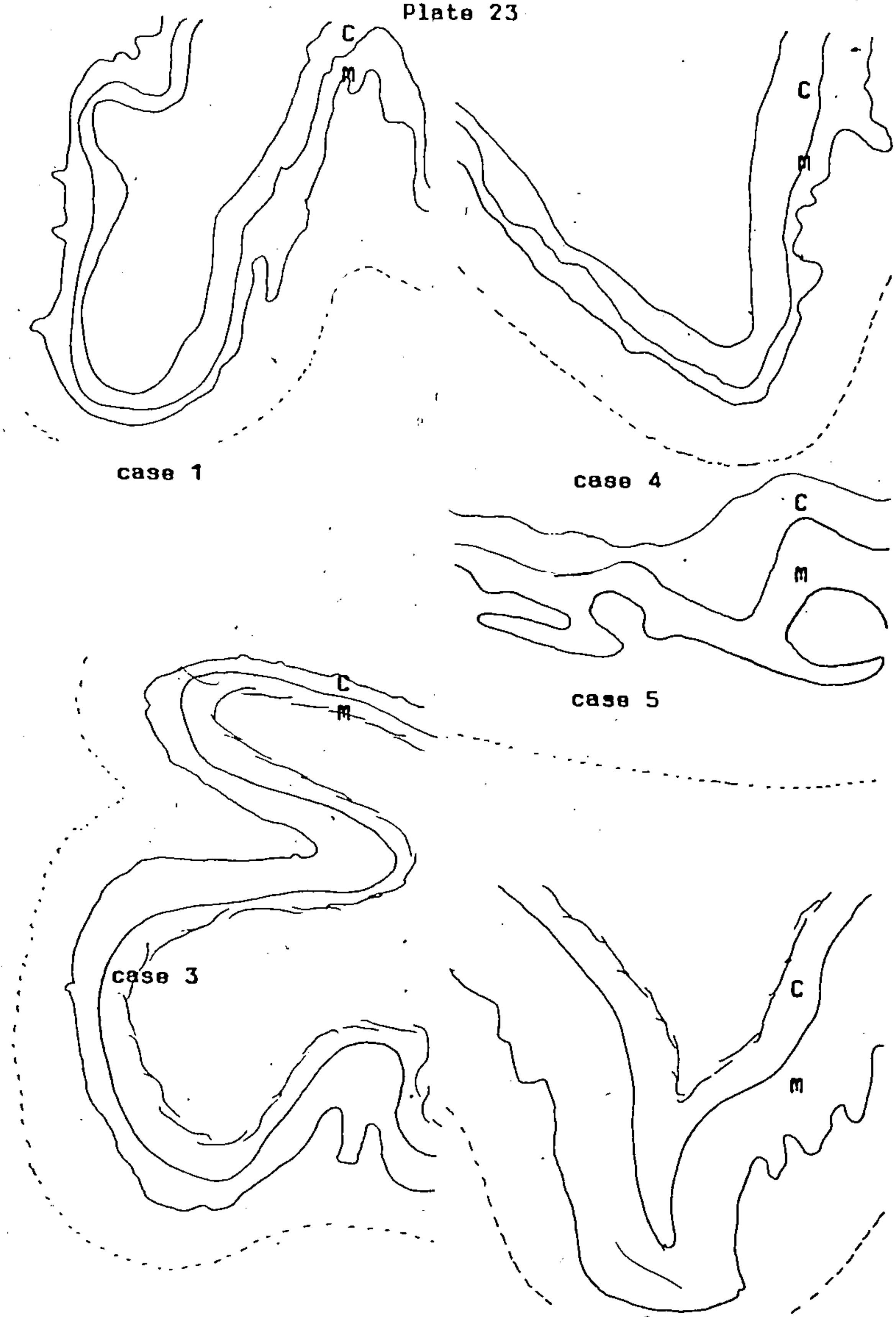

case 3



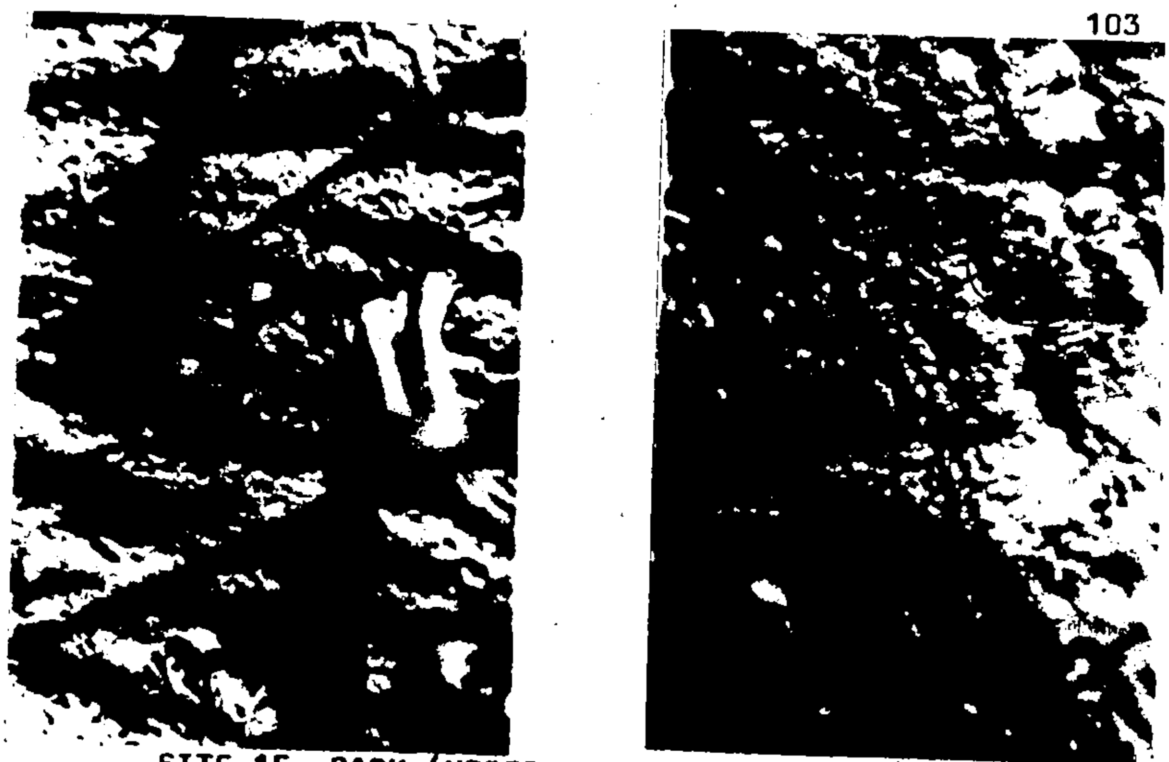

case 6

Site 15, The Back, Upper Lateral Portion

Plate 23




Site 16, The Gluteal Fold



SITE 15, BACK (UPPER LATERAL PORTION)

SITE 16, THE GLUTEAL FOLD

erable morphologic variation. Case 1 has numerous low profile rete pegs. Case 2 has rete pegs many times larger and irregularly shaped. The epidermal interface presents parallel ridges within which a few well formed craters made by the rete Malpighii are seen. The majority of the elongate depressions formed by the rete seem to orient at right angles to the principle parallel ridges. The dermal interface has some essentially flat regions and a few regularly shaped dermal papillae. The dermal papillae, for the most, part, seem to have coalesced into ridges running obliquely to what seem to be folds. The epidermal-dermal interface would seem to have been directed by the need of this tissue to expand and contract.

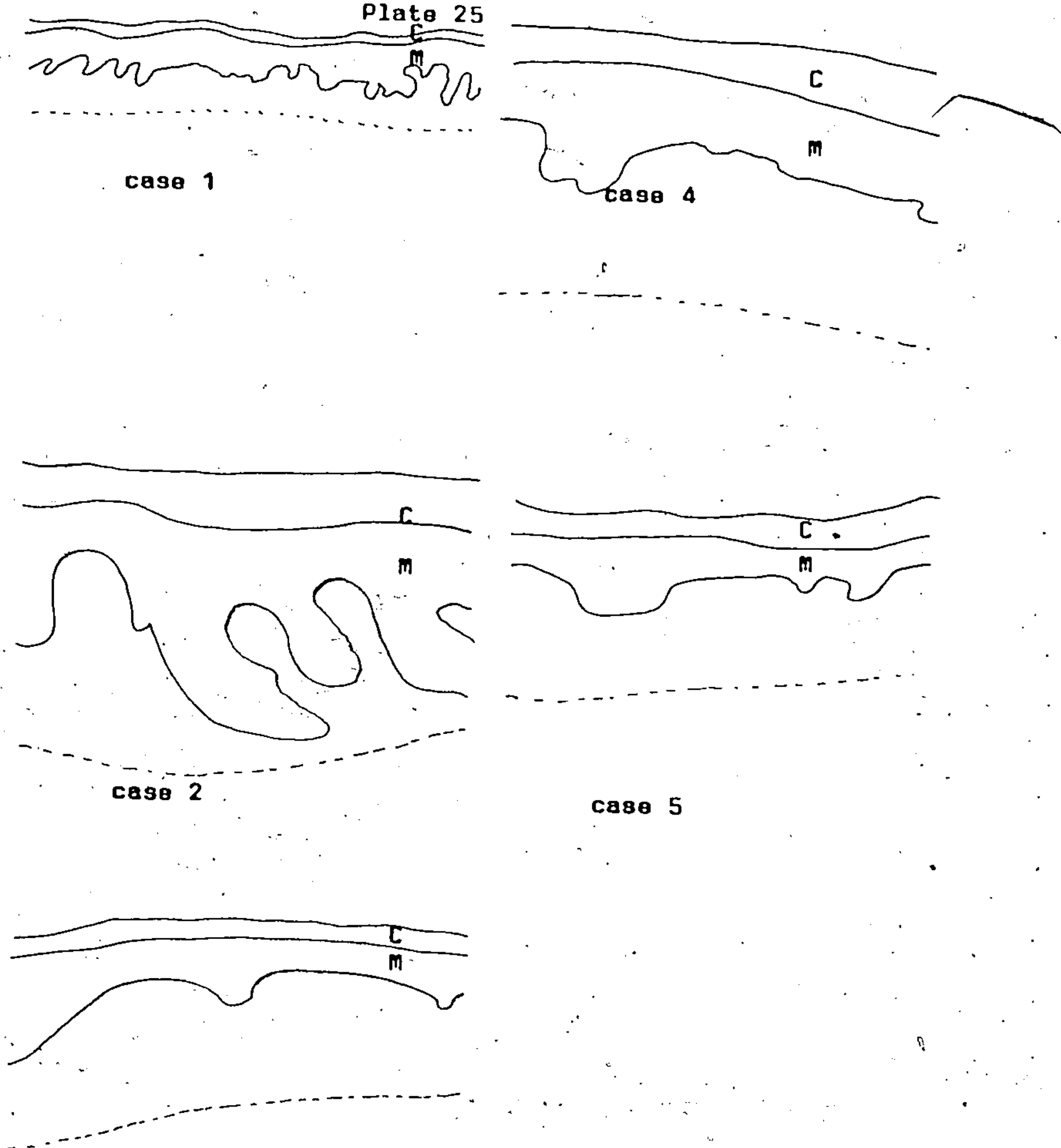
Site 18, Ear, Posterior Helical Margin

Functional Anatomy - The saucer-like outer margin of the ear presents a rounded covering of skin investing the auricular cartillage. There is little subcutaneous tissue and no motion can be demonstrated.

Epidermal Characteristics - The epidermal thickness of the outer margin of the ear is in the middle third of all tissues examined. The mean thickness is .06 mm with a wide range of variation from .03 to .12 mm. The stratum Malpighii dominates making up around 65% of the total thickness. Rete ridges numbered 7 per mm with a median length of .05 mm and the range from .03 to .06 mm.

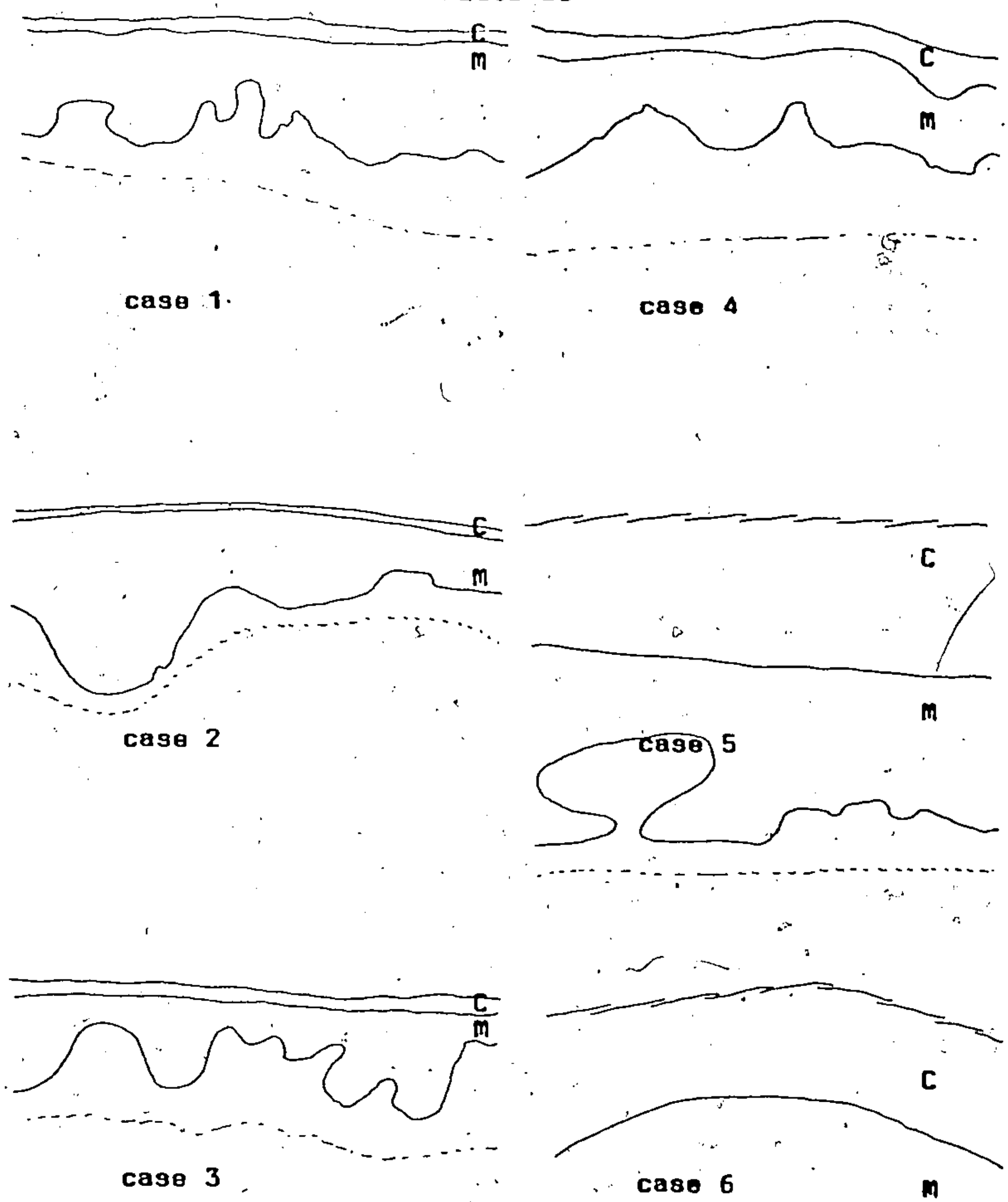
Interface Characteristics - The sine interface presented extreme variability and no association with function can be made. The epidermal interface is dominated by hair follicles and adnexa. There are some diffuse craters formed by the rete ridges on the essentially flat inter-

Plate 25

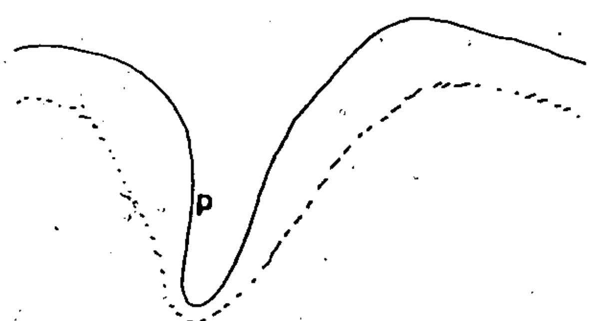



Site 17, The Shaft of the Penis

Plate 26




Site 18, The Ear, Posterior Margin




SITE 17, SHAFT OF THE PENIS


SITE 18, POSTERIOR MARGIN OF THE EAR

face. The dermal interface has numerous depressions for the reception of the adnexa, but numerous small dermal papillae can be seen. This region of skin covering a rounded prominence is anchored by adnexa to the underlying tissue. The dermal papillae are numerous and low and must be received into the rete ridges which are not well demonstrated in this preparation. Adhesion is doubtless firm when the two systems, adnexa and rete are considered.

Site 19, Ear Lobe

Functional Anatomy - The ear lobe is invested by skin of rounded covering type with tough areolar and adipose tissue beneath.

Epidermal Characteristics - The epidermis of the ear lobe is among the thinnest of all sites studied. The mean thickness was .03 mm with an observed narrow range of .03 to .04 mm. Rete ridge or peg count averaged 6 per mm with a mean length of .03 mm and a range of .03 to .05 mm.

Interface Characteristics - The sine interface was variable. Case 1 had almost no structure while the other cases showed irregularly distributed usually low profile rete pegs. The epidermal interface is dominated with hair follicles and adnexa with very few craters formed by ridges of the rete Malpighii. The dermal interface is unique with its regularly placed depressions for the reception of adnexa. Only a few dermal papillae are in evidence. No functional inferences can be drawn from this morphological pattern.

Site 20, Inner Aspect of the Elbow

Functional Anatomy - The elbow is a ginglymus joint and hinges the ulna and radius below with the humerus above. Vessels become prominent in the inner fold of the elbow as the biceps musculature becomes tendinous at the lower end of the humerus for insertion into ulna. The inner aspect of the elbow is subject to a marked degree of flexion, but may extend only to the neutral position placing the humerous, radius and ulna in a straight line relationship.

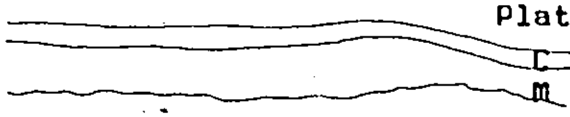
Epidermal Characteristics - The epidermal thickness of the inner elbow places this tissue among the middle third of all sites examined. The mean thickness was .06 mm with the range widely spread from .04 to .11 mm. The rete peg count averaged 2 per mm and the length ranged from .01 to .04 mm.

Interface Characteristics - The sine interface was dominated by the folding of the free surface of skin. True rete were sparse and occured peripheral to the fold itself. The epidermal interface had few well formed craters formed by the rete ridges. The predominant structure was criss-crossing ridges. Some hair follicles and adnexa are present. The dermal interface shows a central depression with random papillae at the side. Low profile folds rather than papillary structures are the rule. The fold of the elbow seems without structure except for grooves and ridges and is suggestive of the flexor fold of the finger where epidermal-dermal interface structure is lost in deference to strong fibrous connective tissue anchoring the epidermis at the point of greatest use. The pronounced flexing function of this site may have influenced a loss of dermal papillae since a tough fibrous connective tissue raphe is required.

Site 21, Posterior Achilles Tendon

Functional Anatomy - The ankle joint is of the ginglymus type

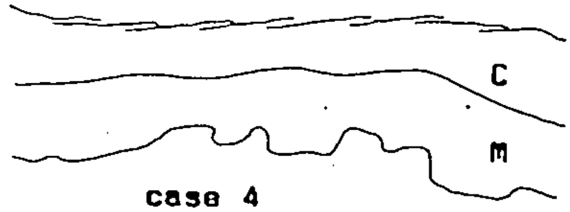
Plate 28



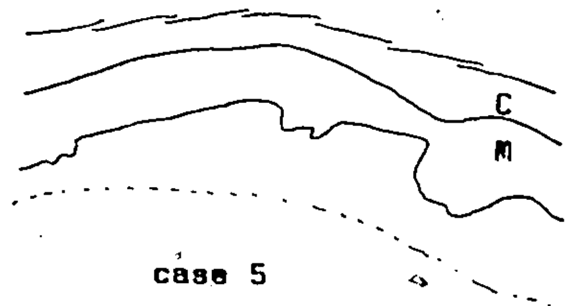

case 1


case 2

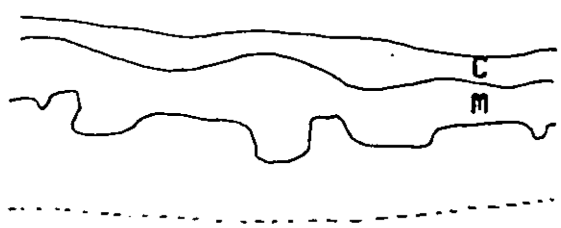

case 3




case 4



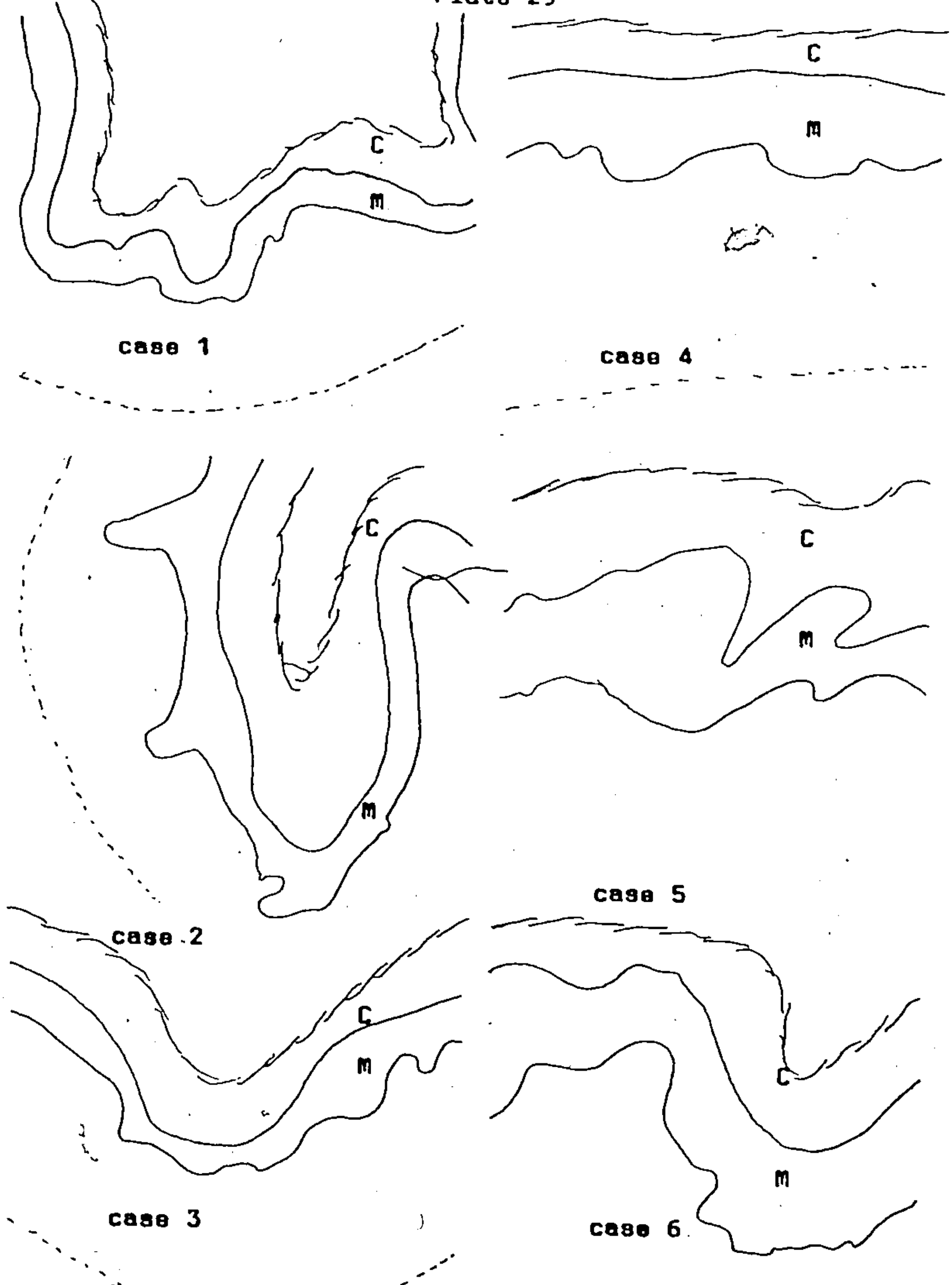

case 5




case 6

Site 19, The Ear Lobe

Plate 29




Site 20, The Inner Aspect of the Elbow

SITE 19, THE EAR LOBE

SITE 20, INNER ASPECT OF THE ELBOW

acting as a hinge for flexion and extension of the foot on the leg where the malleoli of the tibia and fibula above articulate with the talus below. The talus in turn transmits weight to the os calcis or heel bone where the Achilles tendon inserts at the posterior tuberosities. The skin excised covering the Achilles tendon just above its insertion is much folded due to the flexion and extension of the foot on the leg and must be considered to transmit weight from the body above.

Epidermal Characteristics - The epidermis of the posterior ankle has a mean thickness of .24 mm placing this among the uppermost 10% of all sites studied. The range of epidermal thickness is most variable, from .15 to .33 mm and the stratum corneum constitutes 65% of the whole. The number of rete pegs tends to increase with respect to other sites studied ranging from 5 to 10 per mm with 8 the median. Rete length ranges from .02 to .10 mm, but the median is .07 mm.

Interface Characteristics - The sine interface is variable. Case 5 shows numerous and elongate rete pegs. Case 4 and 6 seem to be more irregular and of lower profile. The epidermal interface has parallel folds. Craters formed by the rete ridges are numerous, well formed and regular as they occur between the folds. The dermal interface presents numerous well formed finger-like projections of the dermal papillae regularly placed about a deep straight fold. This site is unusually hard working, reflected by the highly structured epidermal-dermal interface. The epidermis is firmly anchored on the dermis by the well formed elongate and numerous interdigitating dermal papillae and rete ridges.

Site 22, Posterior Thigh

Functional Anatomy - This site is a covering for the heavily muscled posterior thigh in which the bellies of the semitendinosus and the long head of the biceps femoris are found. The dense fibrous fascia lata is invested in this region as well.

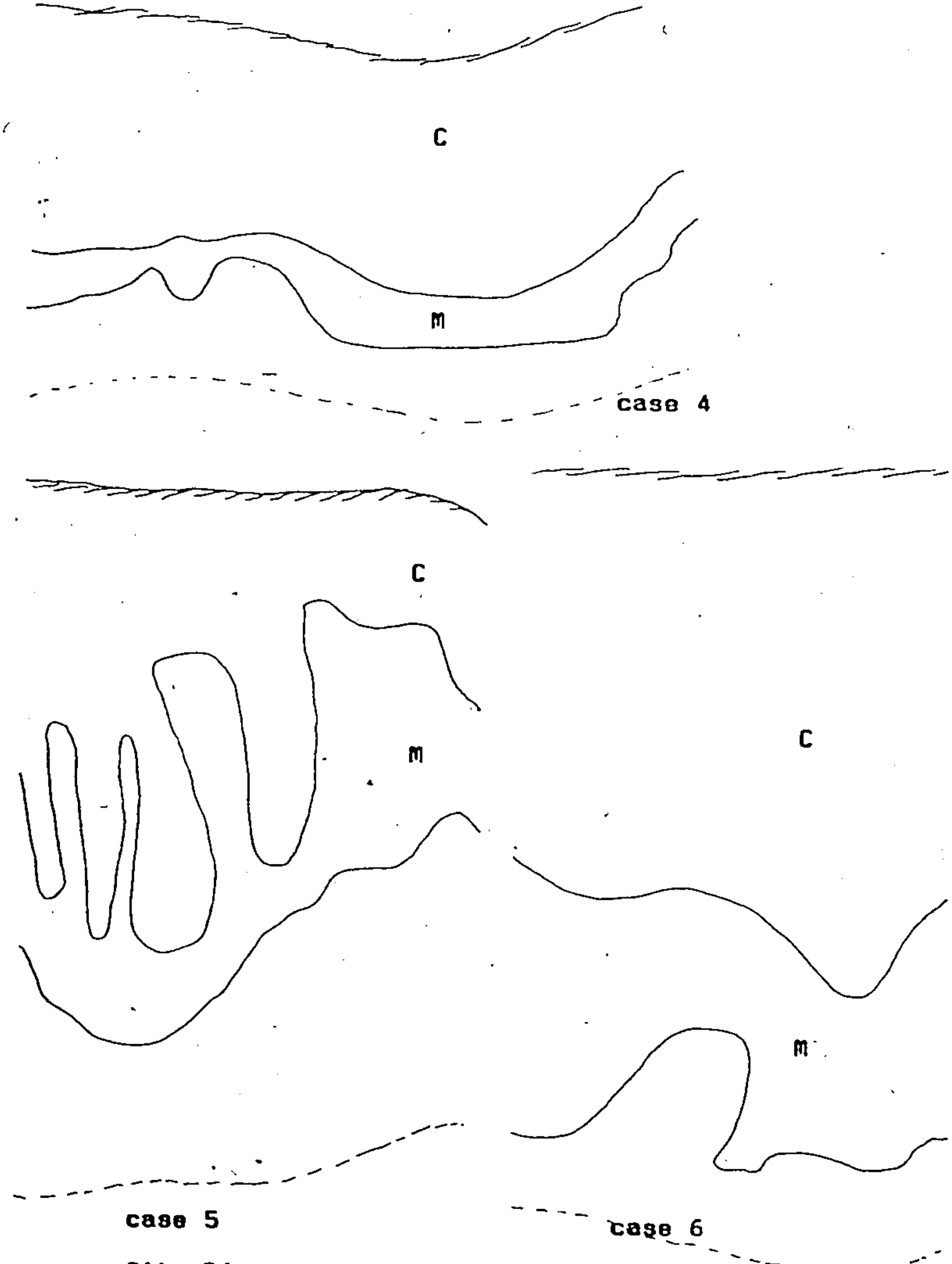
Epidermal Characteristics - The epidermis is relatively thin at this point and has a mean thickness of .05 mm with a range of .03 to .07 mm. In terms of epidermal thickness it is among the lower third of all sites studied. Stratum Malpighii and stratum corneum are about equally distributed. Occurrence of rete ridges ranges from 0 to 7 per mm with the mean count at 3. The mean length of rete pegs is .02 mm.

Interface Characteristics - The sine interface is varied. Cases 1, 3 and 4 have little structure. Cases 2, 5 and 6 present more or less well formed rete pegs. The epidermal interface is varied within itself. There are clusters of craters formed by the rete ridges, but the epidermal interface is mostly flat with several elongate continuous infoldings. Several pronounced hair follicles and adnexa are present. The dermal interface presents numerous parallel folds with discrete well formed papillae randomly placed. This region is not called upon to bear weight or flex and extend and appears not to require elaborate structuring of the interface.

Site 23, Popliteal Space

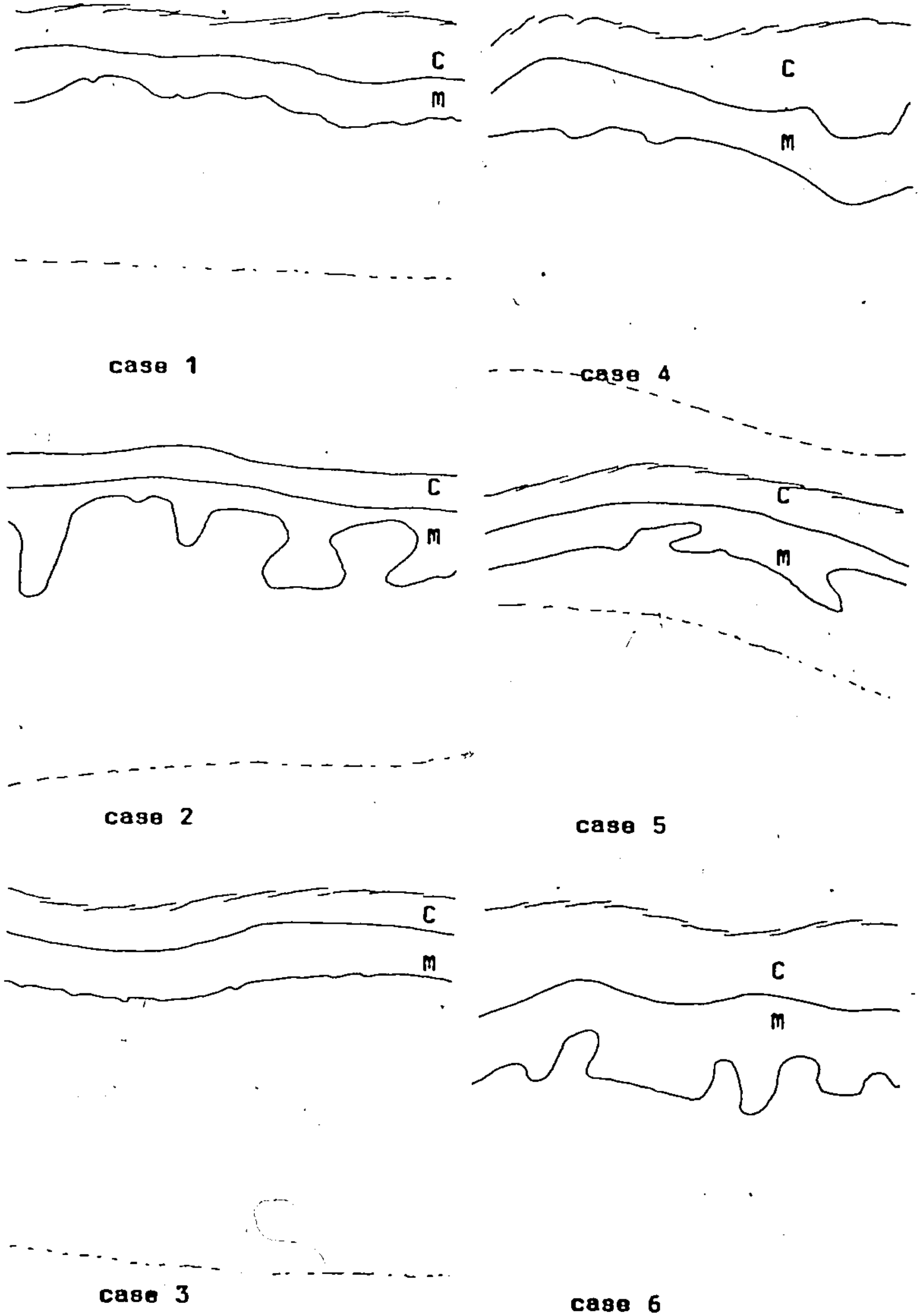
Functional Anatomy - The knee joint is a ginglymus joint acting as a hinge and allowing flexion of the lower leg on the thigh at the articulation of the femur above with the tibia below. Extension is limited

Plate 31

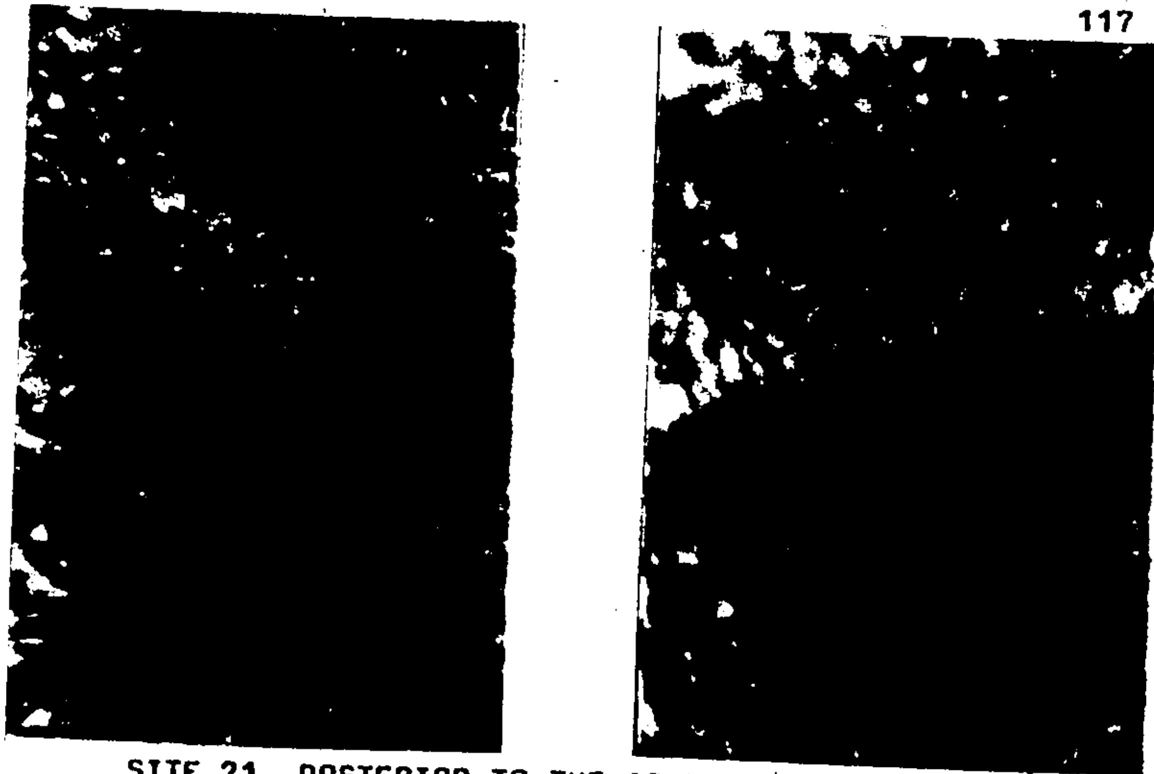



Site 21, Posterior Aspect of the Achilles Tendon

Plate 32




Site 22, Posterior Aspect of the Thigh



SITE 21, POSTERIOR TO THE ACHILLES TENDON

SITE 22, POSTERIOR THIGH

to alligning the leg to a straight line relationship with the thigh. The skin at the popliteal space is superficial to the popliteal vessels which are bounded medially by tendons of the semimembranosus and semitendinosus and laterally by the biceps femoris.

Epidermal Characteristics - The epidermal thickness of the popliteal space ranges from .03 to .06 with the mean .04 mm. The tissue is among the lower third in thickness of all sites examined. The stratum Malpighii tends to predominate slightly forming 55% of the total. Rete pegs number from 0 to 7 per mm with 3 being average. Length of the rete pegs varies from .02 to .06 mm.

Interface Characteristics - The sine interface is usually smooth. The well muscled case 2 has several elongate thin rete pegs. The epidermal interface has adnexa and cutaneous nerves which emerge from the rather flat surface. A tendency to furrow in parallel can be observed about which craters formed by the rete ridges can be seen in sparse clusters. The dermal interface seems furrowed. It is occasionally smooth but interrupted by clusters of small discrete papillae. This much flexed site has comparatively little structure and it is probable that deep dense fibrous connective tissue assumes much of the binding of the integument.

Site 24, Anterior Thigh

Functional Anatomy - The femur is covered anteriorly by heavy musculature of the rectus femoris and vastus intermedius invested by superficial fascia. The skin here is involved in covering and little motion can be attributed to it.

Epidermal Characteristics - The mean thickness of the epidermis of the anterior thigh is .06 mm placing it in the lower third of all sites examined. Mean epidermal thickness was .06 mm and ranged from .04 to .09 mm. Stratum Malpighii and stratum corneum were about equal. The rete pegs numbered from 0 to 5 per mm and the mean length was .03 mm.

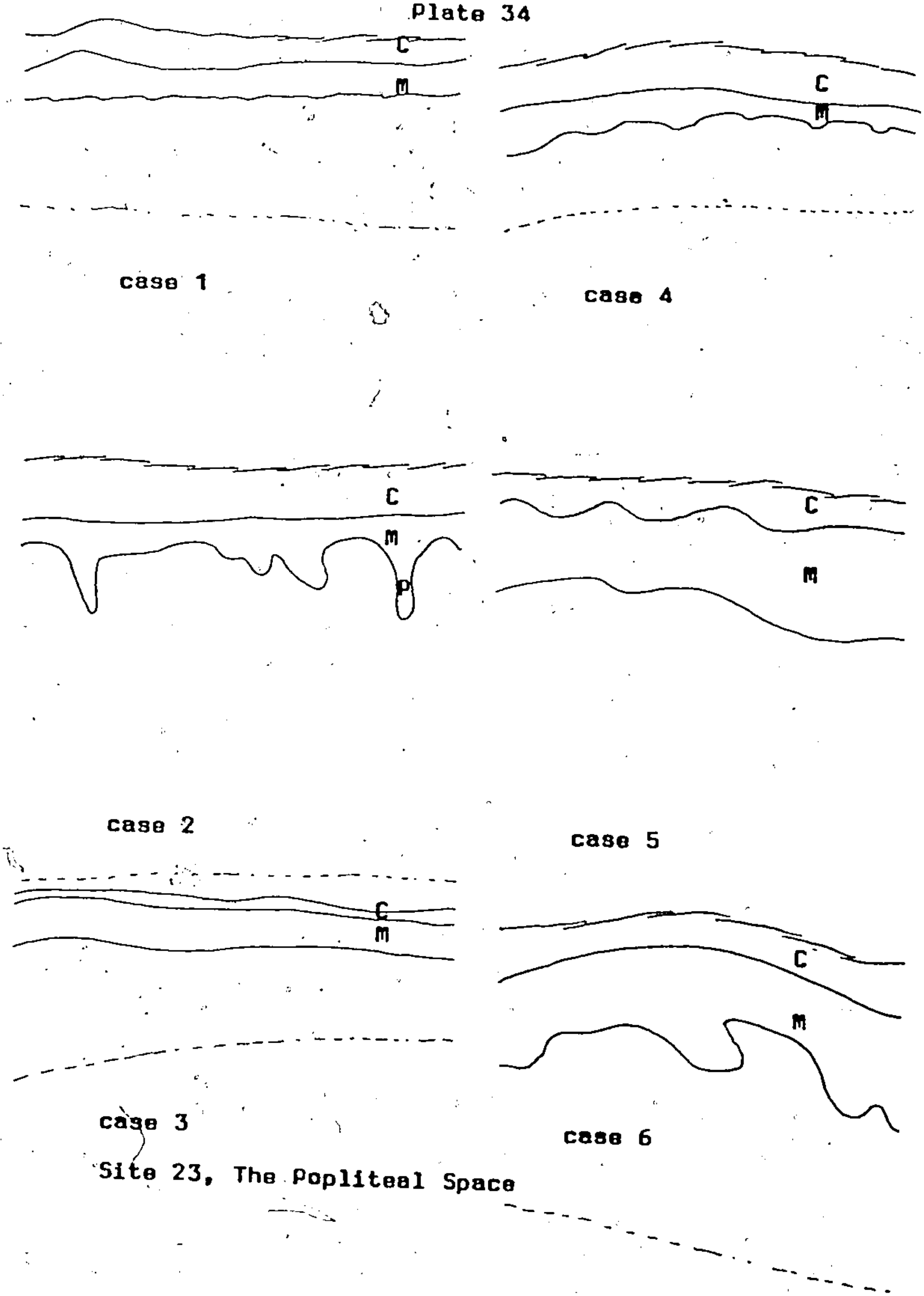
<u>Interface Characteristics</u> - The sine interface was of low profile as indicated by number and length of rete pegs, although case 6 demonstrated several well formed broad pegs. The epidermal interface had numerous cutaneous nerves. The tissue was furrowed with clusters of craters formed by rete ridges for reception of dermal papillae. The dermal interface demonstrated more pronounced parallel ridging with areas of numerous small papillae. This tissue which functions in the main as a covering has little need for highly developed interface structures and has ridges and furrows supported by low profile papillae.

<u>Site 25, Supra Patella</u>

<u>Functional Anatomy</u> - The patella is a sesamoid bone lying in the conjoined tendons of the quadriceps femoris musculature which becomes fibrous as it inserts into the tibial tubercle. When the knee joint is extended, this tissue tends to wrinkle but becomes tense as the knee is flexed.

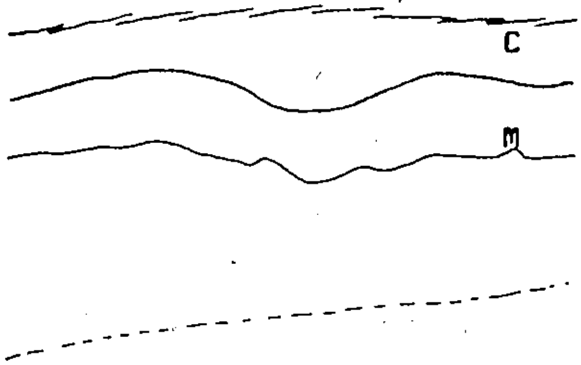
<u>Epidermal Characteristics</u> - The epidermis of the supra patellar region is active in flexion and extension and in the transmission of weight and is found in the upper third in thickness of the 50 sites examined. The range of epidermal thickness was from .06 to .12 mm with the mean .08 mm. Stratum corneum predominated (60% of total thickness) as work demands increased at this site. Rete peg length ranges from .02 to .06 mm with .04 mm

Plate 34

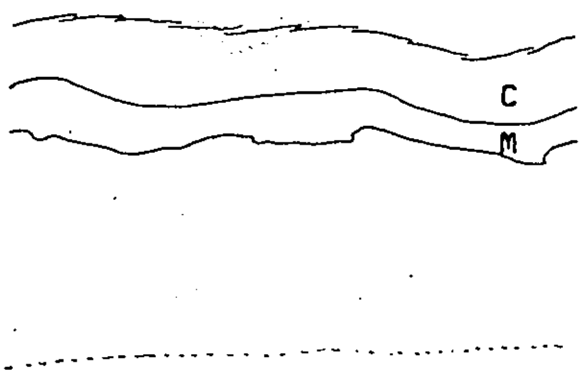



Site 23, The Popliteal Space

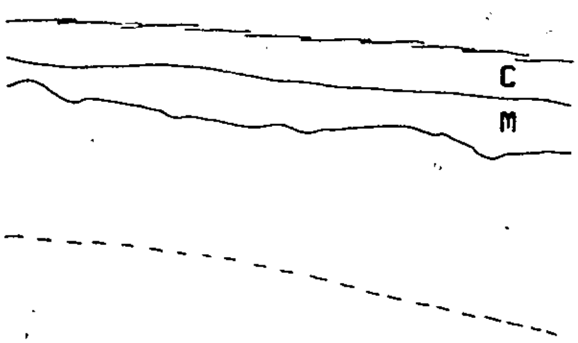
Plate 35



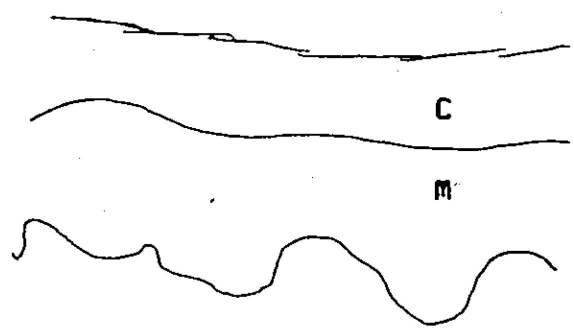

case 1




case 2

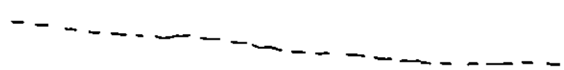


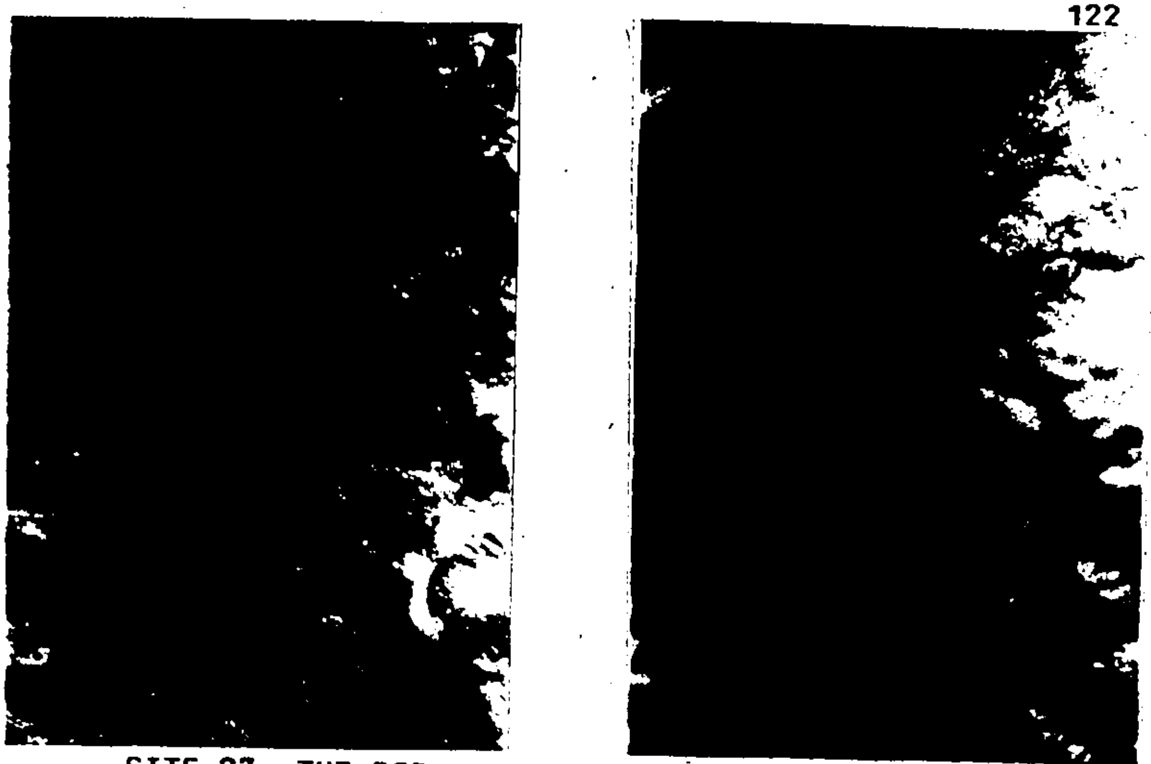

case 3



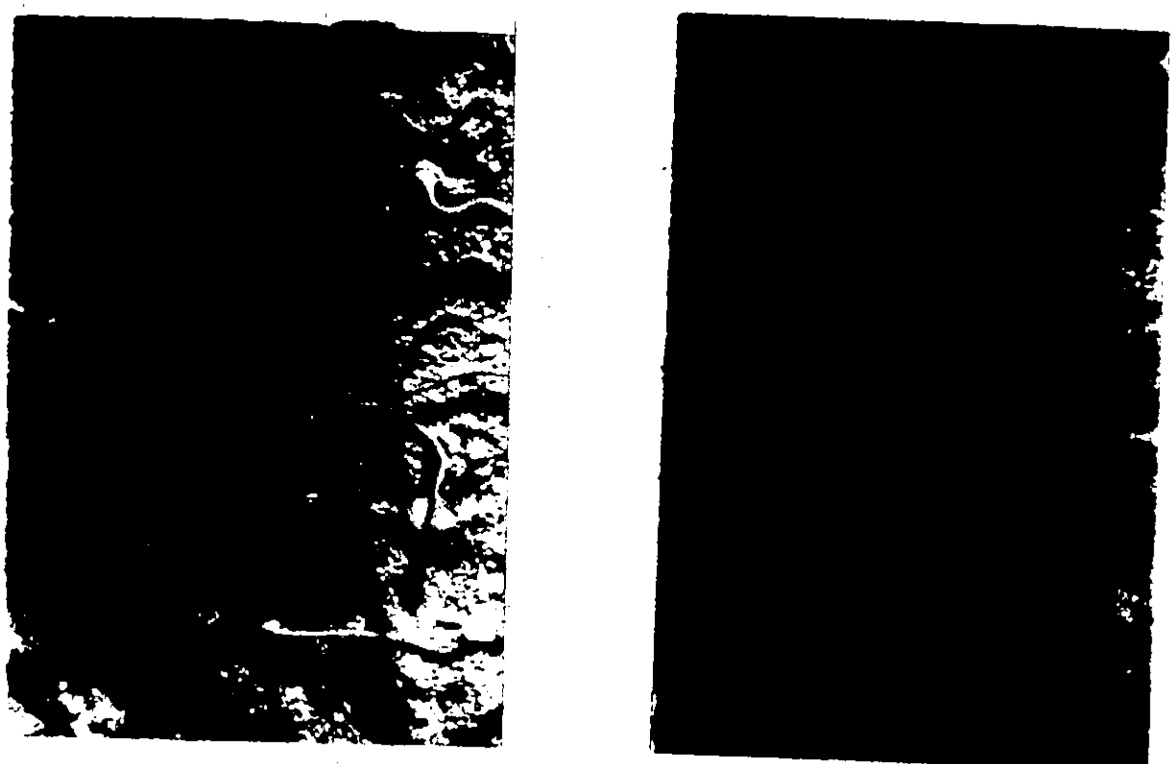

case 6

Site 24, The Anterior Aspect of the Thigh





SITE 23, THE POPLITEAL SPACE



SITE 24, THE ANTERIOR THIGH

the mean. Occurrence of the rete pegs was 2 to 7 per mm with the average number at 5.

Interface Characteristics - The sine interface demonstrates the occurrence of rete pegs of variable shape and length. Case 6, had particularly well formed regular rete pegs. The epidermal interface revealed a straight line folding about which well formed moderately regular craters formed by the rete ridges can be seen. Some adnexa is present. The dermal interface presents a deep fold about which well formed dermal papillae are numerous. The stress of folding as the knee is flexed and extended apparently demands a moderately well structured epidermal-dermal interface.

Site 26, Lateral Thigh

Functional Anatomy - The femur is covered on its lateral aspect by the vastus lateralis muscle which abducts the thigh at the hip. The muscle belly is massive and covered by the though fibrous connective tissue of the fascia lata. The skin is subject to little motion and functions as a cover. When the center of gravity of the body is shifted laterally, stress and tension is placed on the skin.

Epidermal Characteristics - The mean epidermal thickness of the skin of the lateral thigh is .06 mm placing this tissue among the middle third of all sites studied. The range of epidermal thickness is variable from .03 to .11 mm. The stratum Malpighii tends to predominate, its thickness contributing just over 50% of the total epidermis. The mean occurrence of rete pegs per mm is 3, the median length .03 mm with a range of .02 to .08 mm.

Interface Characteristics - The sine interface is most varied. Case 1 and 4 have little structure, but the remaining 4 cases present well structured rete ridges. The well muscled case 2 demonstrates long finger-like rete. The epidermal interface is much more structured than the anterior aspect of thigh, possibly because of the stress accepted by the underlying tensor fascia lata. There are shallow structureless folds surrounded by small craters formed by the rete ridges. The dermal interface presents several parallel ridges and numerous small papillae filling the region between.

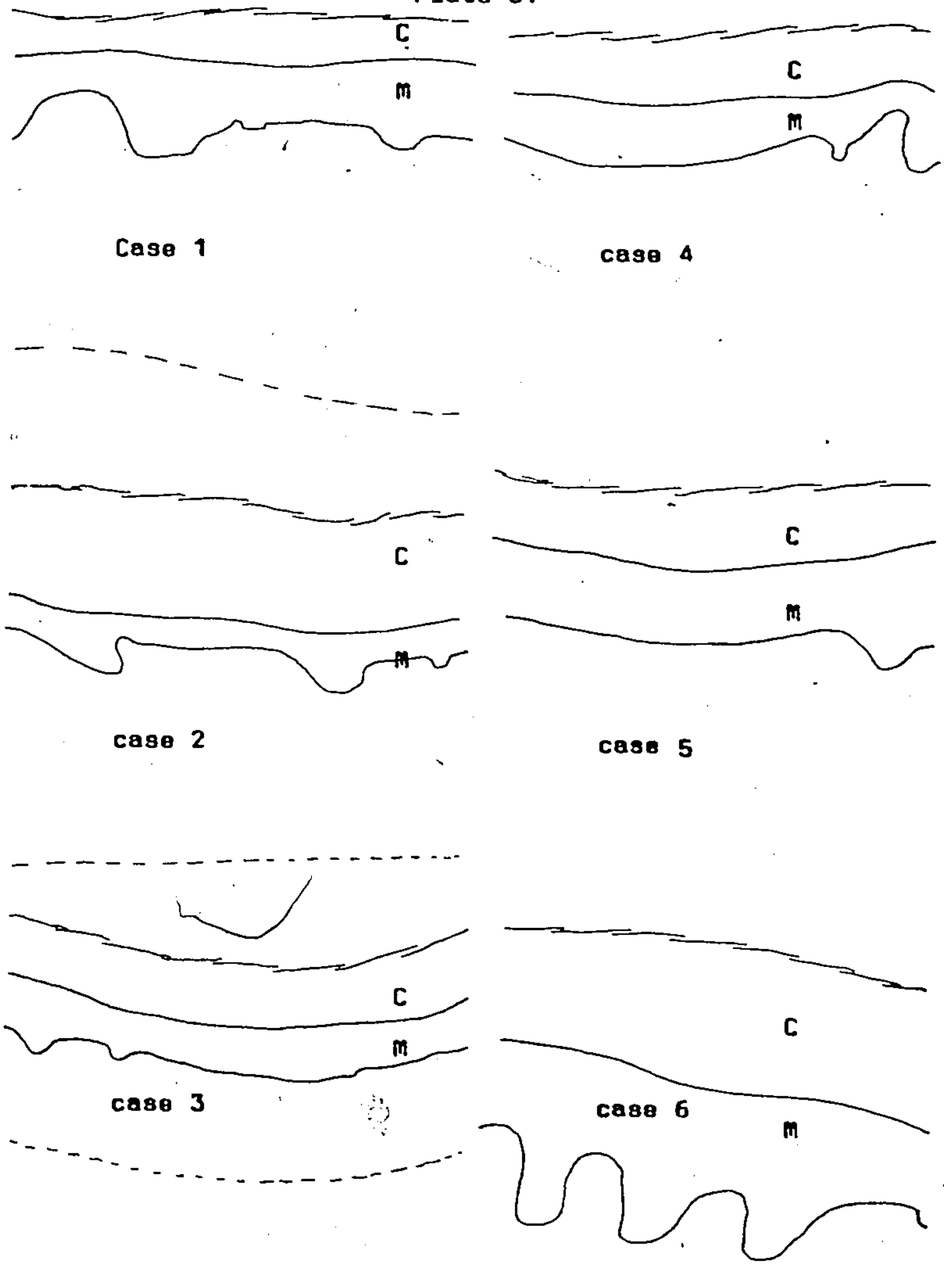
Site 27, Medial Thigh

Functional Anatomy - The medial aspect of the femur is covered by the adductor musculature which brings the thigh into the mid line body. The adductors magnus and longus are quite dense at mid thigh where the skin specimen was excised.

Epidermal Characteristics - The median epidermal thickness of the medial aspect of the thigh is .04 mm placing this tissue among the lower third of all sites studied. The epidermal thickness ranged from .03 to .06 mm and the stratum Malpighii is slightly predominant. It constitutes just over 50% of the total epidermal thickness. The rete peg count is 2 per mm with the length of rete .02 to .03 mm.

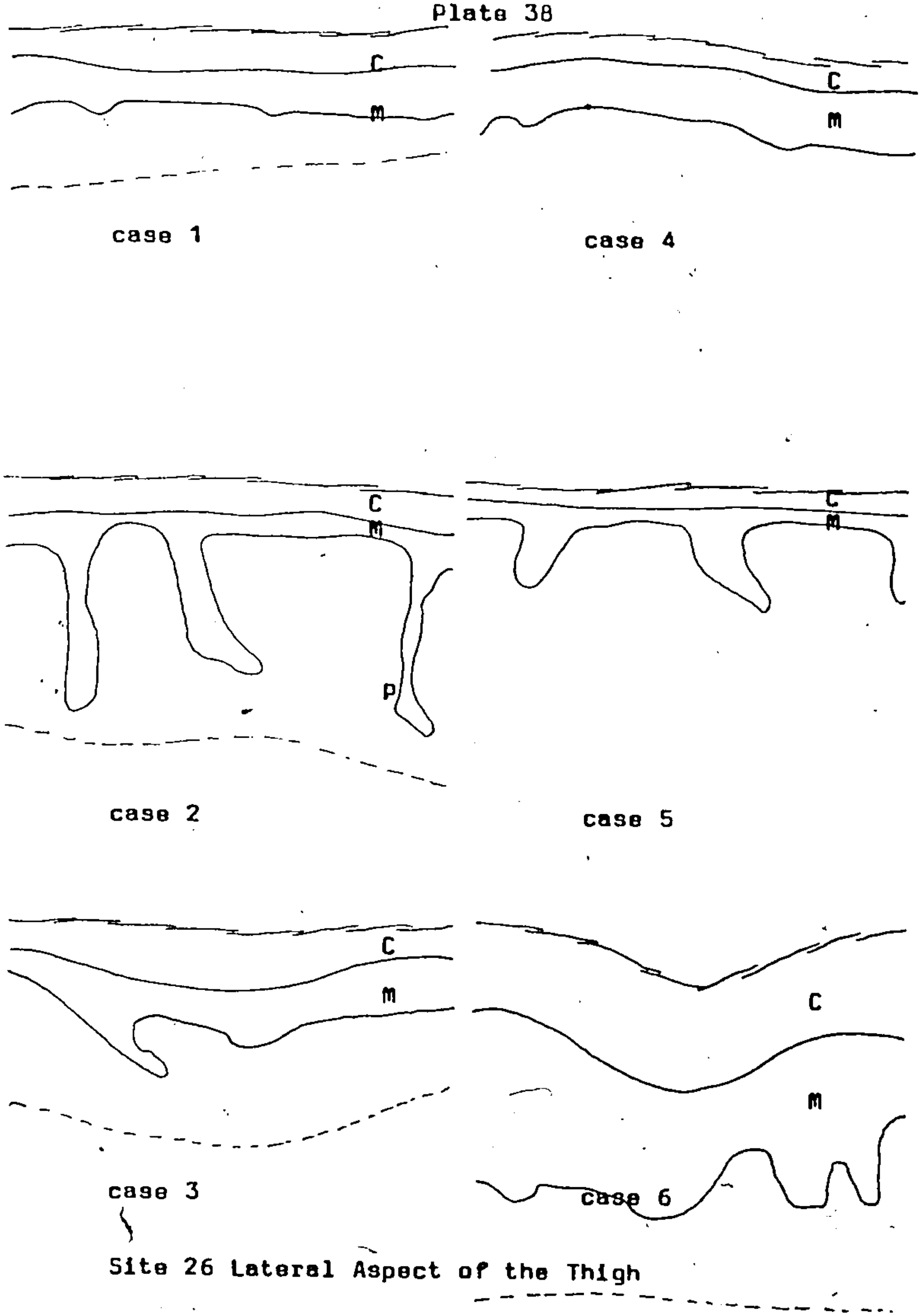
Interface Characteristics - The sine interface is of unusually low profile although the fleshy female, case 6, does demonstrate some broad rete pegs. The epidermal interface is rather structureless. Parallel folded lines cross an unusually flat surface with only a few random craters formed by the rete ridges. A few hair follicles are in evidence.

Plate 37

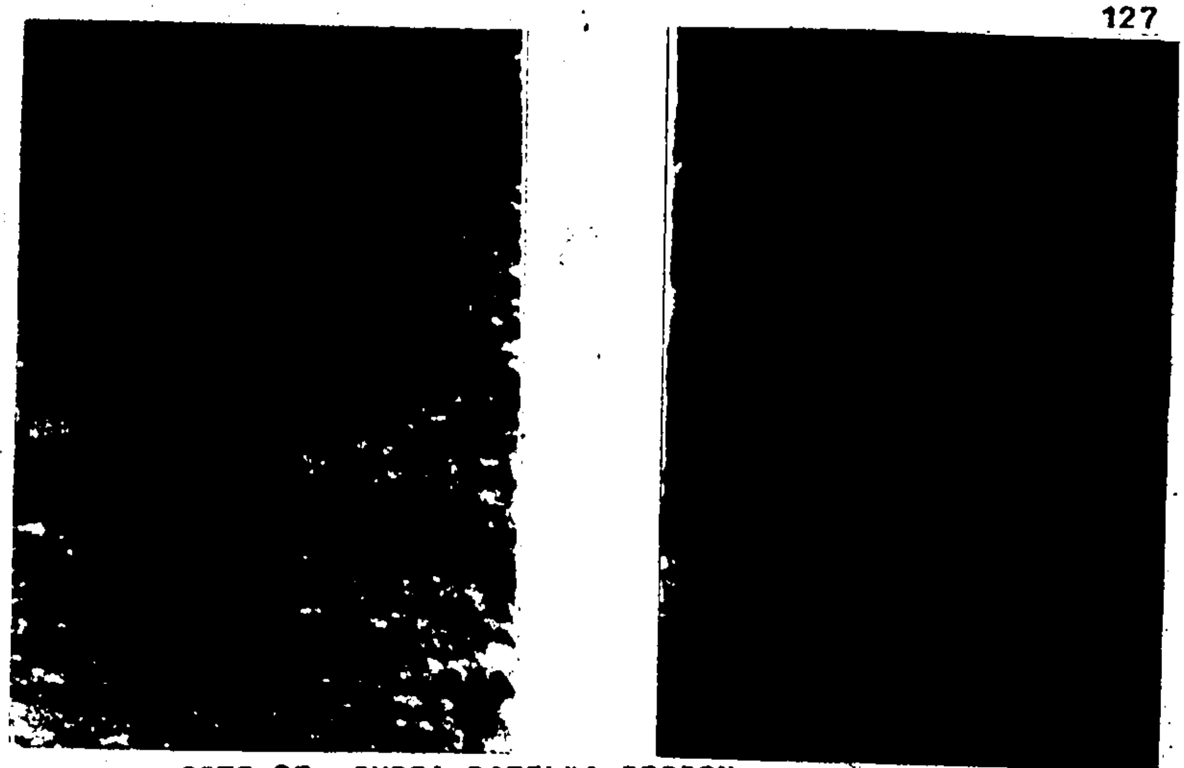



Site 25, Supra Patellar Region

Plate 38




Site 26 Lateral Aspect of the Thigh



SITE 25, SUPRA PATELLA REGION

SITE 26, LATERAL THIGH

The dermal interface is equally structureless except for parallel folds. It would seem that few functional demands are placed on this covering and the epidermal-dermal interface lacks structure.

Site 28, Crest of the Tibia

Functional Anatomy - The anterior aspect of the tibia is superficial and along its mid shaft serves as origin for the tibialis anticus muscle. Little motion is found in the skin along this site, although it is firmly attached to the underlying fibrous connective tissue and bone.

Epidermal Characteristics - The epidermis of the skin of the region of the tibial crest is among the lower third in thickness of all sites studied. The mean thickness is .04 mm with a range of .03 to .08 mm. The stratum Malpighii and stratum corneum are about equal. The rete peg is 3 per mm with a range of .02 to .05 mm in length. The mean length is .03 mm.

Interface Characteristics - The sine interface of most cases is of low profile. The heavily muscled case 2 is unusual in having several long finger-like rete pegs. The epidermal interface is varied. The craters of the ridges of the rete are clustered about hair follicles and adnexa. This region is adjacent to a flat structureless area of the interface. A cutaneous nerve can be seen. The dermal interface has papillae of small size in parallel orientation. There is a flat structureless area and a depression for the reception of adnexa around which papillae are found in rosette configuration. It is probable that the structureless regions are at the points of greatest adhesion where dense fibrous connective tissue connects skin to bone. The more structured low profile rete emerge as the muscular tissue develops and slight movement is imparted to the site.

Site 29, Posterior Leg

Functional Anatomy - The posterior aspect of the tibia and fibula forming the lower leg is covered by fleshy thick and powerful musculature, the gastrocnemius and soleus, which flex the leg on the thigh and the foot on the leg.

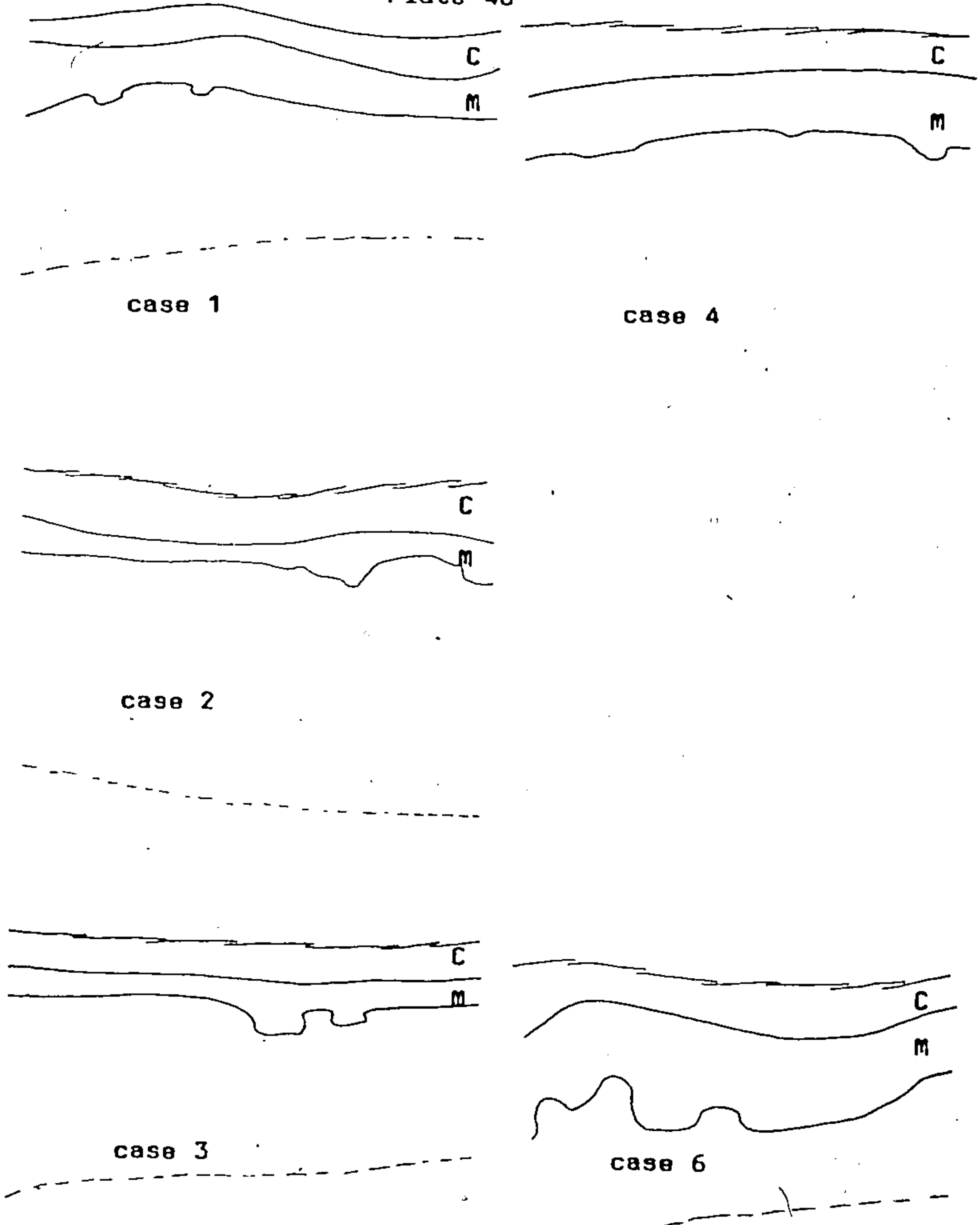
Epidermal Characteristics - The epidermal thickness of the skin of the posterior leg is found among the middle third of all sites studied. The mean thickness is .06 mm with the range of .03 to .08 mm. The stratum Malpighii and stratum corneum are about equally divided. The rete peg count averages 3 per mm and the mean rete elngth is .03 mm. The range of rete length is from .02 to .08 mm.

Interface Characteristics - The sine interface varied considerably from case to case. Case 1 was essentially structureless, while the heavily muscled case 2 demonstrated long finger-like rete pegs and the other cases were intermediate in structure. The epidermal interface presents continuous ridges which, for the most part, run parallel with several running transversely. Between the ridges or folds, small craters formed by the smaller rete ridges, occur regularly. The dermal interface is dominated by intersecting folds between which numerous small papillae can be seen. The posterior leg skin functions in the main as a covering, and deep structures of the interface are not called for. The flexing of the gastrocnemius may account for the prominent folds.

Site 30, Plantar Heel

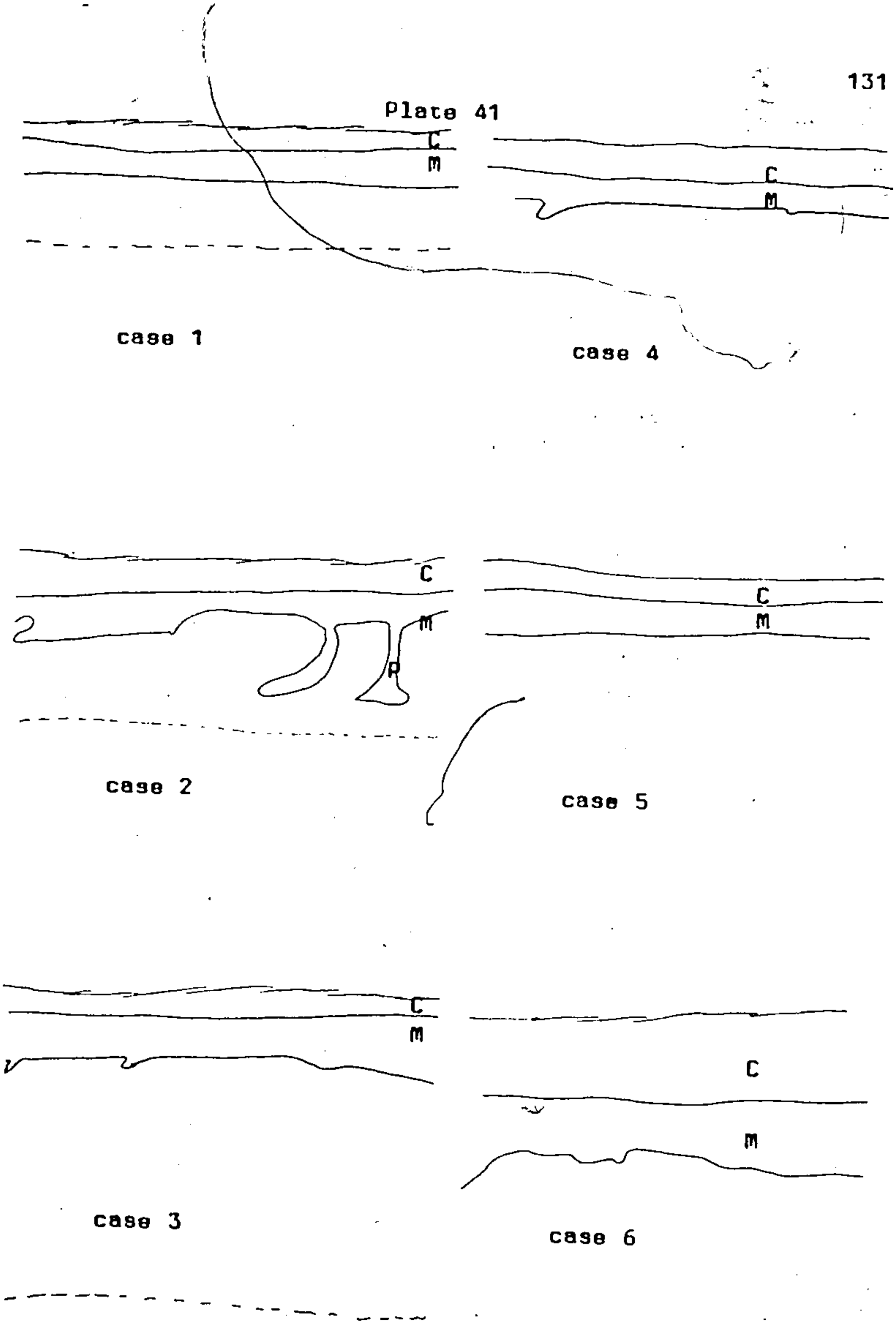
Functional Anatomy - The weight bearing tuberosities of the os

Plate 40




Site 27, Medial Aspect of the Thigh

Plate 41




Site 28, The Tibial Crest

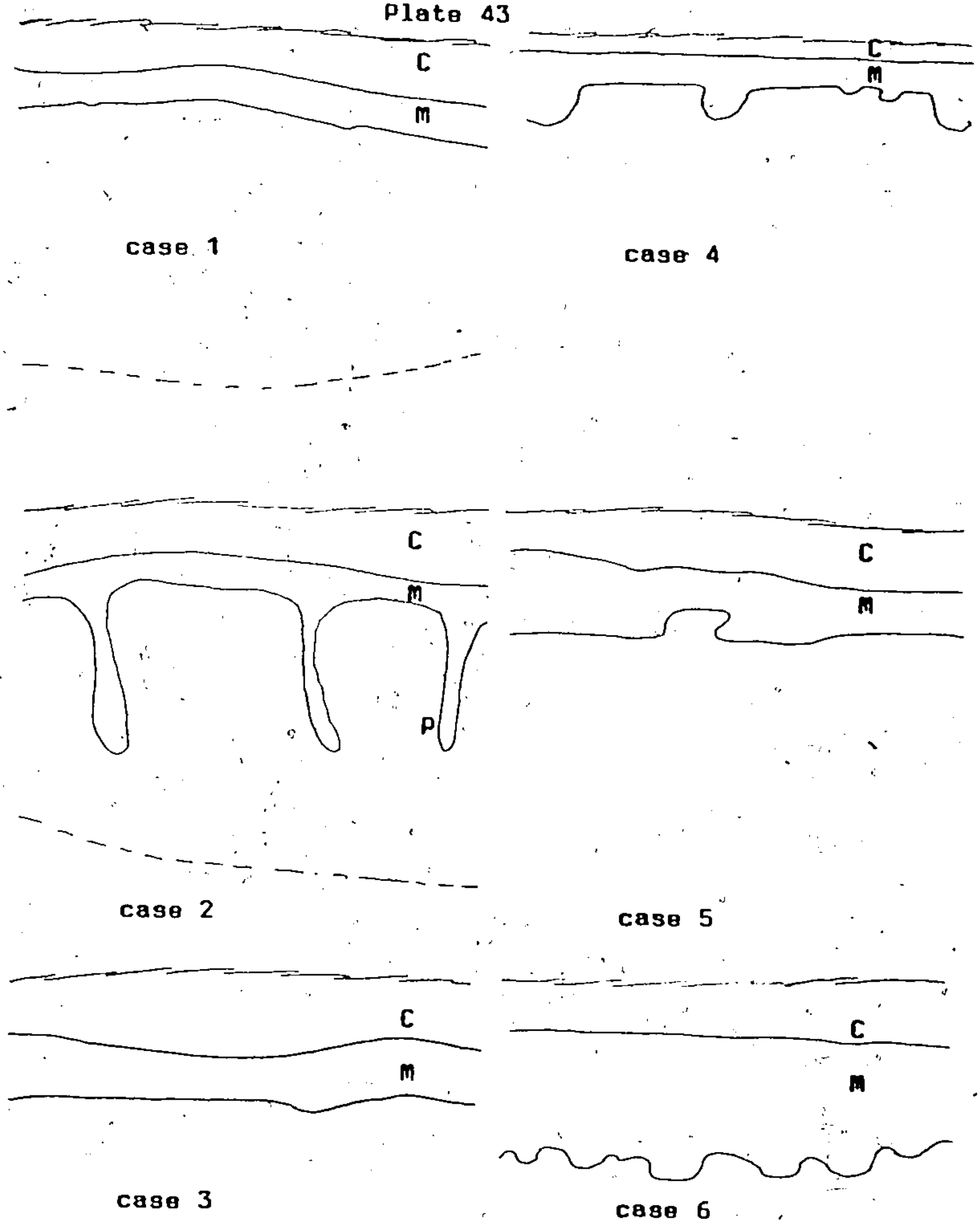
SITE 27, THE MEDIAL ASPECT OF THE THIGH

SITE 28, THE CREST OF THE TIBIA

calcis (heel bone) are covered by a firmly anchored raphe formed by the expansion of the Achilles tendon and the planter fascia of the foot. No motion is found at this site, but the weight bearing function is unmistakable. At one point in walking,the entire weight of the body is transmitted through the heel bone.

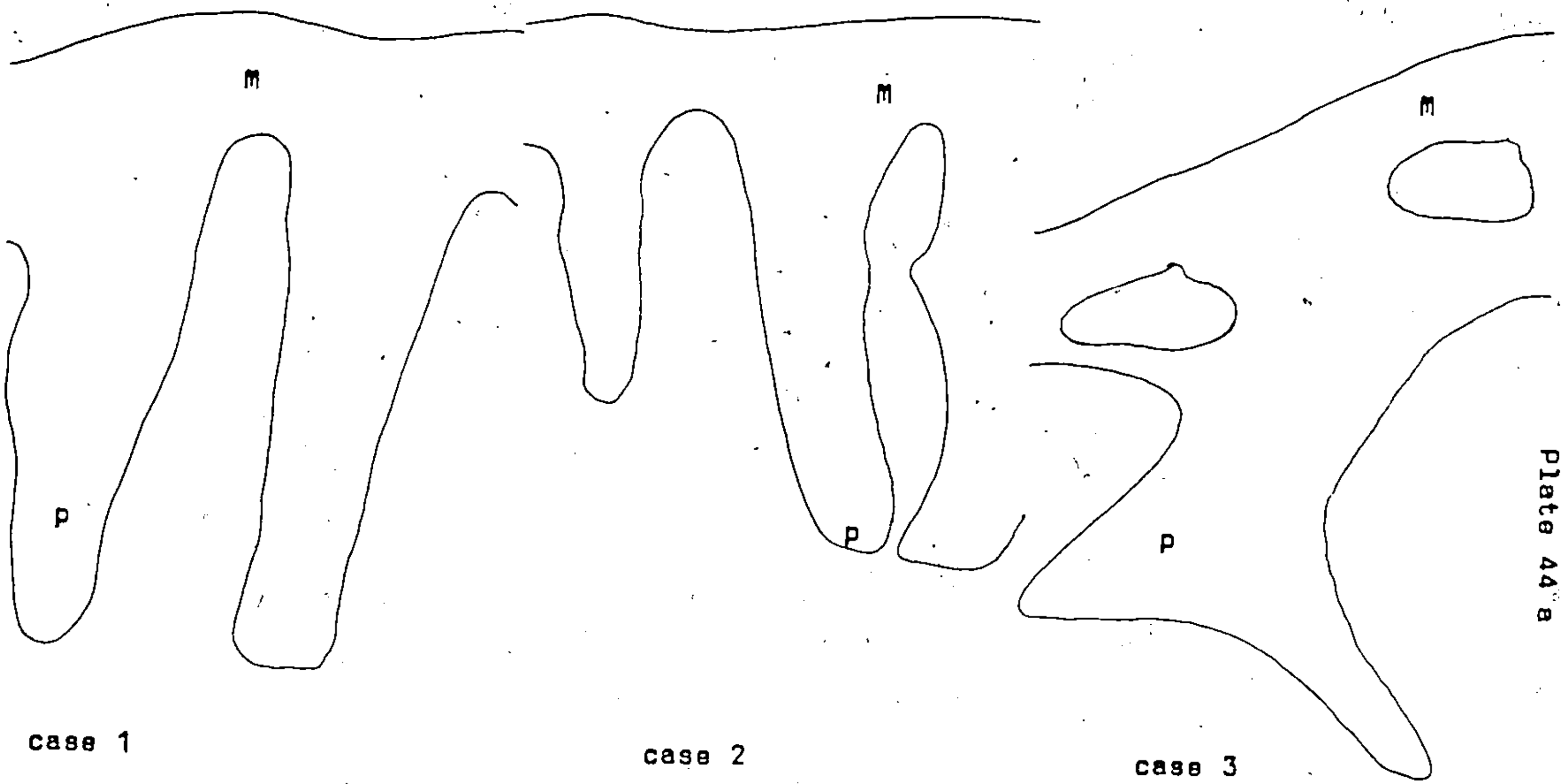
Epidermal Characteristics - The epidermis of the heel is the thickest of all sites examined. The mean epidermal thickness is .63 mm with the range from .50 to .85 mm. The stratum corneum is decidedly predominant and constitutes about 80% of the total epidermal thickness. The rete peg number averages 7 per mm, and their length ranges from .12 to .30 mm. The mean rete length is .23 mm the greatest of all sites studied. The sine interface exhibits massive long and broad rete pegs. Cases 3 and 4 demonstrate pegs which have been bent to parallel the free surface of the skin. The dermal papillae likewise have been deflected and portions of the dermis appear as islands within the stratum Malpighii. The epidermal interface is most interesting as it demonstrates the most massive structuring of all interfaces studied. The rete ridges occur in parallel folds and the craters usually present for the reception of dermal papillae appear to have coalesced into elongate troughs. The dermal papillae are usually long and numerous. They occur in parallel fashion with deep grooves between. The massive structuring of the rete pegs and the dermal papillae seem to be in response to the weight bearing function of the heel and the parallel ordering may provide added mechanical advantage much as the grooves of a wrench or pliers provide.

Plate 43




Site 29, Posterior Aspect of the Lower Leg

Plate 44 a

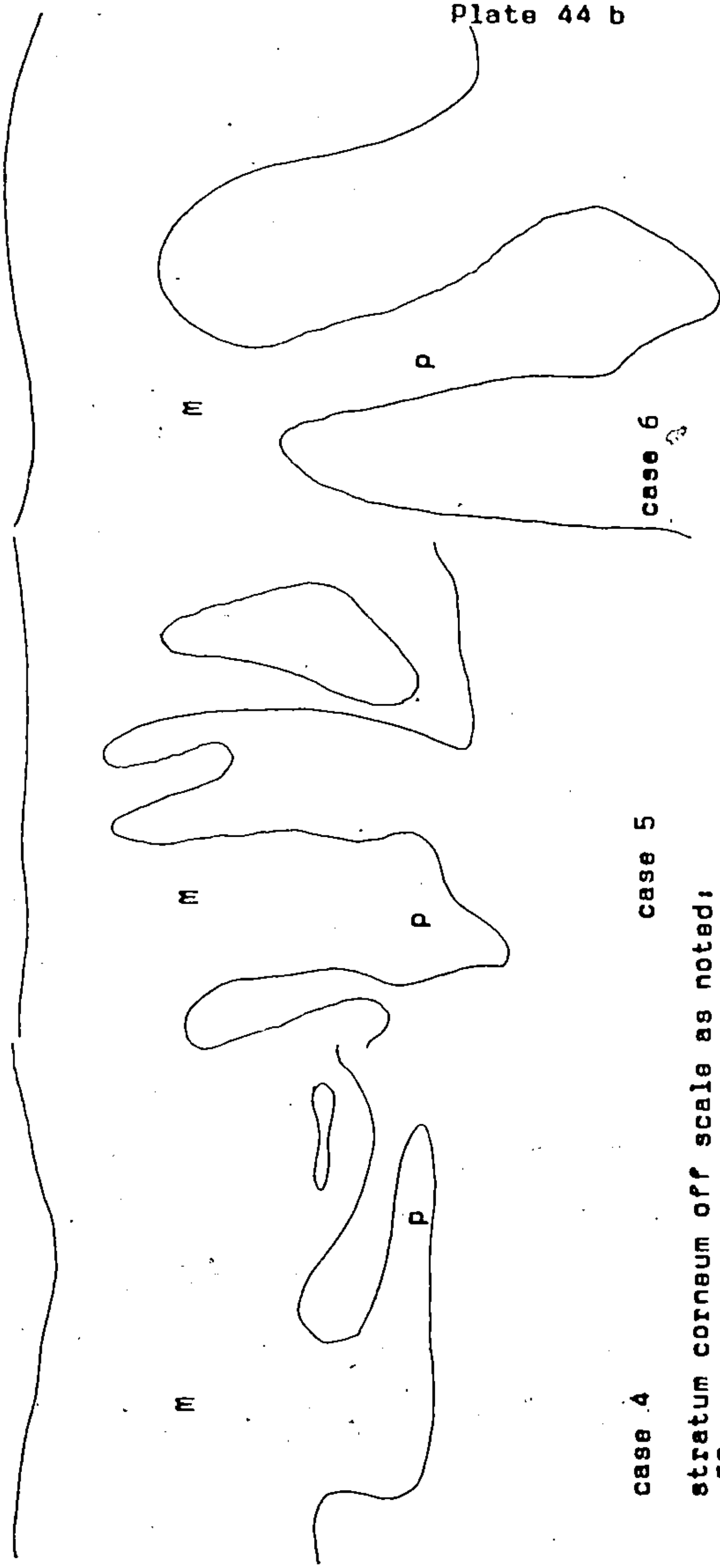



case 1 | case 2 | case 3

stratum corneum off scale as noted:
.43 mm | .53 mm | .60mm

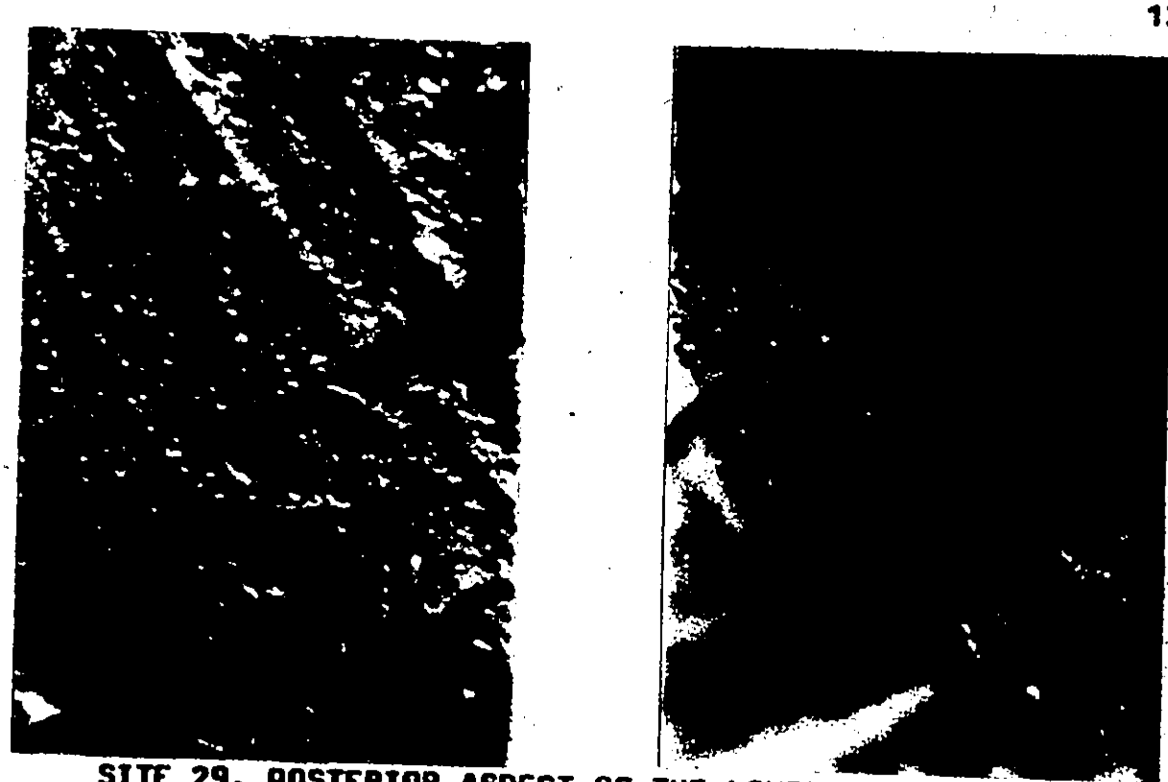
Site 30 (Plate A), Plantar Aspect of the Heel

Plate 44 b

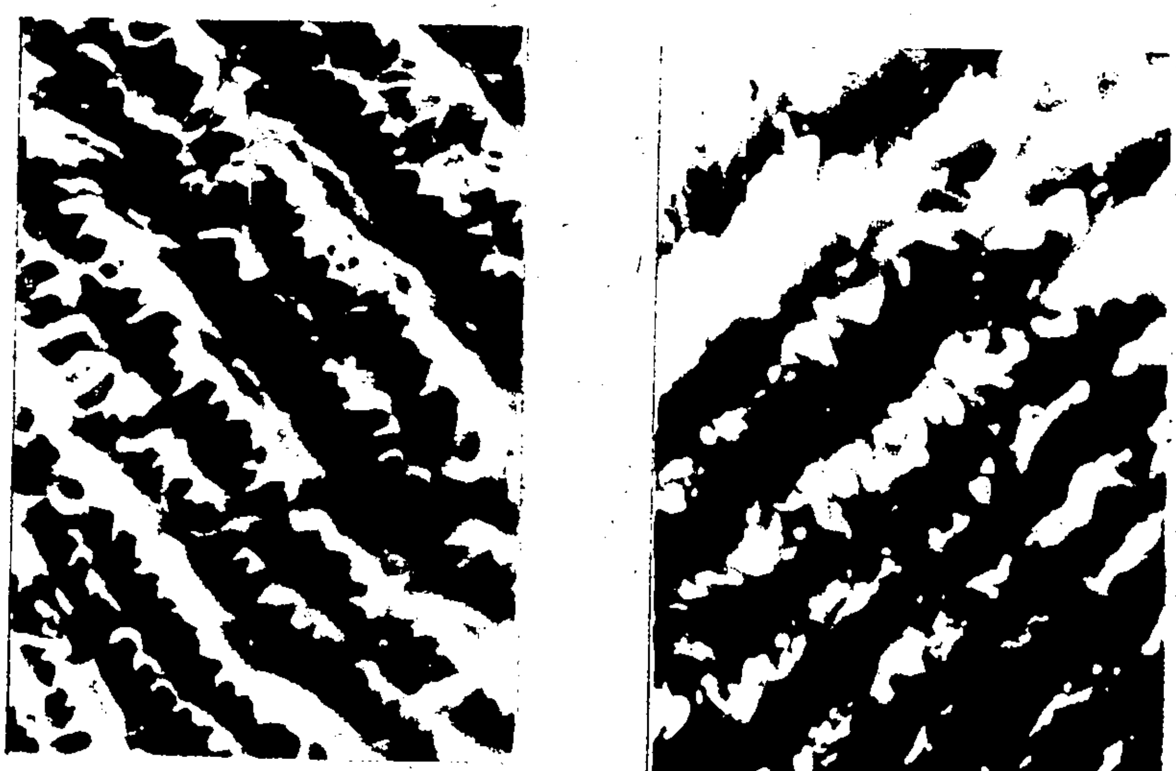



stratum corneum off scale as noted: .50 mm .55mm .75 mm

Site 30 (Plate B), Plantar Aspect of the Heel



SITE 29, POSTERIOR ASPECT OF THE LOWER LEG



SITE 30 PLANTAR ASPECT OF THE HEEL

Site 31, Lateral Malleolus

Functional Anatomy - The distil end of the fibula presents a blunt prominence, the malleolus, which forms part of the ankle joint as it forms an articulation with the talus. The skin covering the malleolus has no motion and overlies dense fibrous connective tissue making up the ligaments and capsule of the ankle joint.

Epidermal Characteristics - the epidermis covering the malleolus averages .06 mm in thickness and is found among the middle third of all sites studied. Thickness range is .04 to .07 mm. The stratum corneum predominates the total epidermis slightly. Rete ridge numbers average 5 per mm with a mean length of .03 mm and ranged from .01 to .07 mm.

Interface Characteristics - The skin of the malleolus has a stretched character over the rounded prominence. The sine interface demonstrates considerable variation. Cases 1 and 3 have low profiles. The other cases show distinct broad rete pegs, some of which are slanted. The epidermal interface has a flat structureless region about which are craters formed by the rete ridges and are widely spaced. The dermal interface has numerous small papillae irregularly spaced about relatively flat regions. It is probable that the epidermis is held by the stretching of the skin over the rounded prominence of the malleolus. Interface structures are absent or reduced. Adjacent regions show the development of low interface structuring for anchoring the epidermis on the dermis.

Site 32, Infra Malleolus

Functional Anatomy - Immediately below the malleolus, flexion and extension of the foot on the leg occurs. Joint capsule and ligamentous tissues form a dense connective tissue raphe and the tendons of the flexor hallucis longus, flexor digitorum longus, and tibialis posterior.

Epidermal Characteristics - Epidermal thickness of the infra malleolar region is found among the upper third of all sites studied. Mean epidermal thickness is .09 mm and range is from .04 to .13 mm. The mean number of rete pegs was 5 per mm and length ranged from .03 to .10 mm with the mean at .05 mm.

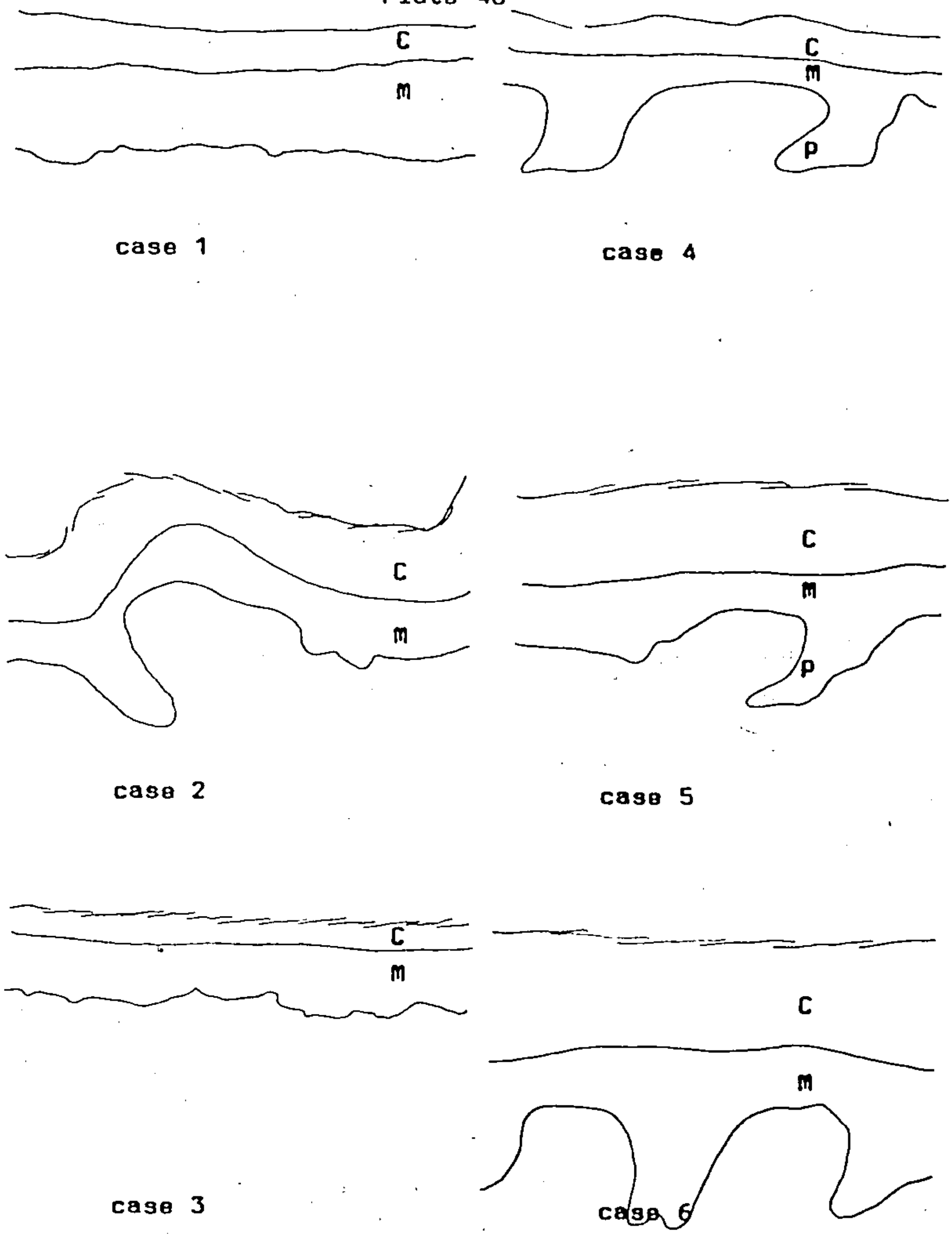
Interface Characteristics - The sine interface showed structuring in all cases. The rete pegs tended to be broad. The epidermal interface showed a much more regular and larger cratering formed by the rete Malpighii than was found in the malleolar region itself. A groove was observed where flexion occurred and where craters were absent. The dermal interface demonstrated numerous regularly spaced well formed papillae. The ankle joint, being a ginglymus or hinge joint, allows motion of the foot on the leg in one plane only and the interface structuring is well ordered except for the fold of flexion.

Site 33, Mid arch, Plantar Foot

Functional Anatomy - The mid tarsal joint is of the arthrodial type allowing for gliding movement between the navicular and cuneiforms. Much weight is transmitted as the foot is plantar flexed in take off during walking. The underlying flexion musculature is made up of the flexor digitorum longus and brevis and the dense plantar fascia on the medial aspect of the arch of the foot.

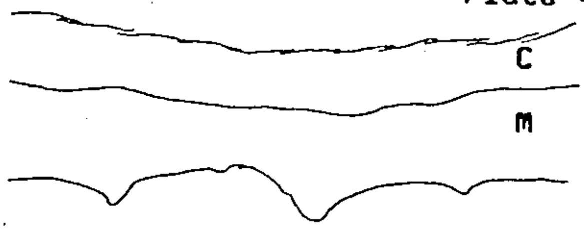
Epidermal Characteristics - Thickness of the epidermis of the plantar arch of the foot ranges from .07 to .48 mm with .26 mm the median.

Plate 46

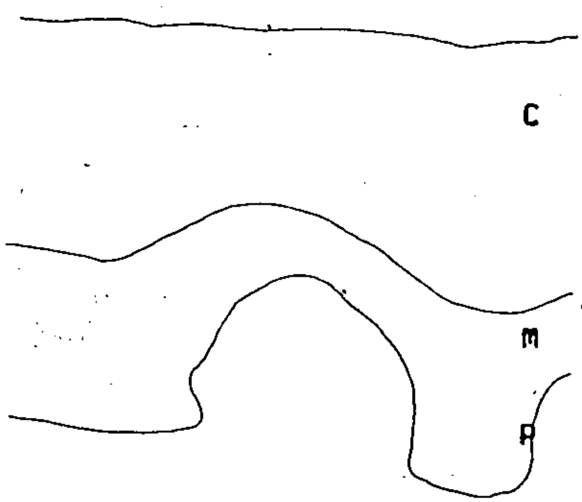



Site 31, the Lateral Malleolus

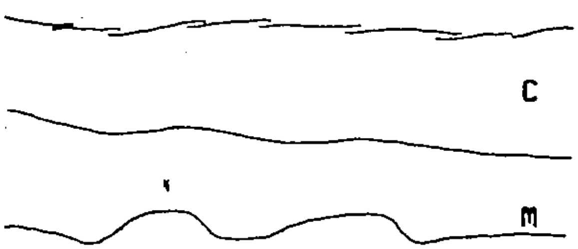
Plate 47



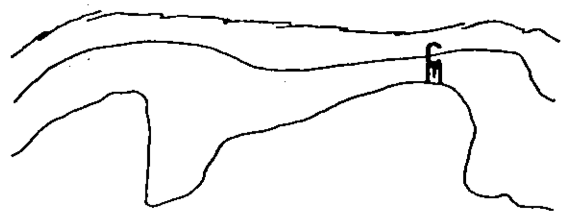

case 1



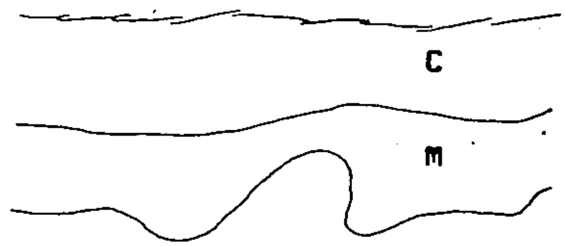

case 2



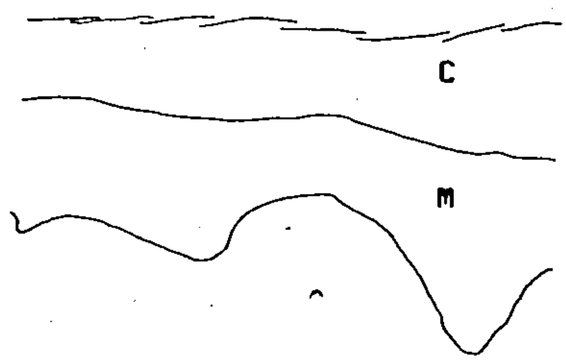

case 3




case 4

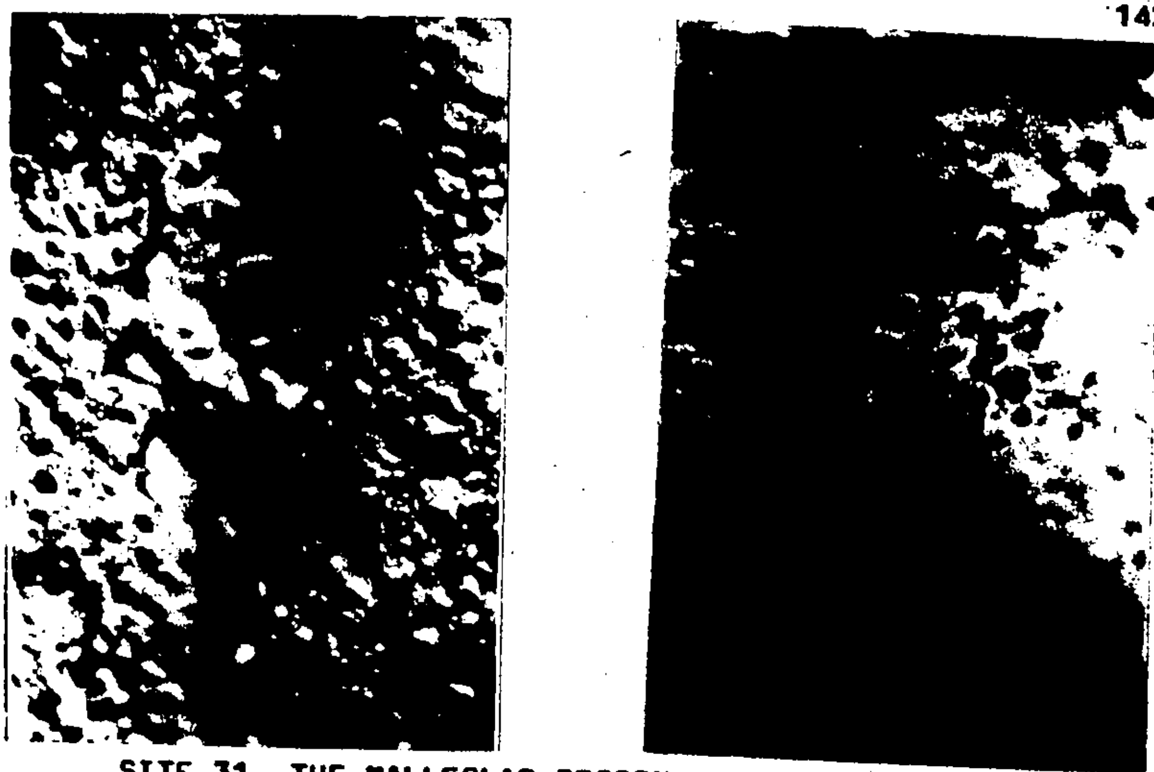



case 5

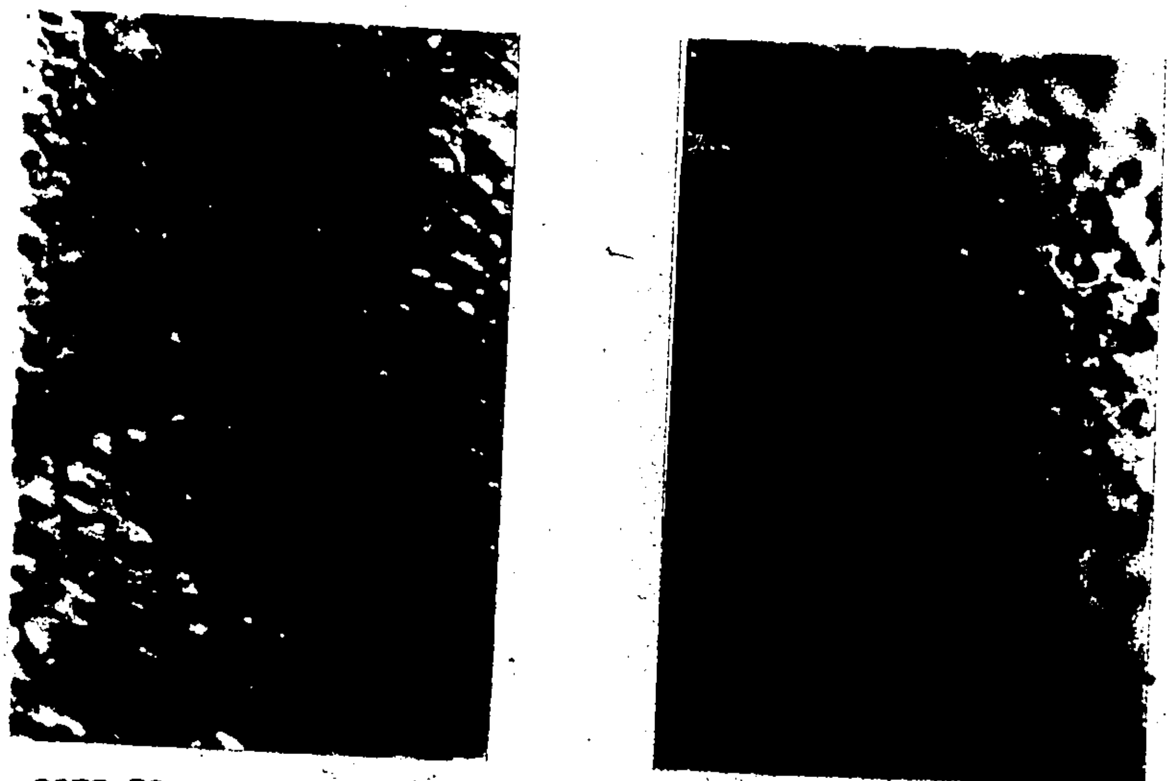



case 6

Site 32, Distil to the Lower Border, Lateral Malleolus



SITE 31, THE MALLEOLAR REGION



SITE 32, THE INFRA MALLEOLAR REGION

This tissue is among the upper third in thickness of all sites studied. Rete pegs are numerous averaging 8 per mm. Rete length ranges from .07 to .14 mm with .09 mm the median.

Interface Characteristics - The sine interface shows varied structure. Rete pegs are sometimes broad, sometimes pointed and often bent with reference to the free surface of skin, possibly because of the combined weight bearing and flexing activities of the site. The epidermal interface has numerous well formed craters formed by rete Malpighii, although not nearly as large as those found at the heel or first metatarsal head. The rete ridging seems to orient on several planes following stress lines that this region is subject to. The dermal papillae are numerous, well formed and seen to orient in parallel, but not in the highly organized order of the heel and first metatarsal head regions.

Site 34, Plantar First Metatarsal Head

Functional Anatomy - The head of the first metatarsal with the base of the proximal hallucal phalanx forms a ginglymus or hinge joint permitting flexion and extension of the great toe. The hallucal sesamoid bones and the tendons of the flexor hallucis longus and brevis cover the plantar aspect of the first metatarsal head.

Epidermal Characteristics - The epidermal thickness of the head of the first metatarsal plantarly is second only to that of the heel. Mean thickness is .39 mm ranging from .15 to 1.05 mm. Rete peg number averages 9 per mm with the length ranging from .08 to .14 mm. The mean rete peg length is .12 mm.

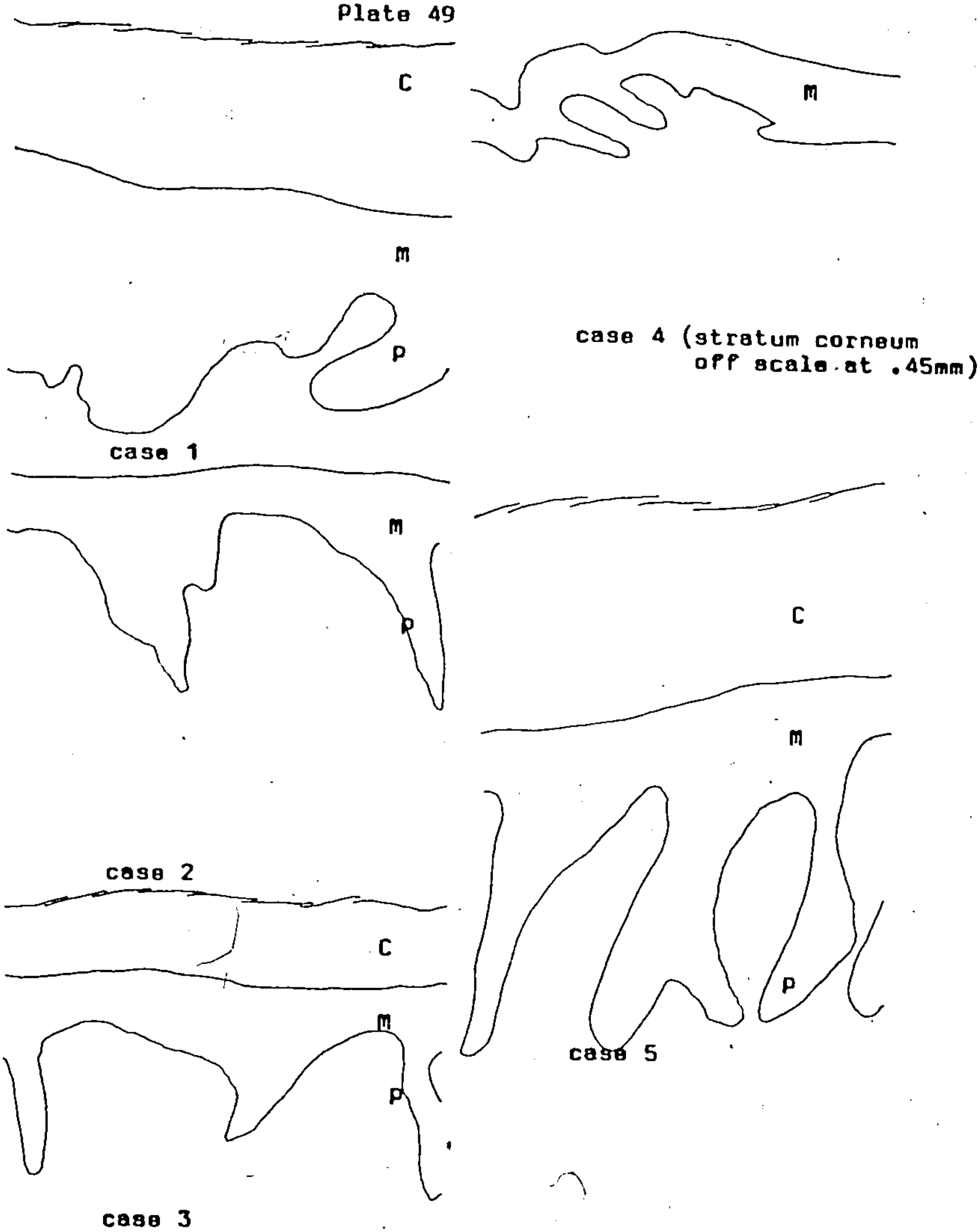
Interface Characteristics - The sine interface in all cases presents deep rete pegs of varied shape. They appear to have coalesced to form broad pegs and are sometimes deflected presumeably by pressure received. The epidermal interface is much like that of the heel, but on a much reduced scale. Broad rete ridges run in parallel with smaller transverse interconnecting bars producing well formed craters for the reception of the dermal papillae. The dermal papillae are large, well formed finger-like projections placed in parallel rows. It would appear that weight bearing surfaces develop definite parallel rows along which epidermal craters and interdigitating dermal papillae firmly come together. The combination of weight bearing and flexion makes for somewhat reduced size of the interface elements, but the parallel ridging provides structural mechanical advantage in take off during walking.

Site 35, Flexor Fold, Second Toe

Functional Anatomy - The interphalangeal joint of the lesser digits are of the ginglymus or hinge type allowing flexion and extension within the digit. There is a joint capsule over which the tendons of the flexor digitorum longus and brevis pass. Weight is transmitted through the lesser digits, but not to the degree transmitted through the first metatarsal.

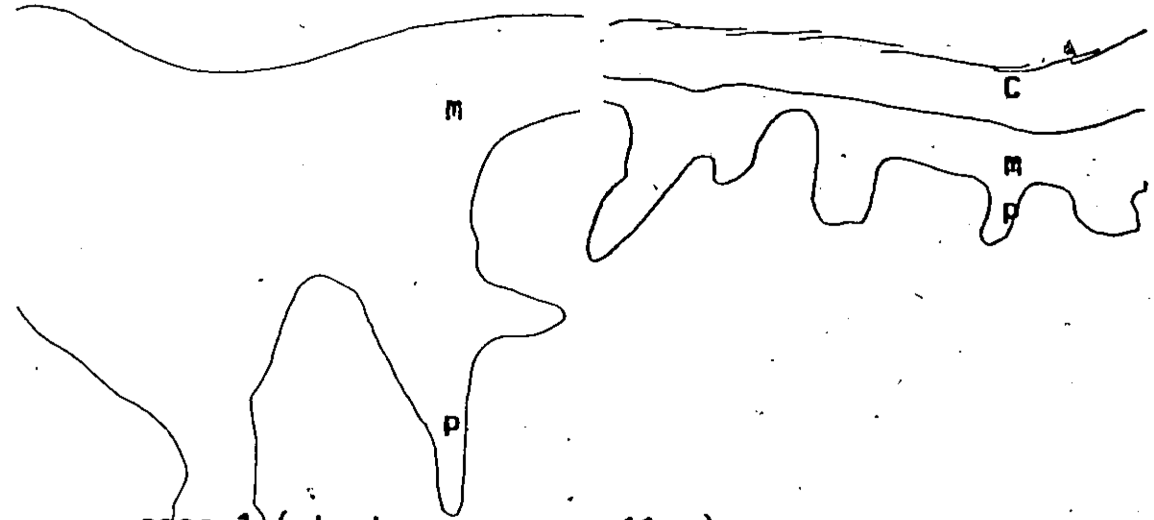
Epidermal Characteristics - The mean epidermal thickness of the flexor fold of the toe is .17 mm and ranges from .09 to .22 mm. This tissue is among the upper third in thickness of all sites studied. The mean number of rete pegs is 9 per mm. The mean rete length is .10 mm with the range from .09 to .12 mm. As with most thicker tissues, the stratum corneum tends to predominate the total epidermal thickness (60%).

Plate 49

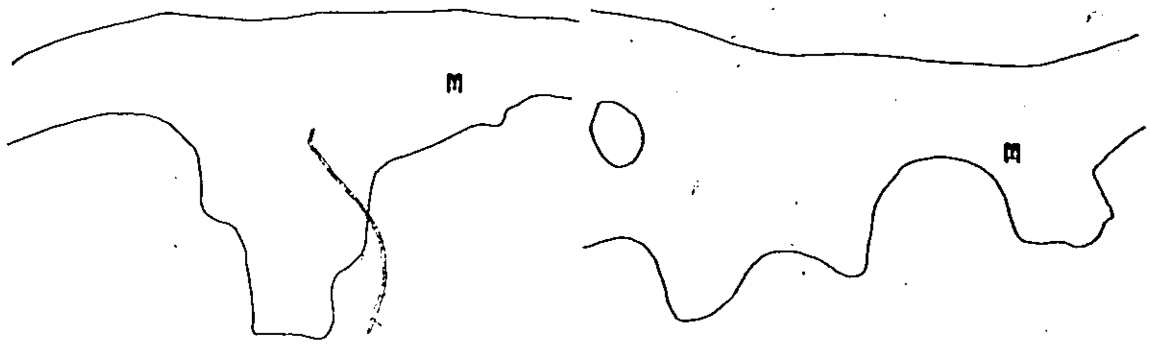



Site 33, Middle Region of Medial Arch of the Foot

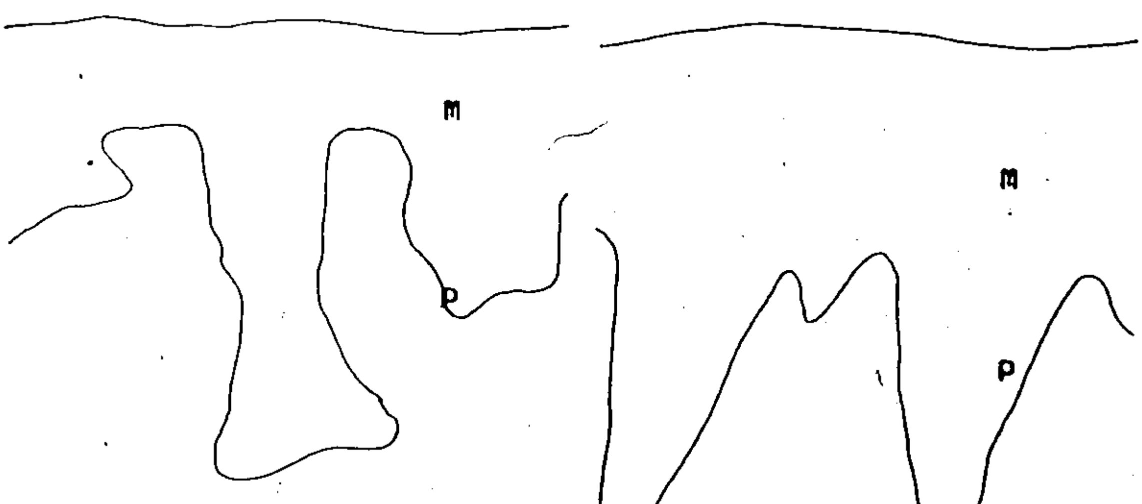
Plate 50




case 1 (stratum corneum .11mm) case 4



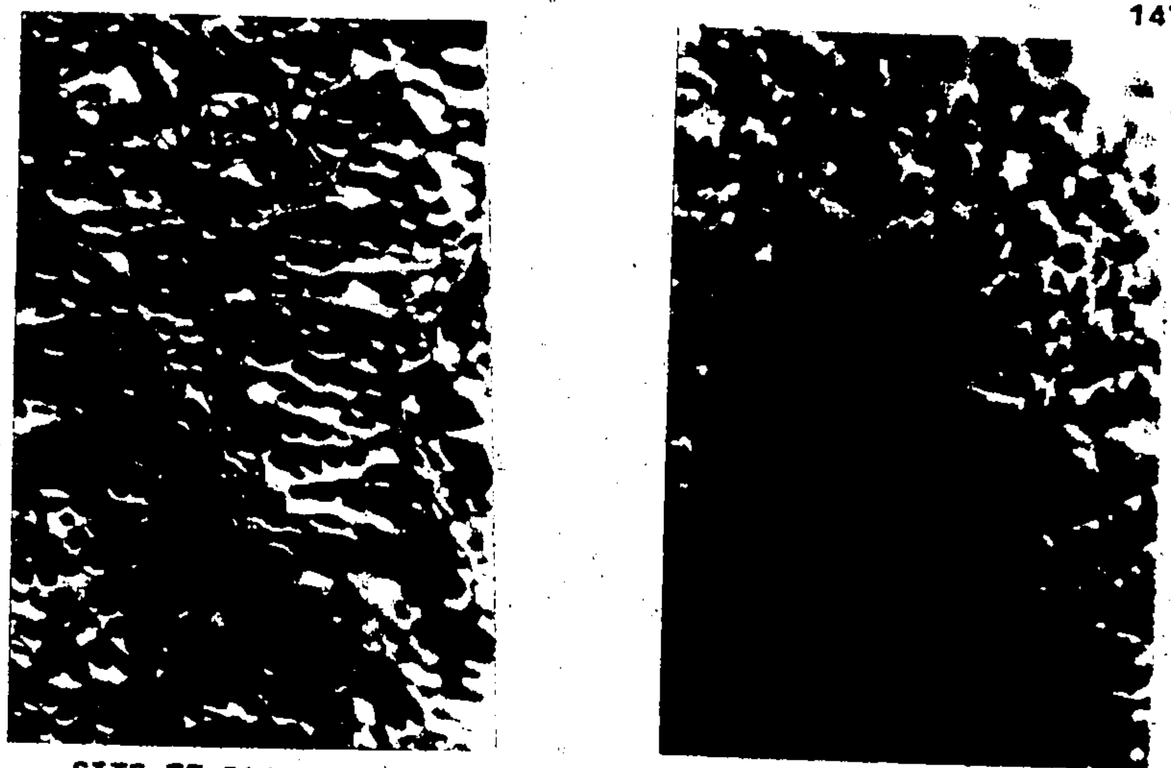

case 2 (stratum corneum .42mm) case 5(stratum corneum .11mm)



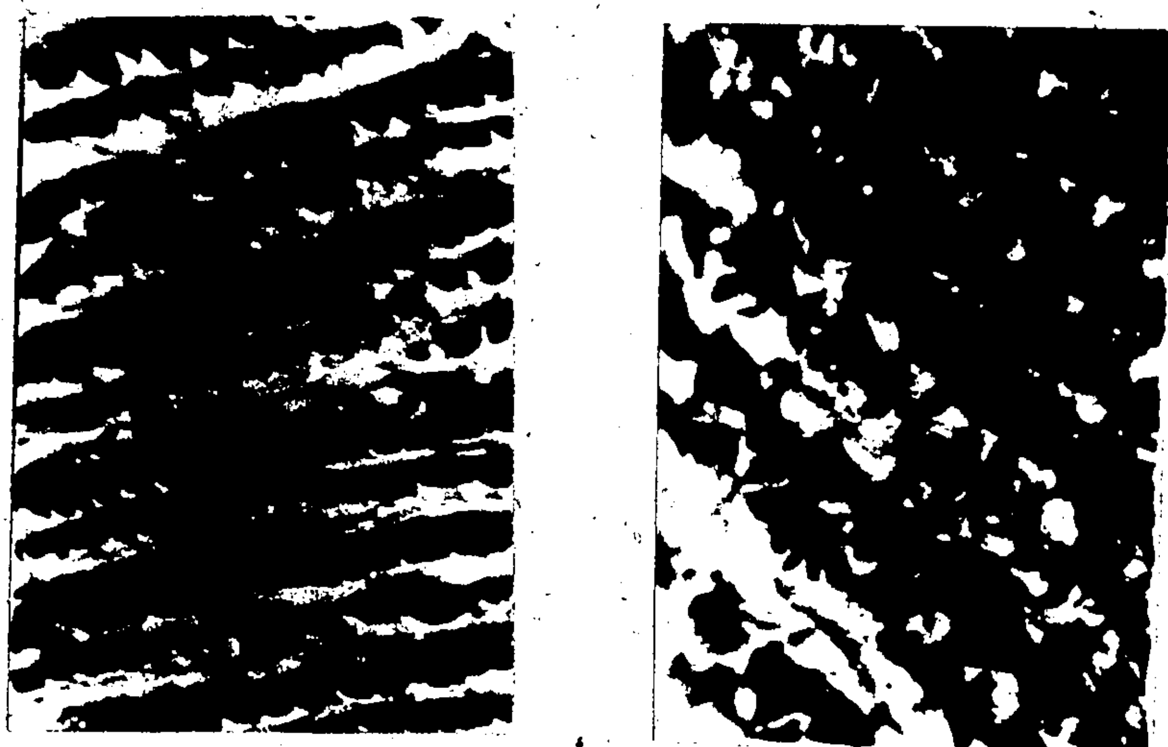

case 3 (stratum corneum .37mm) case 6 (stratum corneum .95mm)

(stratum corneum off scale where thickness is noted)

Site 34, Plantar Aspect of the First Metatarsal Head



SITE 33. PLANTAR ASPECT OF THE MID ARCH OF THE FOOT



SITE 34. PLANTAR ASPECT OF REGION OF THE FIRST METATARSAL HEAD

Interface Characteristics - The sine interface characteristically demonstrates long finger-like rete pegs which tend to deflect away from the free surface of the skin. The epidermal interface maintains a slight ridging characteristic of other regions of the plantar foot. The interphalangeal fold is marked by a flat structureless band. Moderately large well formed craters formed by the rete ridges are abundant about the fold. The dermal interface also reveals a deep fold about which are numerous well formed finger-like dermal papillae although they seem to be less organized than other regions of the plantar of the foot. The weight bearing function of the planter digit demands a well structured interface, but the smaller size of the toe together with the necessity of flexibility reduces size and organization of interface elements.

Site 36, Dorsal Aspect, Great Toe

Functional Anatomy - The interphalangeal joint of the great toe is of the ginglymus or hinge type. The principle motion is flexion, but a slight degree of dorsi-flexion (hyperextension) is permitted. The tendons of the flexor digitorum longus et brevis are palpable just dorsal to the dense fibrous connective tissue constituting the interphalangeal joint capsule.

Epidermal Characteristics - The epidermis of the dorsum of the great toe ranges in thickness from .04 to .11 mm with .09 mm the mean. It is placed among the upper half in epidermal thickness of all sites studied and the stratum corneum is slightly predominant. The mean number of rete ridges is 7 and ranges from 3 to 9 per mm. The rete ridges range in length from .03 to .09 mm with .06 mm the mean.

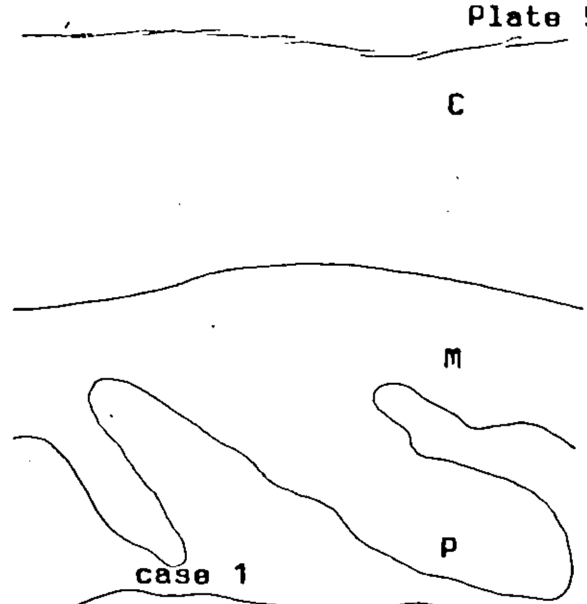
Interface Characteristics - The sine interfaces usually show well developed rete ridges. Case 1 has no rete, but the well muscled Case 2 has unusually deep and variably shaped rete. The epidermal interface is marked by intersecting grooves without structure. Between the grooves are numerous well formed and regularly spaced craters formed by the rete ridges. The dermal interface has numerous well formed finger like dermal lying in parallel to a structureless fold. The papillae are usually oriented upright but clusters are slanted. Lines of stress where greatest flexion occurs are structureless but the adjacent areas require interdigitating structures of the epidermal-dermal interface to anchor skin with a reasonable degree of firmness.

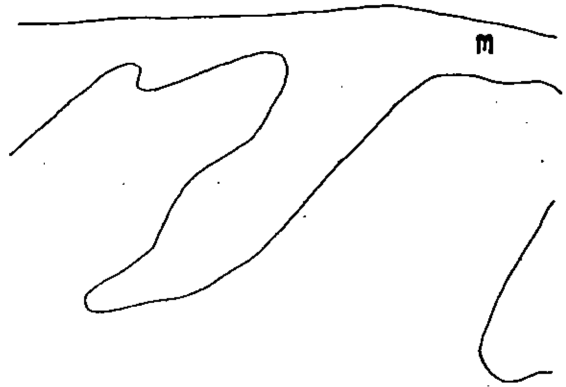
Site 37, Infra Patellar Fold

Functional Anatomy - The conjoined tendons of the quadriceps femoris musculature becomes superficial after passing over the patella and inserting into the tibial tubercle as the ligamentum patella. The dense fibrous connective tissue of the knee joint capsule is immediately beneath. The joint is of the ginglymus type and allows flexion of the knees. Extension is limited to permitting the leg to assume a straight line relationship to the thigh at which point the skin becomes folded slightly upon itself. These folds disappear when the knee joint is full flexed.

Epidermal Characteristics - The epidermal thickness ranges from .04 to .15 mm with .08 mm the mean. The tissue is among the upper 1/2 in epidermal thickness of the sites studied and the stratum corneum tends to be predominant. The number of rete pegs per mm range from 4 to 7 with 5 the mean number. The length of the rete pegs range from .03 to .05mm, the mean being .04 mm.

Plate 52

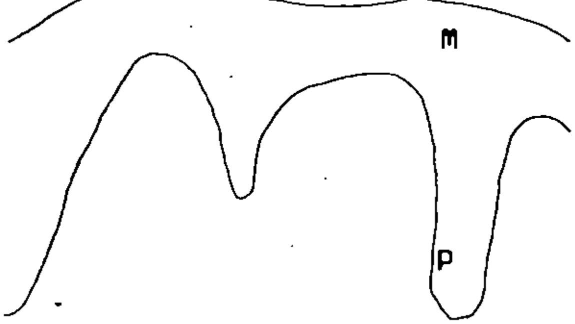


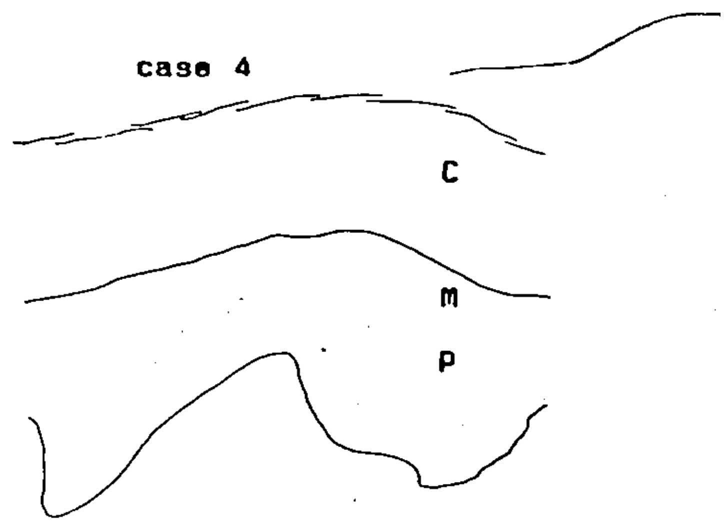




(stratum corneum, .1mm)

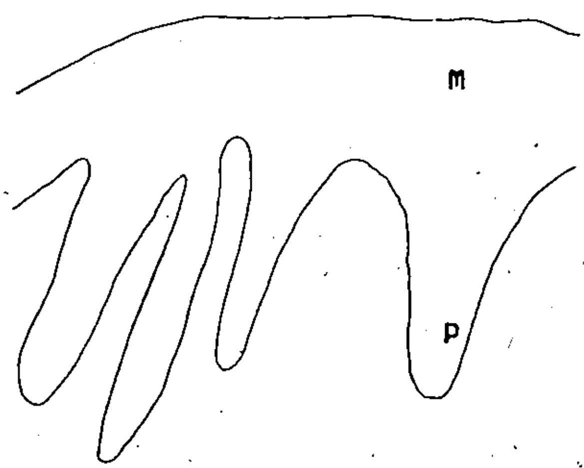
case 1

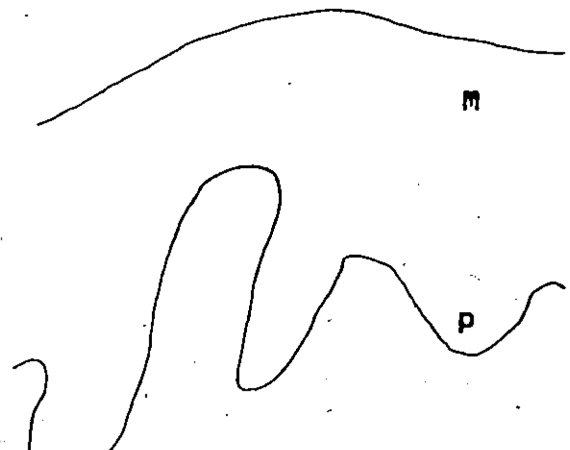
case 4




case 2 (stratum corneum .15mm) case 5



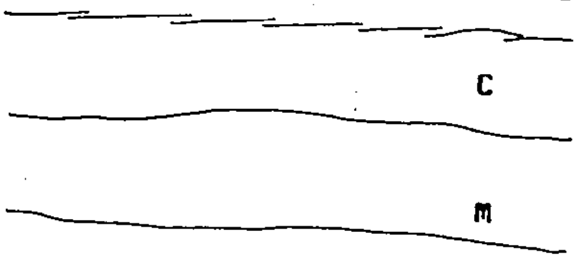




case 3 (stratum corneum .1mm) case 6(stratum corneum .15mm)

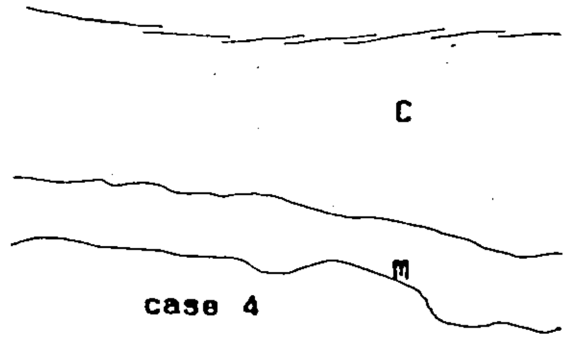
stratum corneum off scale where thickness is noted

Site 35, Flexor Fold of the Second Toe

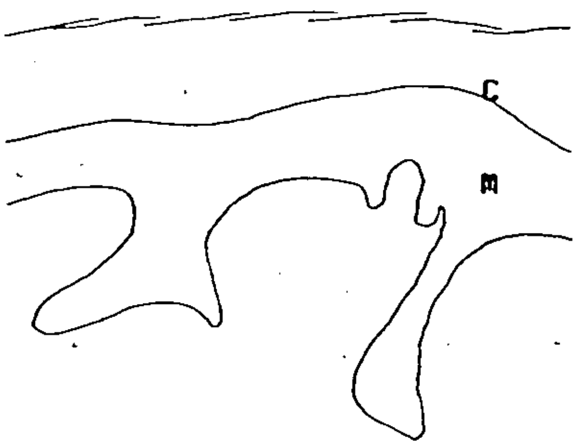
Plate 53



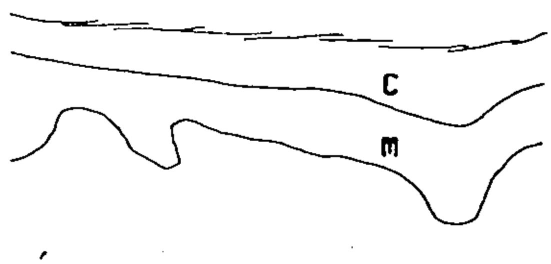

case 1



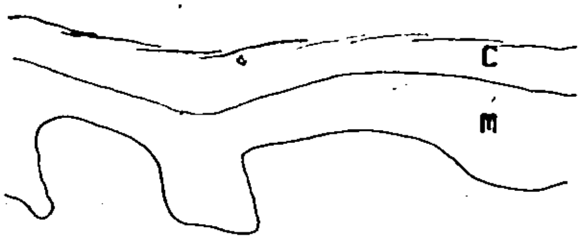

case 4



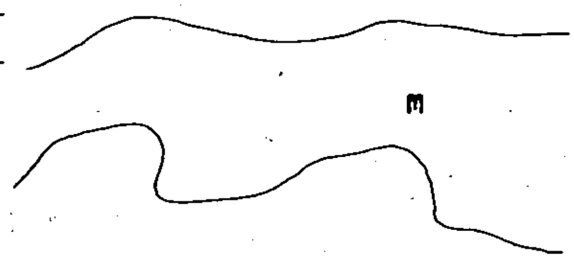

case 2




case 5




case 3




case 6
(stratum corneum off scale
.15mm)

Site 36, Dorsal Aspect of the Great Toe

SITE 35, FLEXOR FOLD OF THE SECOND TOE

SITE 36, DORSAL ASPECT OF THE GREAT TOE

Interface Characteristics - The sine interface demonstrates rete pegs in all cases, but with the morphology varying from quite broad in cases 1 and 6 to finger-like in case 2. The epidermal interface is dominated by numerous continuous parallel folds of low profile for light adhesion of the epidermis on the dermis since this site is often flexed and extended.

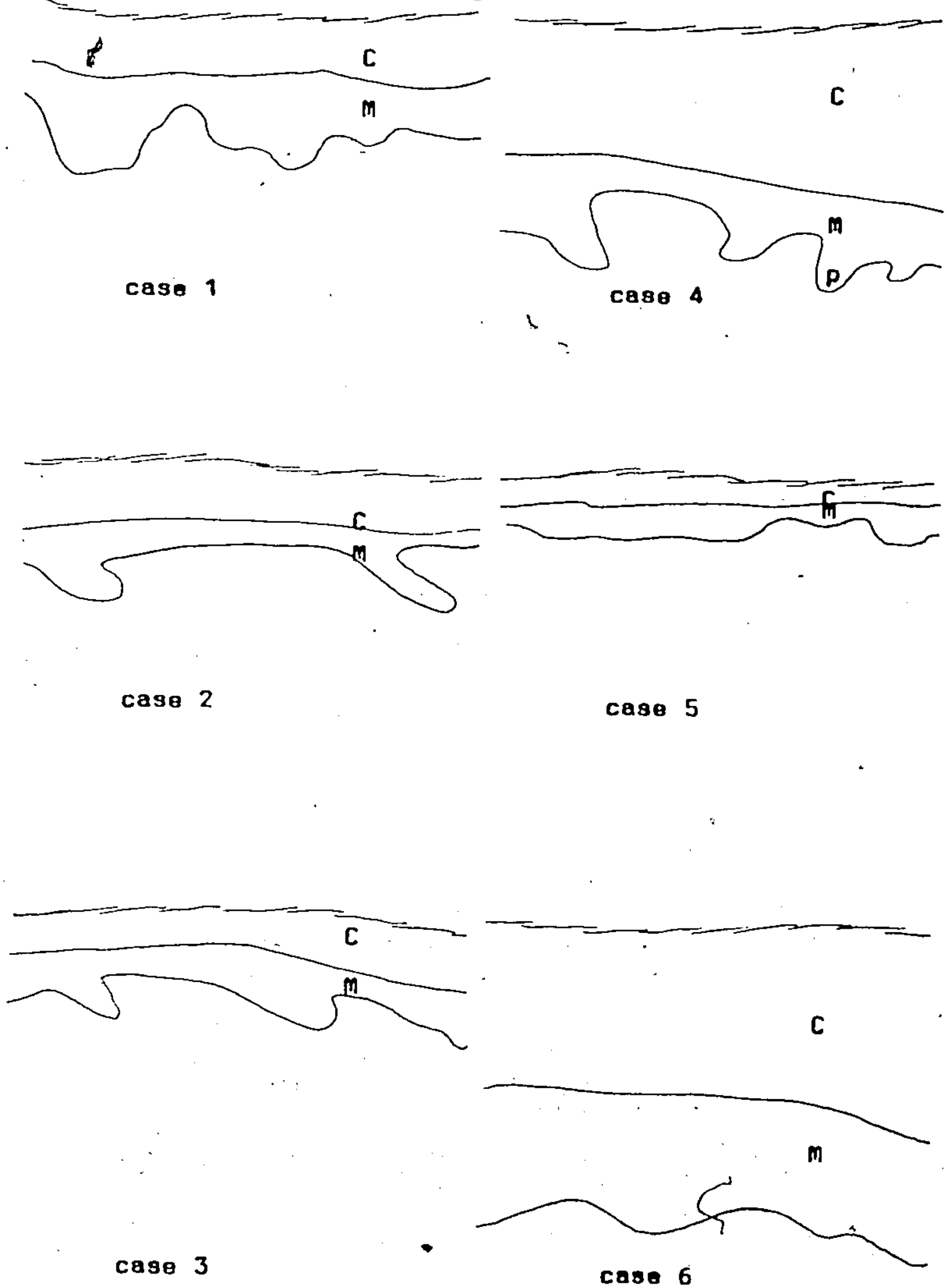
Site 38, Anterior Aspect of the Mid Ankle

Functional Anatomy - The ankle joint is a ginglymus or hinge joint permitting flexion of the foot on the leg dorsally and plantarly in walking. Because of mid tarsal joints below the ankle, the skin of the ankle joint is subjected to some secondary rotational movements. There is a dense fibrous joint capsule over which the thick rounded tendons of the extensor digitorum longus and extensor hallucis longus muscles pass with the annular ligament binding the tendons in place.

Epidermal Characteristics - Epidermal thickness of the anterior ankle ranges from .05 to .10 mm with a median of .06 mm. The tissue is among the upper 1/2 of sites studied and the stratum Malpighii constitutes about 60% of the total. The number of rete pegs ranges from 5 to 7 with 6 as the median. The length of the rete pegs ranged from .03 to .05 mm with .04 mm being median.

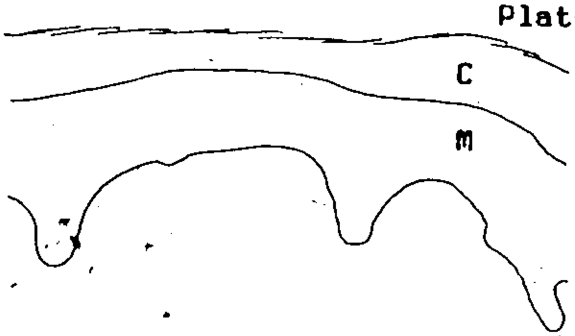
Interface Characteristics - The sine interface is characterized in all cases with obvious rete pegs which were broad in cases 3, 4 and 5. Case 1 was distinct in having well formed vertical rete while the other cases often exhibited coalesced rete pegs. Parallel and intersecting folds characterize the epidermal interface with similar folds on the dermal

Plate 55

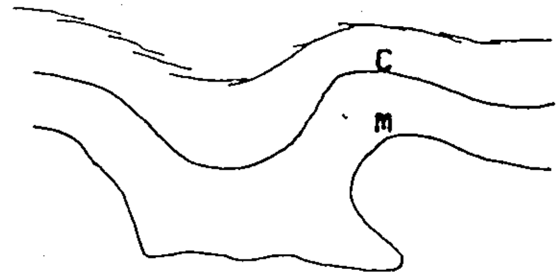



Site 37, Infra Patellar Region

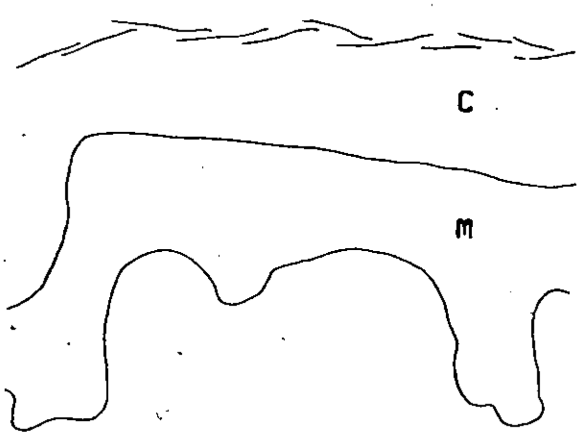
Plate 56



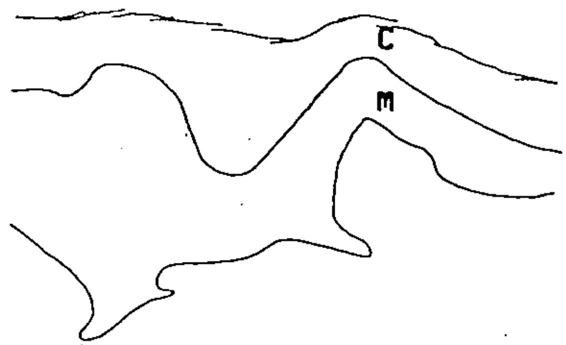

case 1



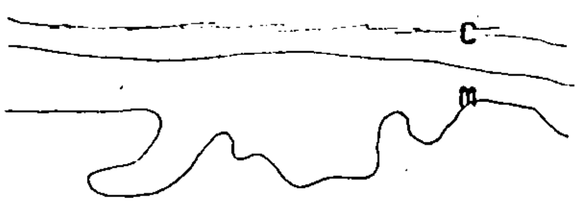

case 4




case 2



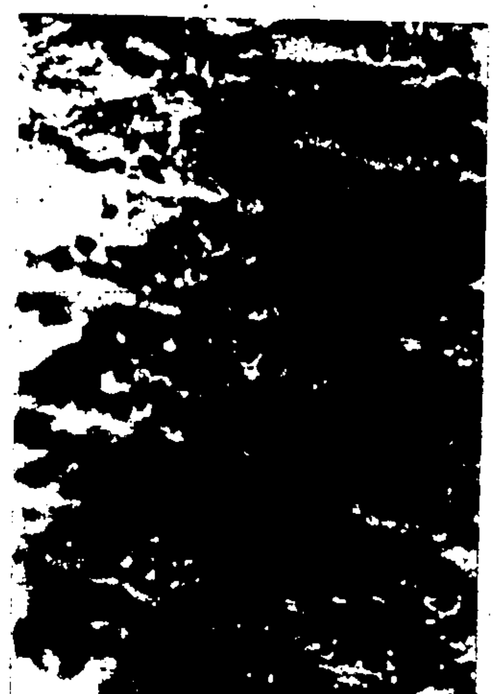

case 5




case 3

Site 38, Anterior Aspect of the Mid Ankle

SITE 37, INFRA PATELLA REGION



SITE 38, ANTERIOR ASPECT OF THE MID ANKLE preparations. This structuring is typical in integument involved in flexion and extension of parts and is strongly in evidence at the ankle. The regions between the folds and ridges develop shallow craters formed by the rete Malpighii for the reception of dermal papillae. The structures become more distinct and large as the middle portions between the folds are approached. The dermal interface is similarly structured with parallel and intersecting folds with papillae between.

Site 39, Dorsal Arch

Functional Anatomy - The mid tarsal joints are of the arthrodial type permitting only gliding motions of the opposing concavo-convex joint surfaces. They are enveloped in dense fibrous connective tissue limiting motion. The site from which the skin of this site was excised has the tendinous expansion of the extensor digitorom longus et brevis bound by the cruciate ligament immediately beneath.

Epidermal Characteristics - The mean epidermal thickness of this site is .09 mm and is among the middle 1/3 of all sites studied. The range is from .03 to .13 mm and the stratum corneum predominates, forming about 60% of the total thickness. The mean rete ridge number per mm is 5 and ranges from 2 to 9. Rete peg length varied from .02 to .06 mm with the median at .04 mm.

Interface Characteristics - The sine interface demonstrates finger-like rete ridge projections flattened on the end although the interfaces of Cases 3 and 6 is rather structureless. The epidermal interface has numerous shallow craters formed by the rete ridges which have an overall parallel orientation. The dermal interface demonstrates numerous well formed finger-like dermal projections with more definite parallel orientation pointing in several directions. This region does not exhibit pronounced movement and has none of the obvious foldings that other regions of the foot have. It does, however, receive partial weight bearing and mild motion and requires the adhesion of the epidermis on the dermis formed by the crowded structuring of the epidermal-dermal interface.

Site 40, Triceps Brachii, Deltoid Region

Functional Anatomy - The shoulder joint is an enarthrosis in which the humerous is capable of rotational movement about an indefinite number of axes at the glenoid fossa. Beneath the superficial fascia are found the fleshy bellies of the triceps brachii and deltoid musculature which come into tension on lifting when the arm is in straight and flexed position. The muscles are especially prominent as the arm rotates or is hyperextended above the head.

Epidermal Characteristics - The mean epidermal thickness is .06 mm ranging from .04 to .06 mm and is found among the lower third of all sites studied. The stratum Malpighii is slightly dominant at about 53% of total thickness. The mean number of rete ridges is 5 with the range from 0 to 11 per mm. The mean length of rete pegs is .03 mm with the range from .02 to .06 mm.

Interface Characteristics - The sine interface has little structure in Case 3, 5 and 6. Cases 1, 2 and 4 have a variety of rete ridge shape; broad, finger-like, vertical and slanted. The epidermal interface demonstrates intersecting low ridging overall. Shallow craters formed by rete ridges for the reception of dermal papillae are found clustered between areas that lack structure. The dermal interface demonstrates numerous and somewhat clustered dermal papillae between areas of little structure. Prominent infolding can be observed. The wide range of motion without deeply wrinkling the skin requires light interdigitation between the epidermal and dermal interface structures with occasional folds which probably related to hyperextension.

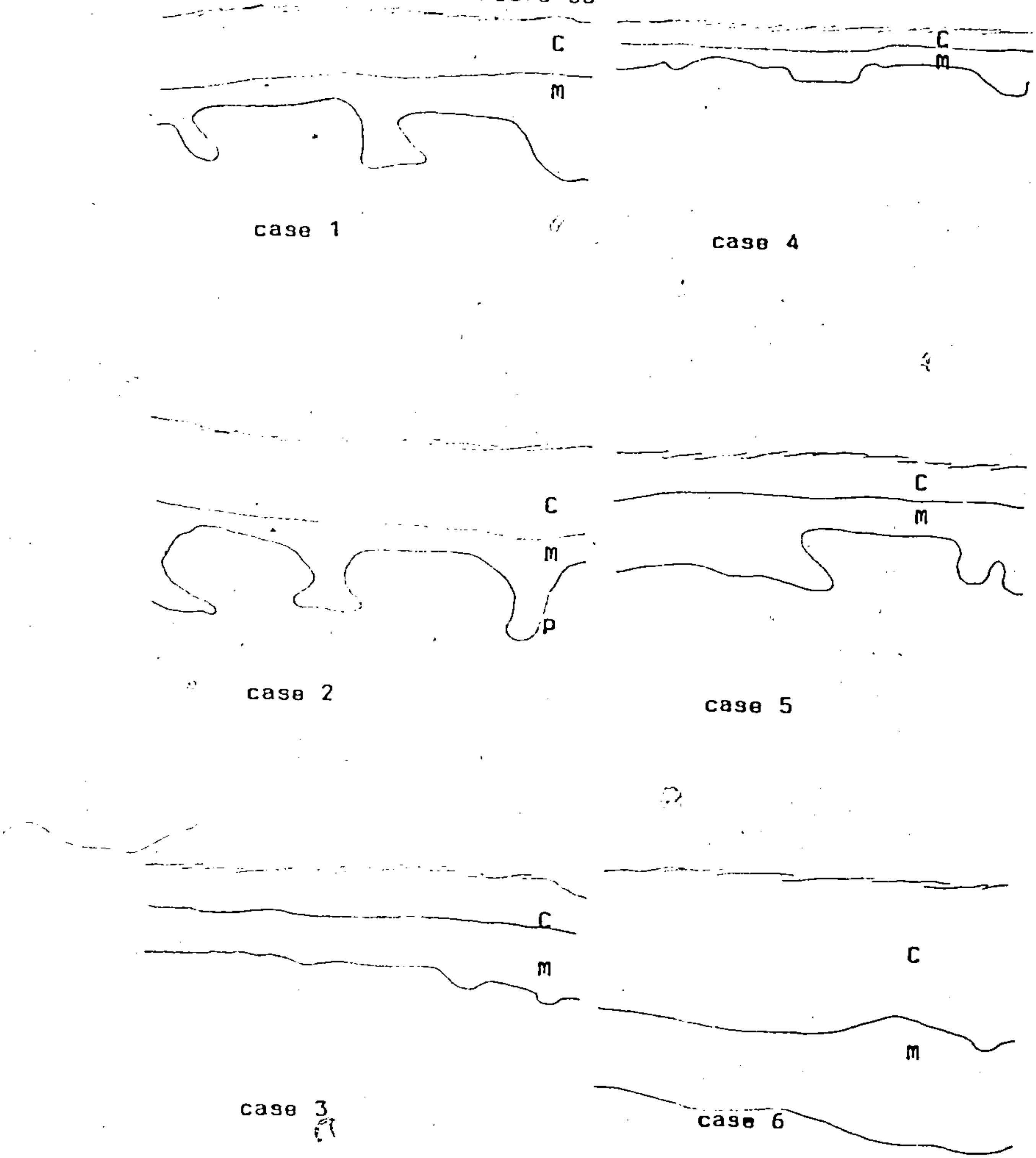
Site 41, Inner Upper Arm

Functional Anatomy - The skin of the inner arm tends to be flabby functioning passively in adduction and abduction of the arm. The brachialis and coracobrachialis musculature underlies the skin excised.

Epidermal Characteristics - The mean epidermal thickness of the inner arm skin is .06 mm with the range of .03 to .07 mm. The tissue is among the lower 1/3 in thickness of all sites studied and the stratum Malpighii is slightly predominant as it forms 52% of the total. The mean occurrence of rete pegs was 0 to 4 with a mean of 2 per mm. The length of the rete pegs ranged from .01 to .03 with the mean at .01 mm.

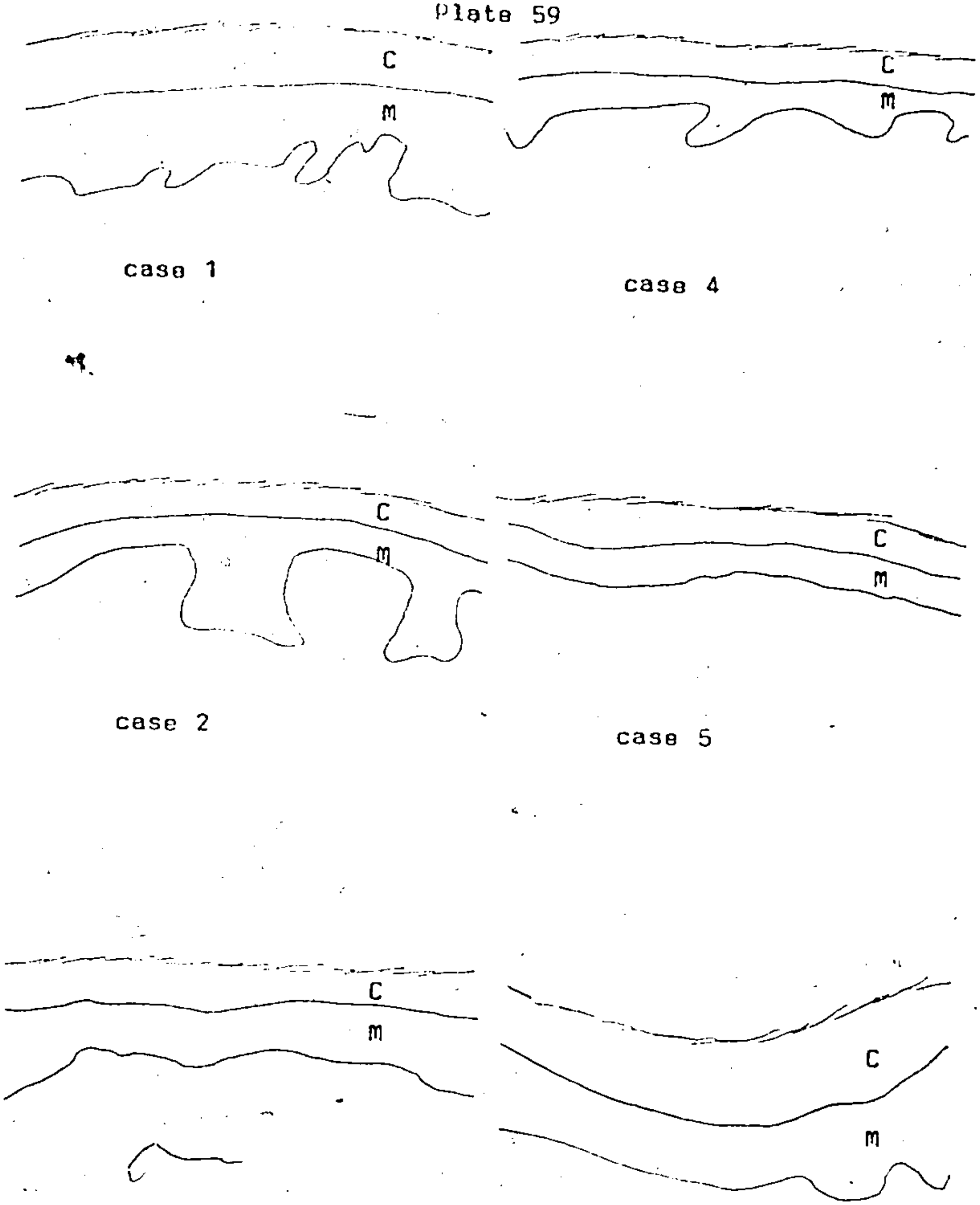
Interface Characteristics - The sine interface of the inner arm was nearly structureless in all cases except for the well muscled Case 2. Here, finger-like rete were present. The epidermal interface showed parallel and intersecting elongate ridging with a mottled flat background. Scattered adnexa can be seen. The dermal portion of the interface is not unlike the epidermal side with parallel and intersecting ridges. The flabby upper inner arm skin which has little movement is accompanied by an absence of interdigitating epidermal-dermal structure. Apparently

Plate 58




Site 39, Dorsal Arch of the Foot

Plate 59




case 1

case 4

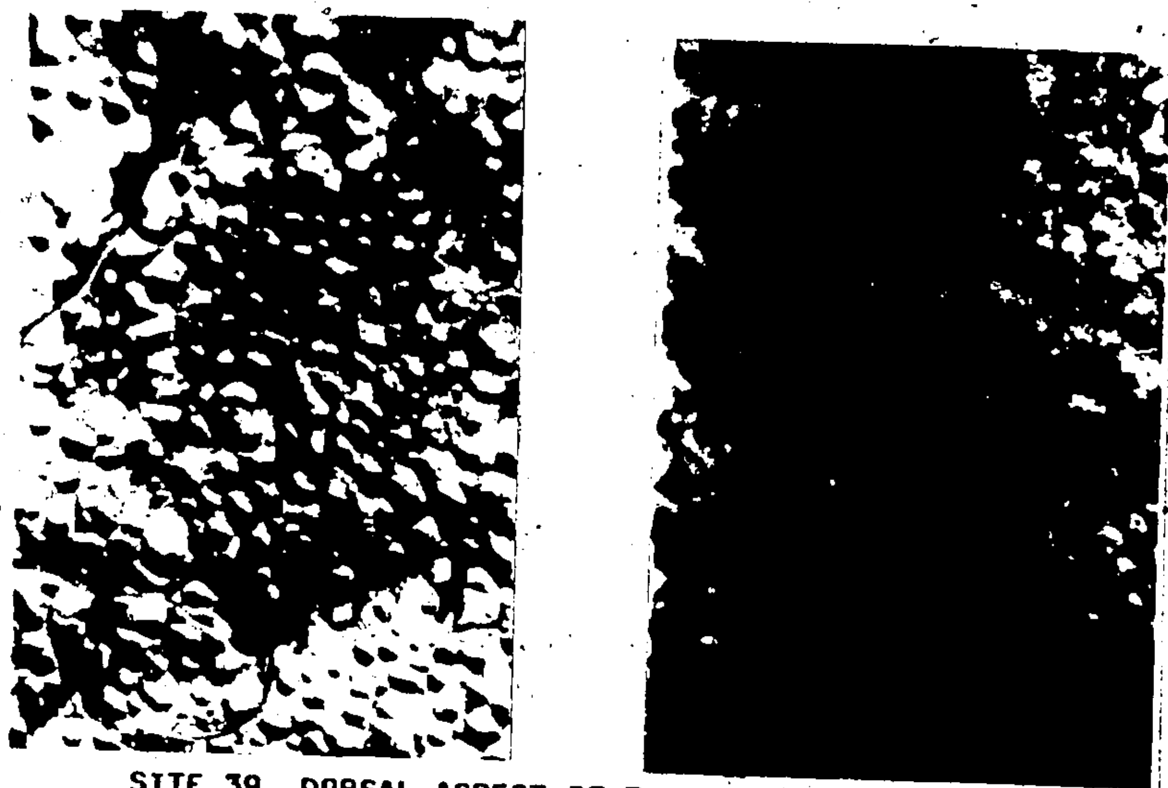
case 2

case 5

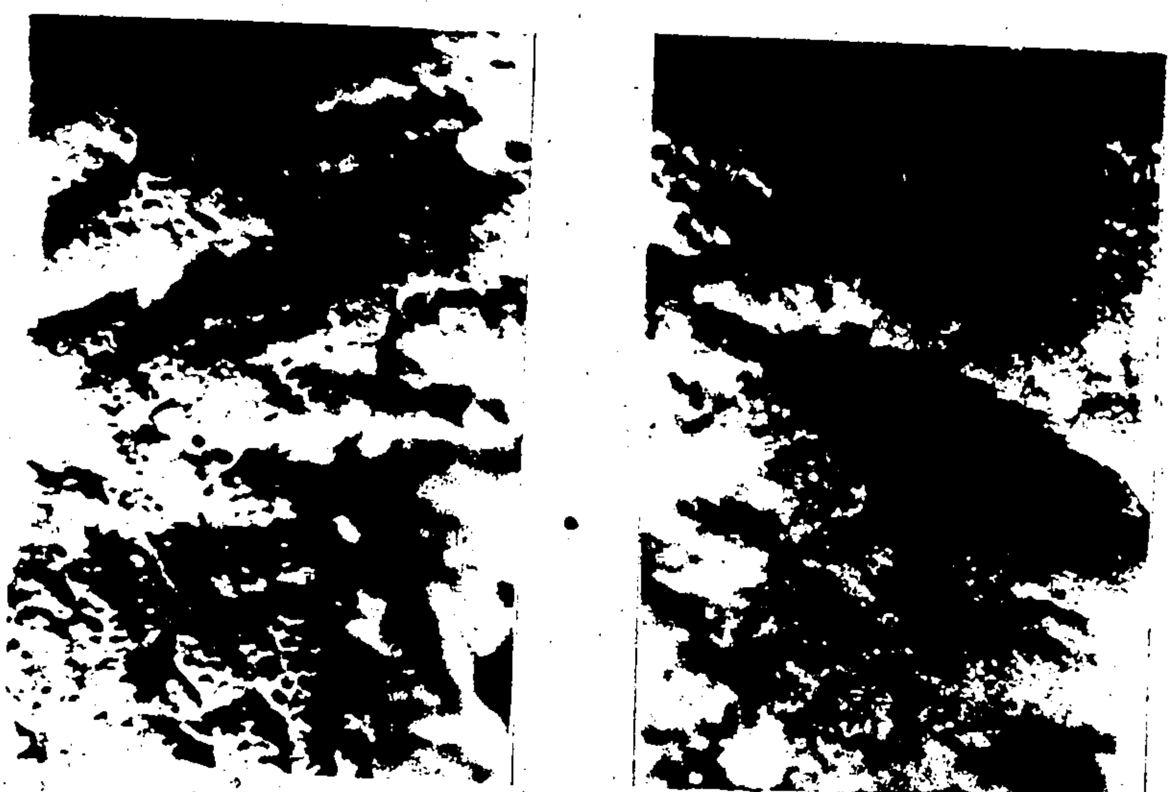
case 3

case 6

Site 40, Superior Region of Triceps Brachii



SITE 39, DORSAL ASPECT OF THE ARCH



SITE 40, REGION OF THE TRICEPS BRACHII

the elongate ridges lie side by side and adhere epidermis to dermis.

Site 42, Outer Elbow

Functional Anatomy - The elbow joint is a ginglymus or hinge joint permitting flexion of the lower arm upon the upper and placing the outer elbow under stretch. When the elbow is extended bringing the upper and lower arm into straight line relationship, the elbow is caused to wrinkle. There is almost no underlying musculature except for the small peripheral anconeus. The olecranon process of the ulna is palpable with only capsular tissue between it and the skin of the outer elbow.

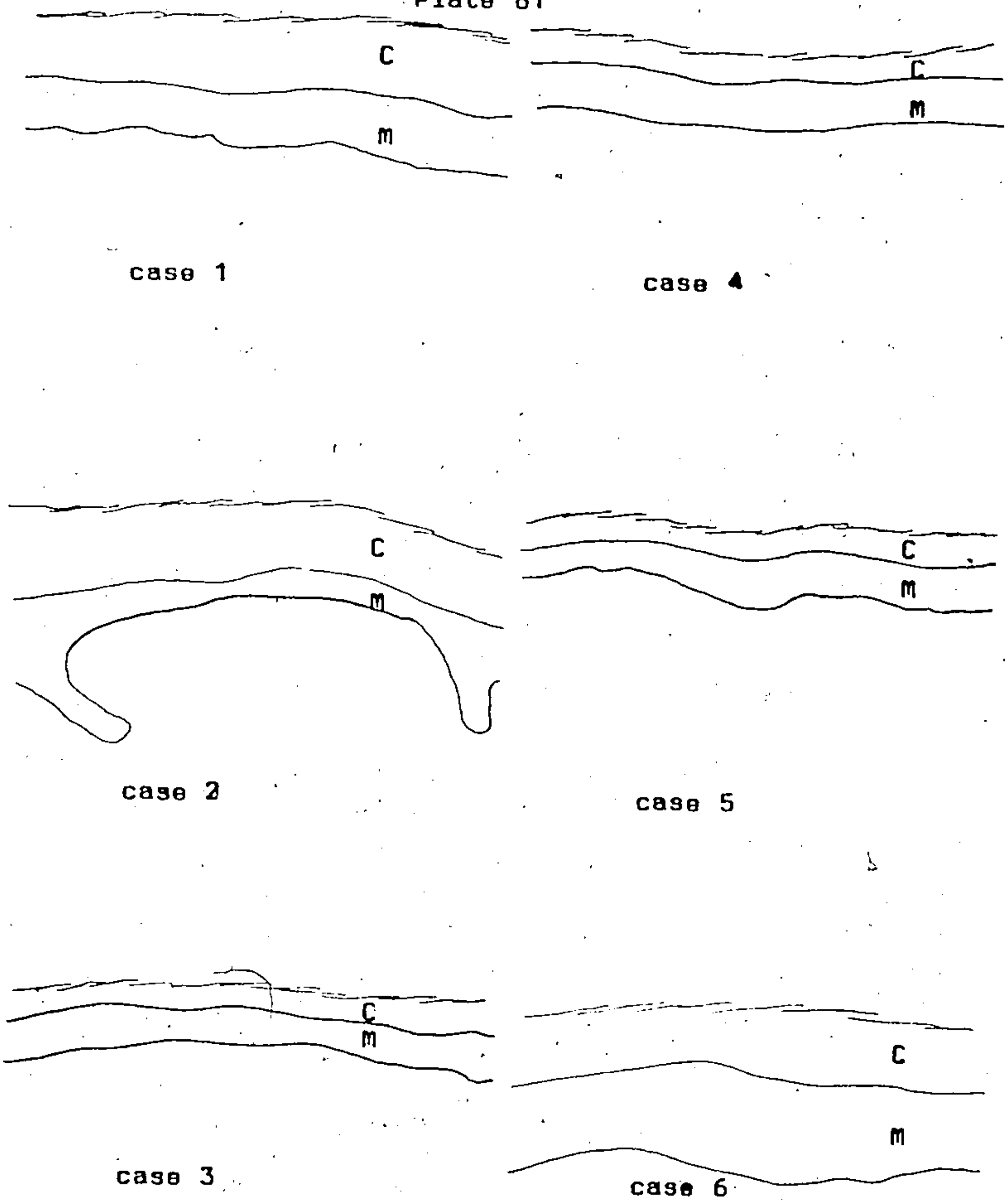
Epidermal Characteristics - The epidermal thickness of the outer elbow ranges from .07 to .15 mm in thickness. The mean thickness is .11 mm placing this tissue among the upper 1/3 of all sites studied. The rete peg number ranges from 5 to 10 with 7 the median. Rete peg length varied from .05 to .07 mm with the mean .06 mm.

Interface Characteristics - The sine interface is highly structured in all cases with broad rete pegs. The epidermal interface is marked with numerous evenly spaced well formed craters formed by the rete ridges for the reception of dermal papillae. There is some banding of a less structured nature. The dermal interface is characterized by numerous finger-like dermal papillae to interdigitate with the equally well structured epidermal interface. This much flexed part with little intervening soft tissue requires a well structured epidermal-dermal interface structuring with a noticeable absence of adnexa.

Site 43, Wrist

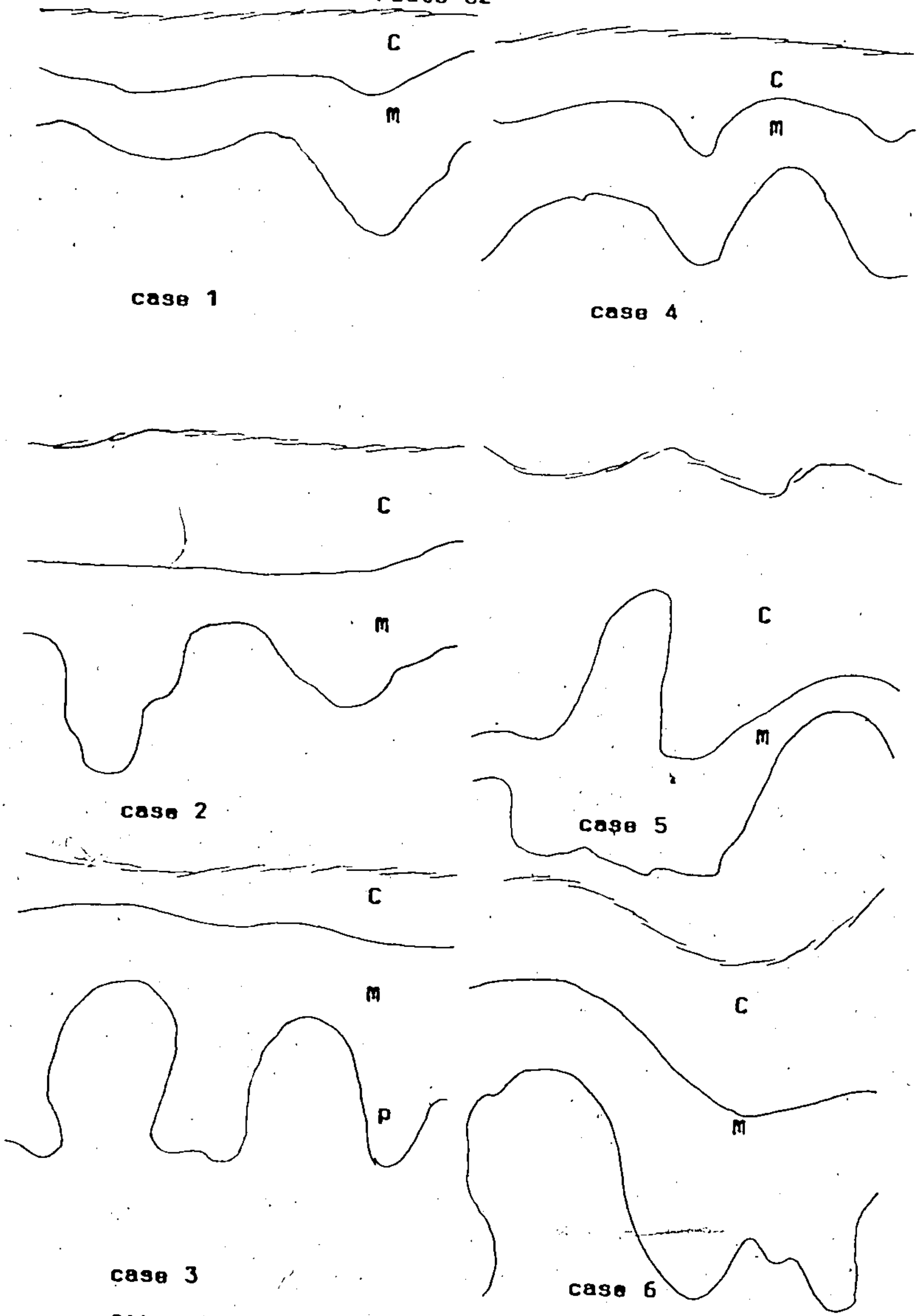
Functional Anatomy - The wrist joint is condyloid and permits flexion, extension, adduction, abduction and circumduction as the ovoid articular surfaces of the navicular, lunate and triquetrum are received

Plate 61

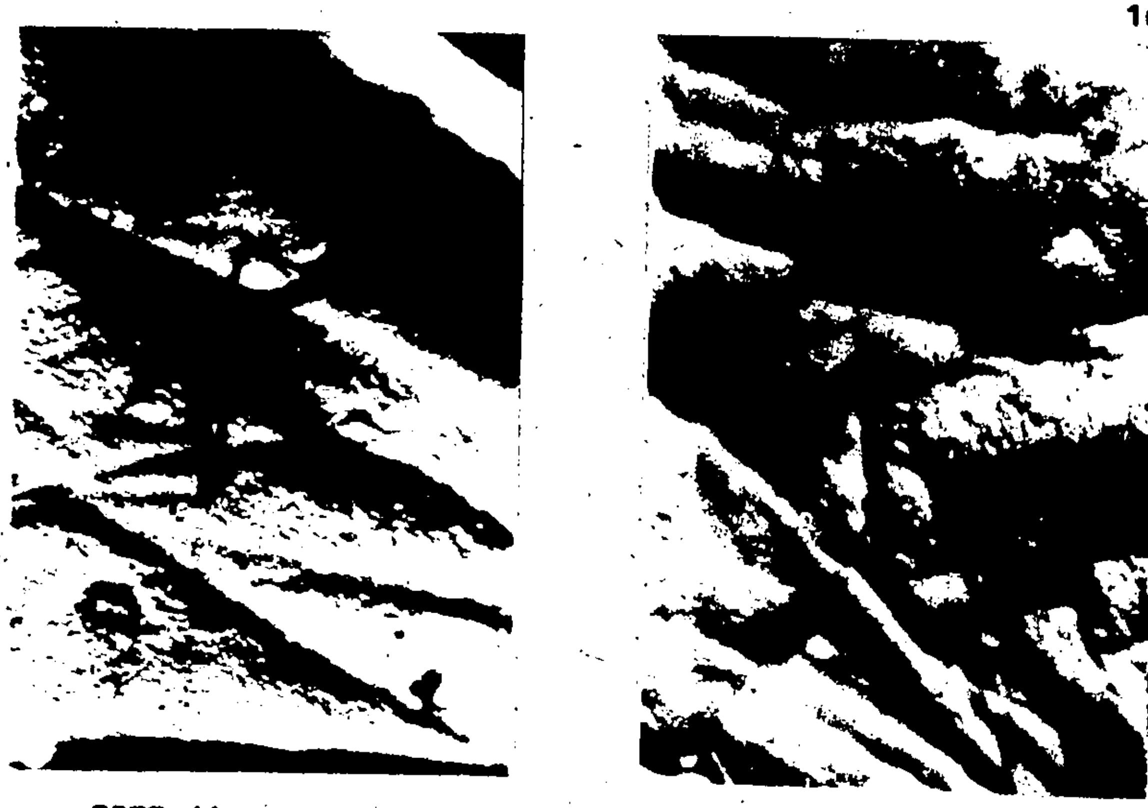



Site 41, Inner Aspect of the Lower Arm

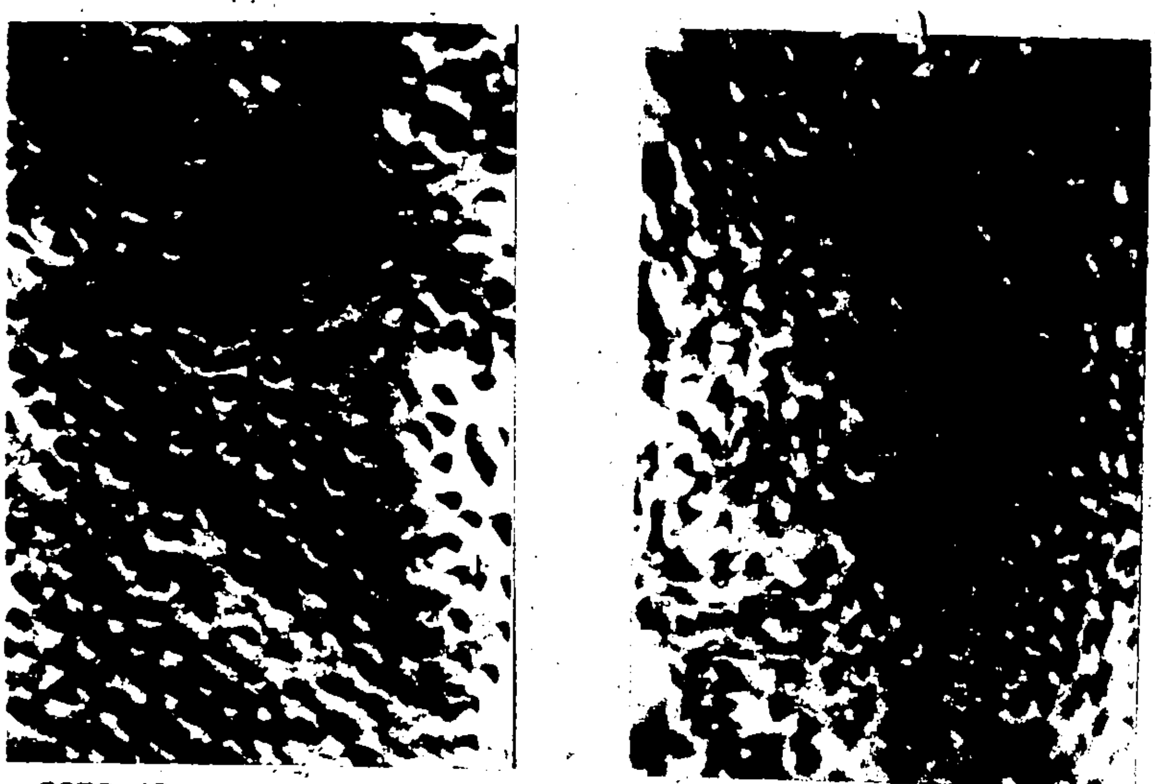
Plate 62




Site 42, The Elbow



SITE 41, INNER ASPECT OF THE ARM



SITE 42, OUTER ASPECT OF THE ELBOW

into the concavity of the distil radius and ulna. Thick round tendons of the flexor carpi radialis and palmaris longus bound by the volar carpal ligament underly the skin excised for this study.

Epidermal Characteristics - Epidermal thickness ranges from .07 to .21 mm with .12 mm the mean. This tissue is among the upper 1/3 in thickness of all sites studied and the stratum corneum predominates forming about 65% of the total. The rete pegs range from 6 to 15 per mm with 8 as the mean. Rete peg length varies from .05 to .07 with .06 mm the mean.

Interface Characteristics - The sine interface is varied. Case 2 has shown a much folded characteristic. All cases showed definite rete pegs usually vertically oriented and broad or finger-shaped. The epidermal interface shows banded rows of crater-like depressions formed by the rete ridges which are moderately deep and well formed. The dermal interface is crowded with numerous finger-like projecting papillae which seem to be directed in the direction of a central fold. This much used part requires a well developed epidermal-dermal interface. The tissue, while flexible at the wrist, is generally firmly interlocked.

Site 44, Dorsal Hand

Functional Anatomy - The articulation of the capitate with the third metacarpal is arthrodial permitting only a limited gliding motion. The tendons of the extensor indicus proprius are prominent as the hand flexes and extends at this point selected to represent dorsal hand.

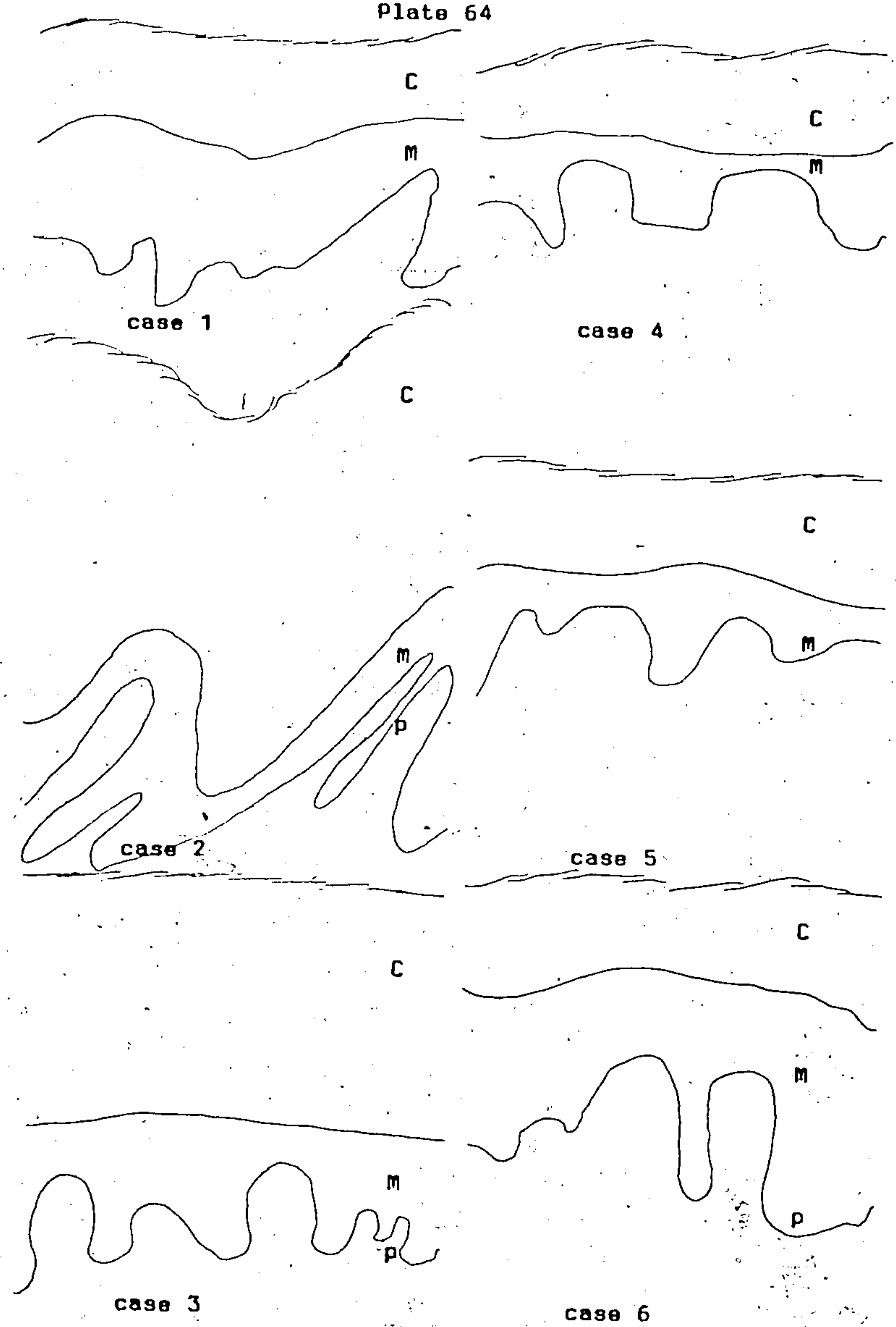
Epidermal Characteristics - The mean epidermal thickness of the dorsal hand is .08 mm with the range from .04 to .10 mm. It is among the upper 1/3 of all sites studied and the stratum Malpighii and stratum corneum are about equally represented. The rete pegs range from 1 to 8 per mm with the mean at 4. The length of the rete pegs range from .02 to .05 mm with .03 mm the mean.

Interface Characteristics - The sine interface is variable. Cases 2 and 4 are nearly structureless while the rest demonstrates a wide variety of structure. Only Case 6 has the rete in vertical orientation. The epidermal interface generally has very small craters formed by rete ridges oriented in a fanning parallel mode. Some of the craters are quite large and they seem to relate to the occasional adnexa. The dermal interface is occasionally pitted for reception of adnexa. Numerous finger-like dermal papillae of low profile can be seen, and they are often coalesced into paralleling ridges. This region of the hand has little motion, but it is subject to stretching. Apparently the adhesion of epidermis to dermis must be reduced, since the dorsal hand wrinkles in hyperextension. The coalescence of epidermal-dermal interface structures is aligned along lines of stress.

Site 45, Volar Hand

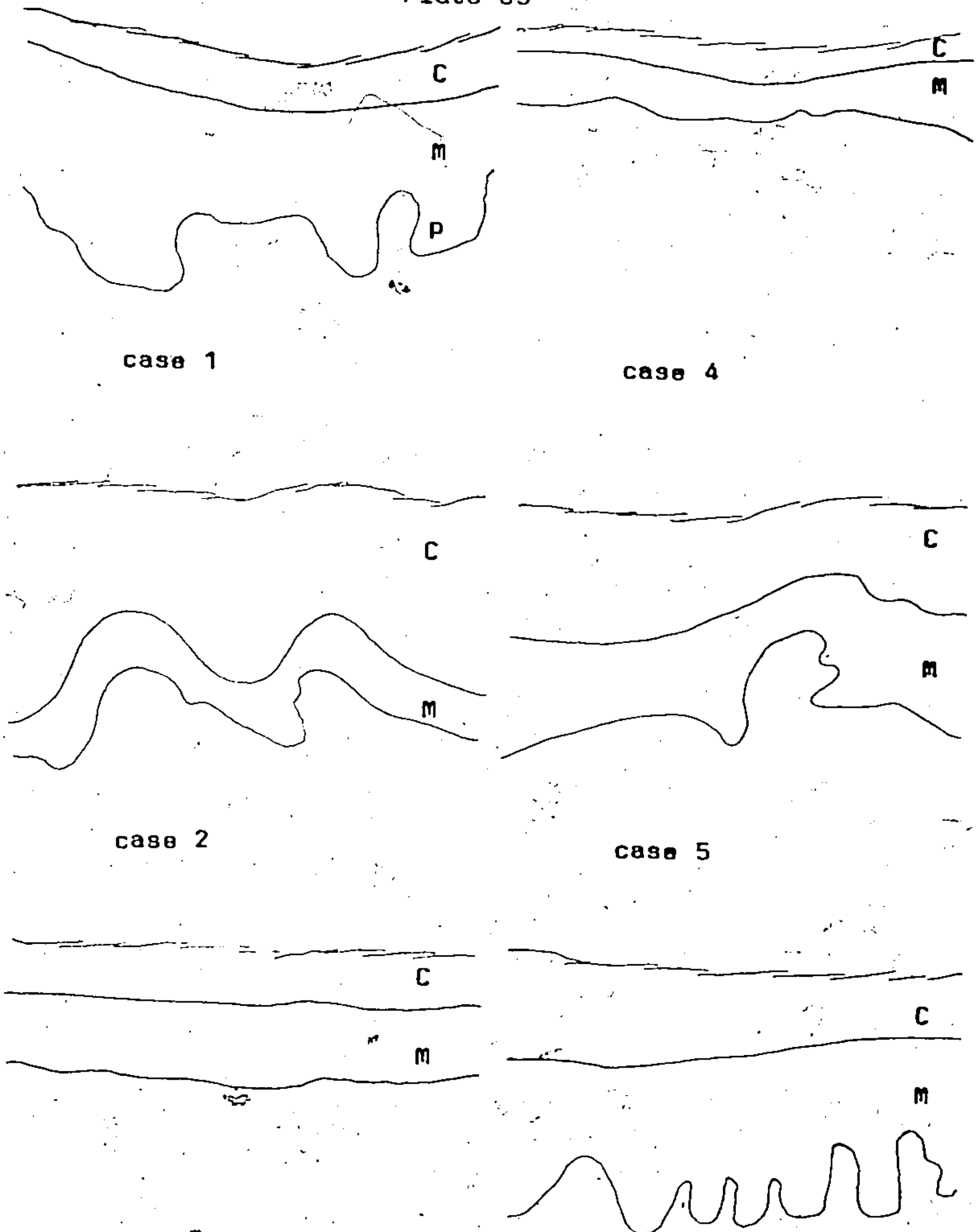
Functional Anatomy - The volar aspect of the hand at the articulation of the capitate with the third metacarpal is covered by the strong musculature of the flexor digitorum sublimis and profundus overlaid with the dense transverse carpal ligament. When the fingers of the hand are strongly flexed, deep grooves appear within the palm of the hand. Conversely, the skin can be stretched by hyperextending the fingers.

Plate 64

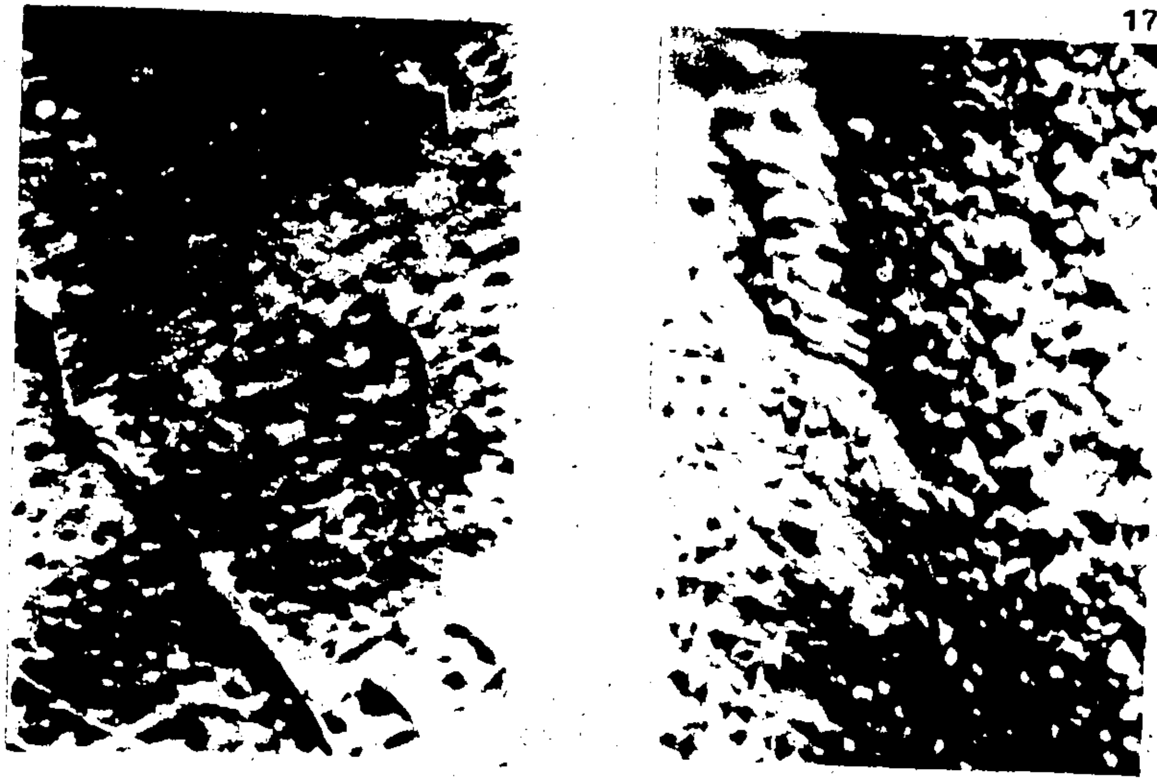



Site 43. Inner Flexing Surface of the Wrist

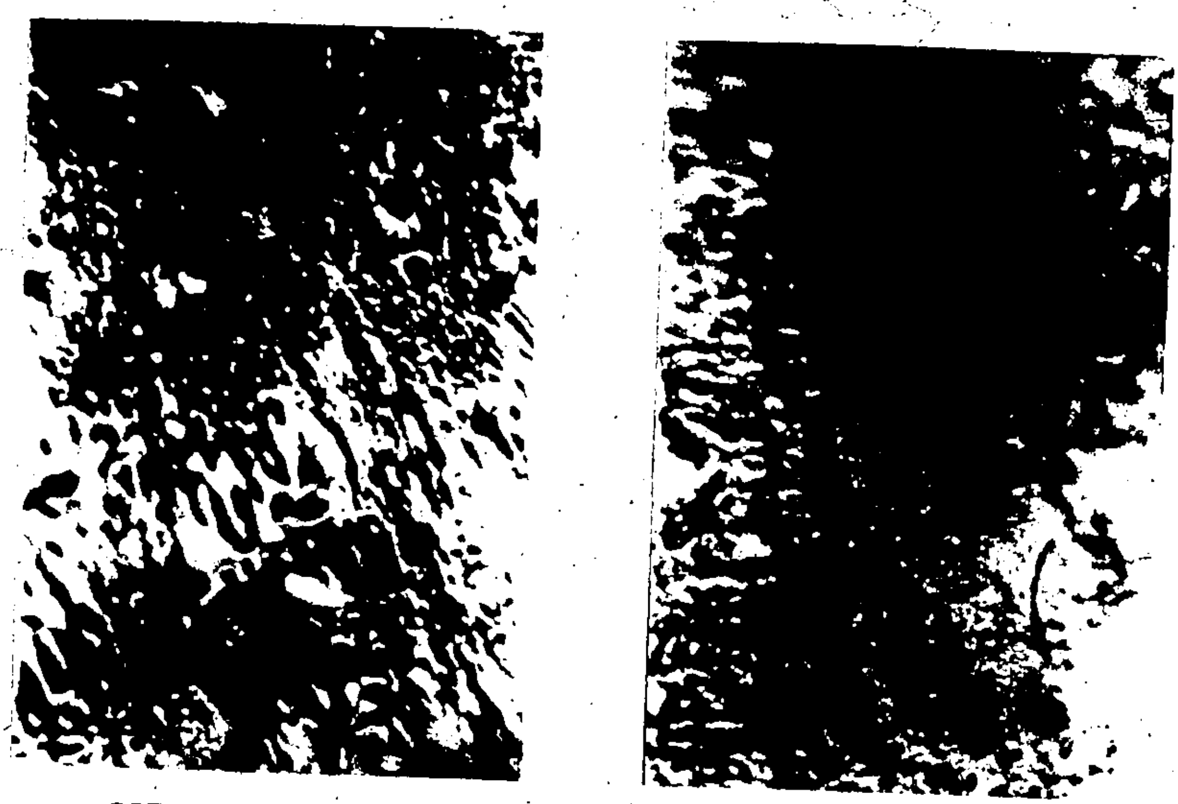
Plate 65




Site 44, Dorsal Aspect of the Hand



SITE 43, INNER ASPECT OF THE WRIST



SITE 44, DORSAL ASPECT OF THE HAND

Epidermal Characteristics - The epidermal thickness range is from .10 to .36 mm with the mean .22 mm. The tissue is in the upper 10% of all sites studied and the stratum corneum predominates with about 70% of the total. The number of rete pegs range from 7 to 11 per mm with 9 the median. The length of the rete pegs ranges from .06 to .10 mm with .07 mm the mean.

Interface Characteristics - The sine interface demonstrates massive rete pegs which in most cases are vertically oriented with only slight deflection. The epidermal interface has a wide structureless region where the fold of the volar hand occurs. Peripheral to the fold, deep well formed craters formed by rete ridges are observed and they are for the most part oriented in parallel. The dermal interface has an equally structureless region where the fold occurs. Peripheral to the fold, numerous finger-like dermal papillae are found to orient in several directions. The powerful flexion and extension of the volar hand requires that deep folds be formed where the underlying connective tissue predominates leaving the interface structureless. Firm anchoring in sites adjacent to the folds require well formed epidermal-dermal interface structures.

Site 46, Superior Aspect of the Knuckle

Functional Anatomy - The carpo-metacarpal joint of the dorsal aspect of the hand (knuckle) is invested in dense fibrous connective tissue capsule over which the tendons of the extensor digitorum communis and extensor indicis proprius become prominent. The joint is ginglymus or hinge type permitting flexion of the fingers on the metacarpals with extension being limited to realigning the part in straight line relationship.

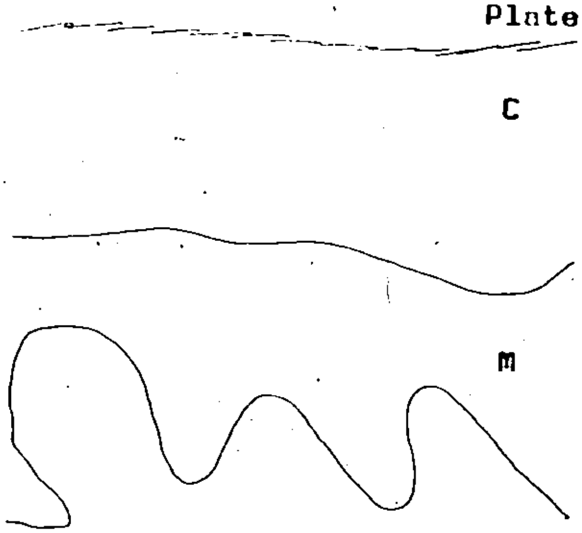
Epidermal Characteristics - The thickness of the epidermis of the knuckle ranges from .06 to .22 mm with the median .13 mm. The thickness places the tissue in the upper 1/3 of all sites studied and the stratum corneum predominates (60%). The rete ridge number ranges from 8 to 10 per mm with 9 the mean. Rete ridge length ranges from .05 to .13 mm with the mean at .07 mm.

Interface Characteristics - The sine interface is well structured in all cases. Cases 4 and 5 show broad flat rete pegs. The other cases show finger-like rete projections. The epidermal interface shows elongate structureless ridges where the knuckle is flexed. The areas between have numerous deep well formed craters formed by the rete ridges. Occasional adnexa can be seen. The dermal interface has numerous well formed papillae of above average size oriented vertically. This region is required to stretch when the joint flexes, but in extension it is caused to wrinkle. The epidermal-dermal interface is well structured and regular. The parallel ridgings are expressed mildly on the interface since the underlying connective tissue is not tightly adherred.

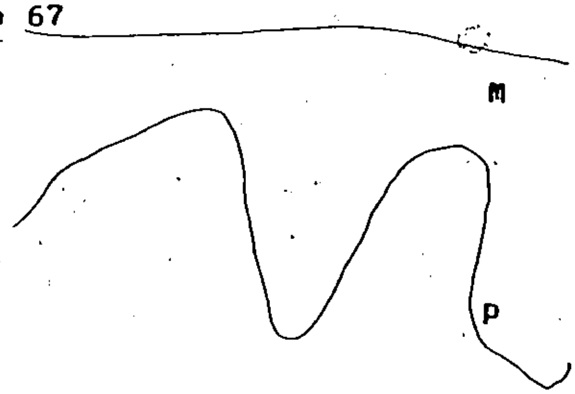
Site 47, Dorsal Interphalangeal Finger

Functional Anatomy - The interphalangeal joints of the fingers are ginglymus or hinge-like permitting flexion of the fingers. Extension is limited to aligning the fingers in straight line relationships when skin folds are formed dorsally. The dorsal interphalangeal joint is covered by a dense fibrous connective tissue capsule with the tendon of

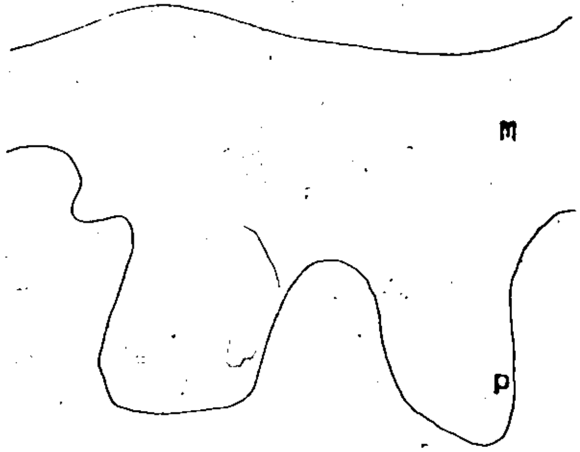
Plate 67



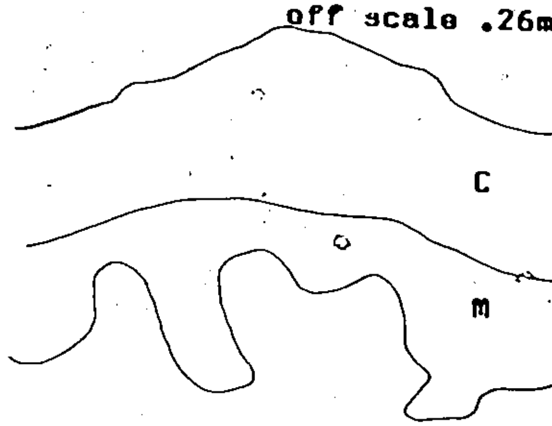

case 1



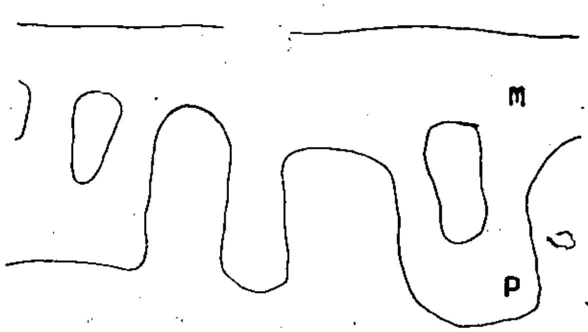

case 4 (stratum corneum off scale .26mm)



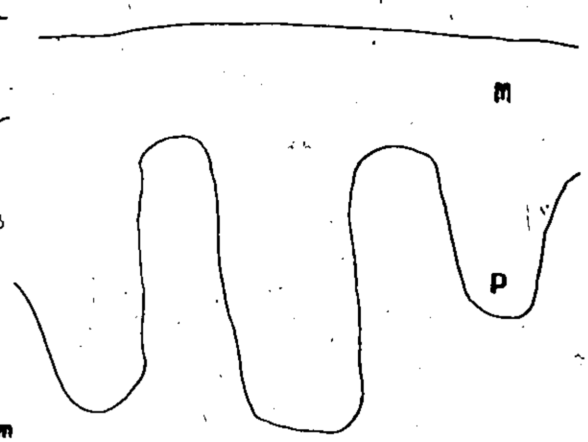

case 2 (stratum corneum off scale .26mm)




case 5



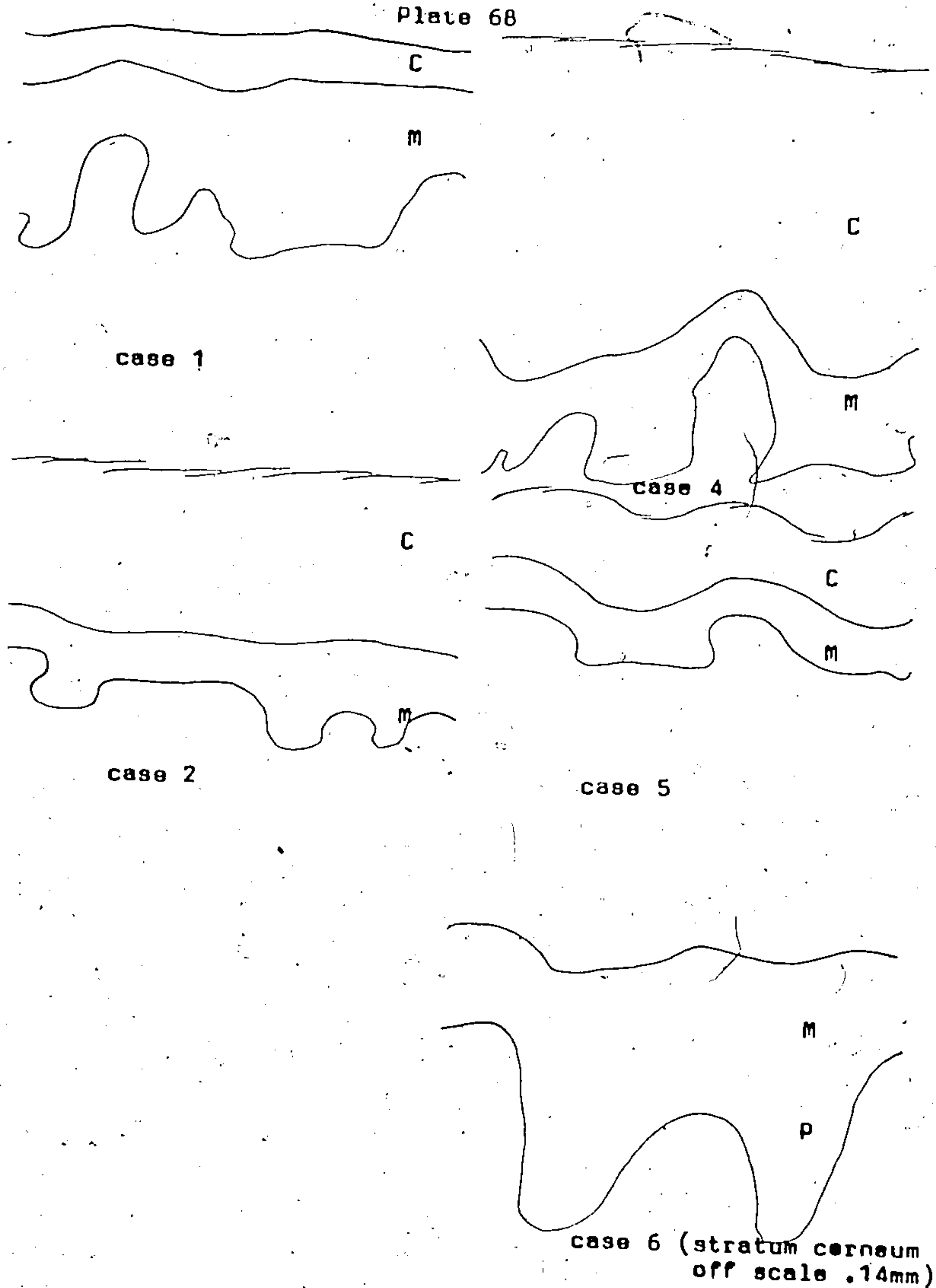

case 3 (stratum corneum off scale at .17mm)



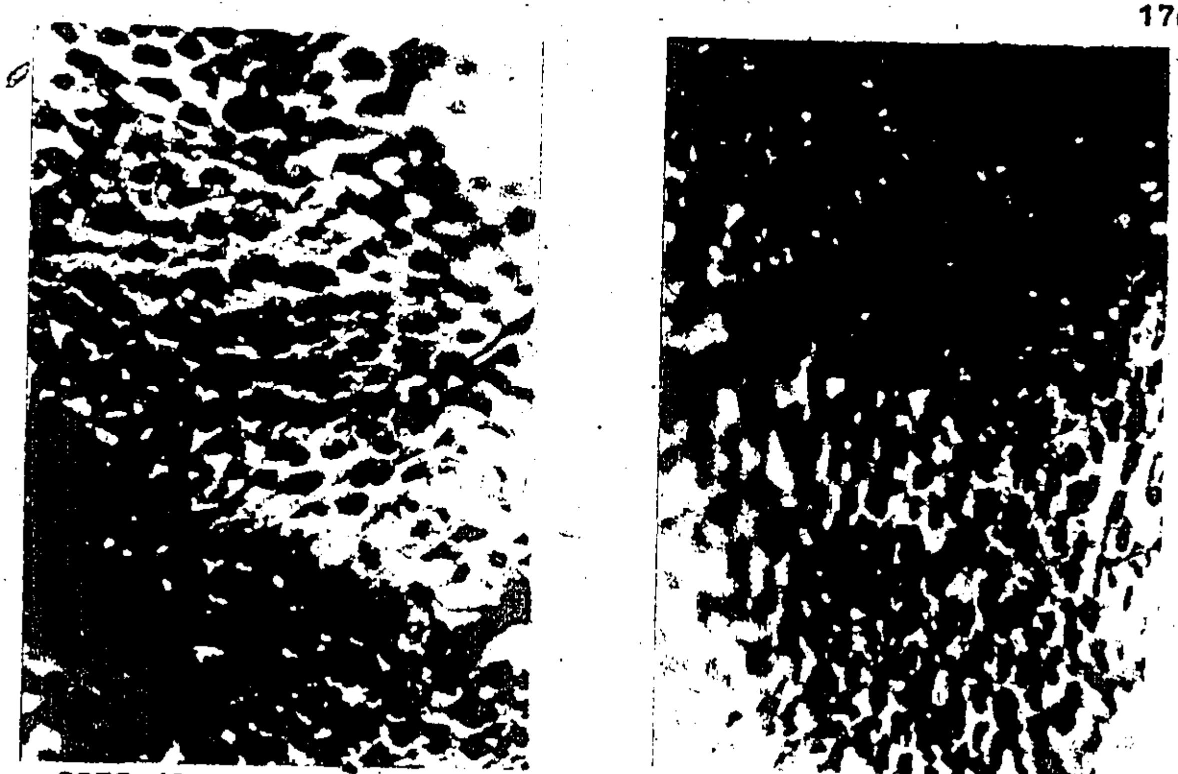

case 6 (stratum corneum off scale at .14mm)

Site 45 Grooved Portion, Volar Aspect of the Hand

Plate 68




Site 46, The Knuckle of the Hand



SITE 45, VOLAR ASPECT OF THE HAND

SITE 46, SUPERIOR ASPECT OF THE KNUCKLE

the extensor inducus proprius closely adherred.

Epidermal Characteristics - The thickness of the epidermis of the dorsal interphalangeal joint of the finger is among the upper 1/3 of all sites studied. The range of epidermal thickness is .06 to .35 mm with the median .16 mm. The number of rete pegs ranges from 7 to 11 per mm with 9 the median. The length of rete pegs ranges from .04 to .12 mm with .09 mm the mean.

Interface Characteristics - The sine interface has various shaped rete pegs which are most often finger-like projections, but are occasionally flat and broad. The free surface of skin is folded, and the sine interface reflects the folds. The epidermal interface has well formed moderately deep craters formed by the rete ridges with thin structureless folds passing across the interface. The dermal interface has numerous finger-like papillae arranged in parallel. The dorsal interphalangeal joint of the finger is called upon to alternately flex and extend with the skin being either stretched or folded. Firm adhesion of epidermis to dermis is supplied by numerous papillae interdigitating with the rete ridges. Folds are apparent, but of lesser width than other flexing sites.

Site 48, Volar Interphalangeal Finger

Functional Anatomy - The interphalangeal joints of the fingers are ginglymus or hinge-like and permit strong flexion with infolding of the skin on the volar surface. When the fingers are extended into a straight line relationship, the deep folding is maintained, but less prominent. The joint capsule of the volar interphalangeal joints of the fingers is dense and closely associated with the tendon sheaths of the flexors digitorum sublimis and profundus.

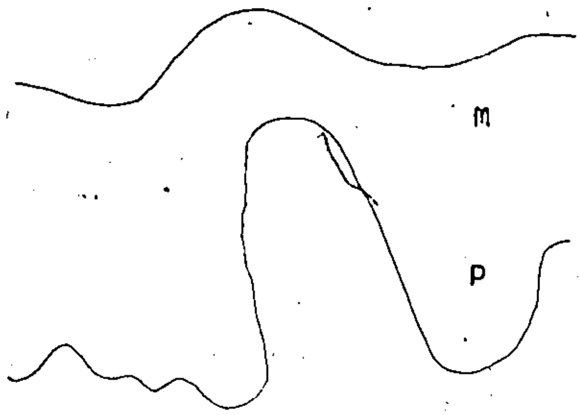
Epidermal Characteristics - The epidermal thickness of the volar interphalangeal joint ranges from .08 to .33 mm with .18 mm the mean. The tissue is found in the upper 1/3 in epidermal thickness of all sites studied and the stratum corneum predominates forming 65% of the total. The number of rete pegs varies from 9 to 12 with 10 the mean. Rete peg length varies from .07 to .16 with .10 the mean.

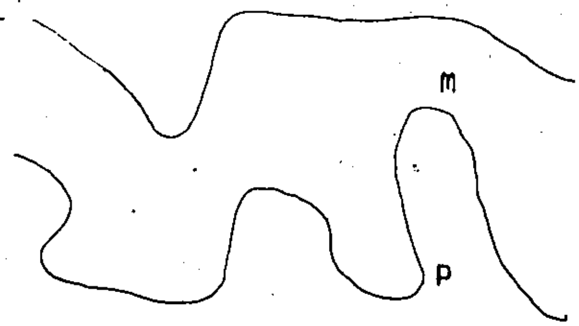
Interface Characteristics - The sine interface demonstrates elongate finger-like rete pegs in all cases except in case 1 where the pegs are broad. The epidermal interface is relatively structureless at the deep fold except for numerous ridges running transversely. Craters formed by the rete ridges are deep and found peripheral to the fold. The dermal interface has a structureless region to complement that of the epidermal portion. Dermal papillae are numerous, finger-like and elongate between the folds. The groove of the volar surface is much more dominant than the folds of the dorsal aspect of the finger. The underlying connective tissue is tightly adherent at the fold but transverse ridges further strengthen the region. Peripheral well formed epidermal-dermal interface structures surround the fold for firm adhesion at all points as the finger is caused to flex and grasp.

Site 49, Distil Finger

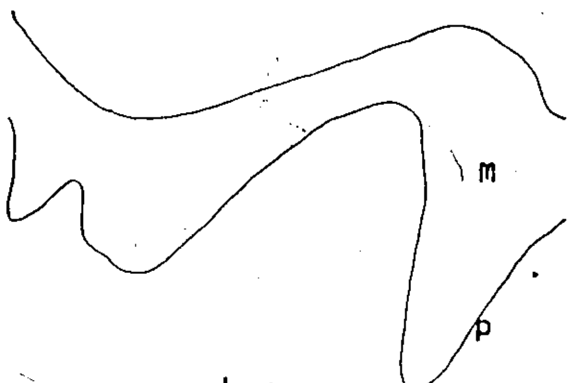
Functional Anatomy - The distil phalanx of the finger receives the terminal insertions of the tendons of the flexor digitorum profundus and sublimis. A well-developed fat pad underlies the skin of the distil finger and characteristically demonstrates whorls forming the "finger print".

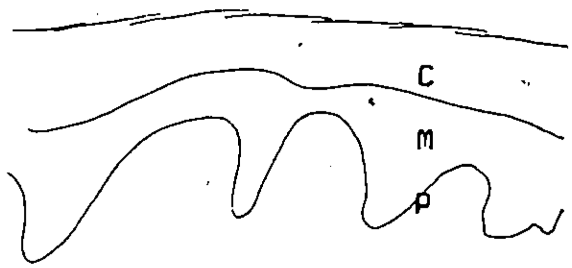
Plate 70



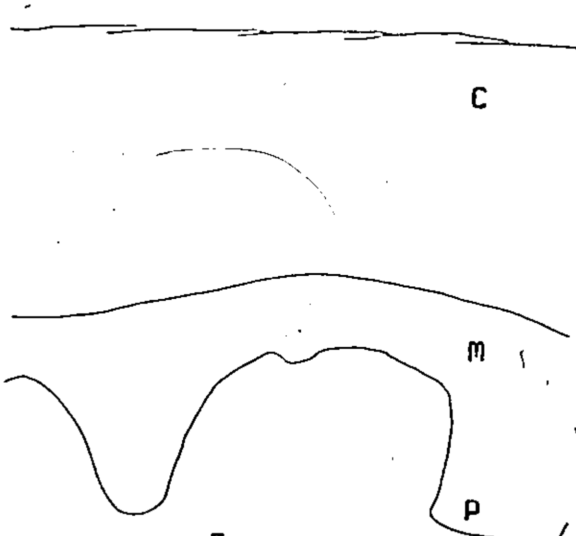



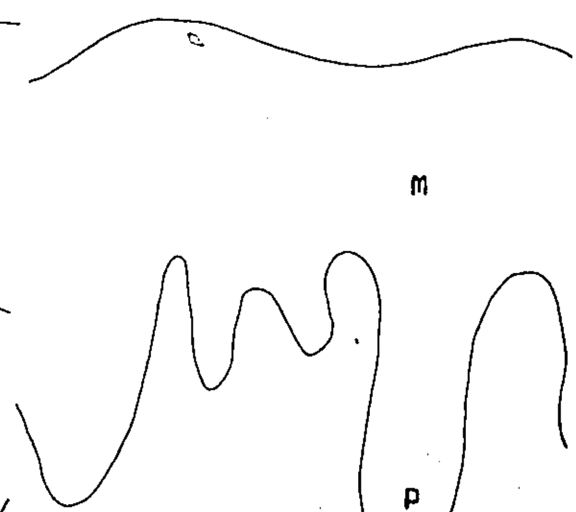

case 1 (stratum corneum .11mm) case 4 (stratum corneum .15mm)




case 2 (stratum corneum .18mm) case 5



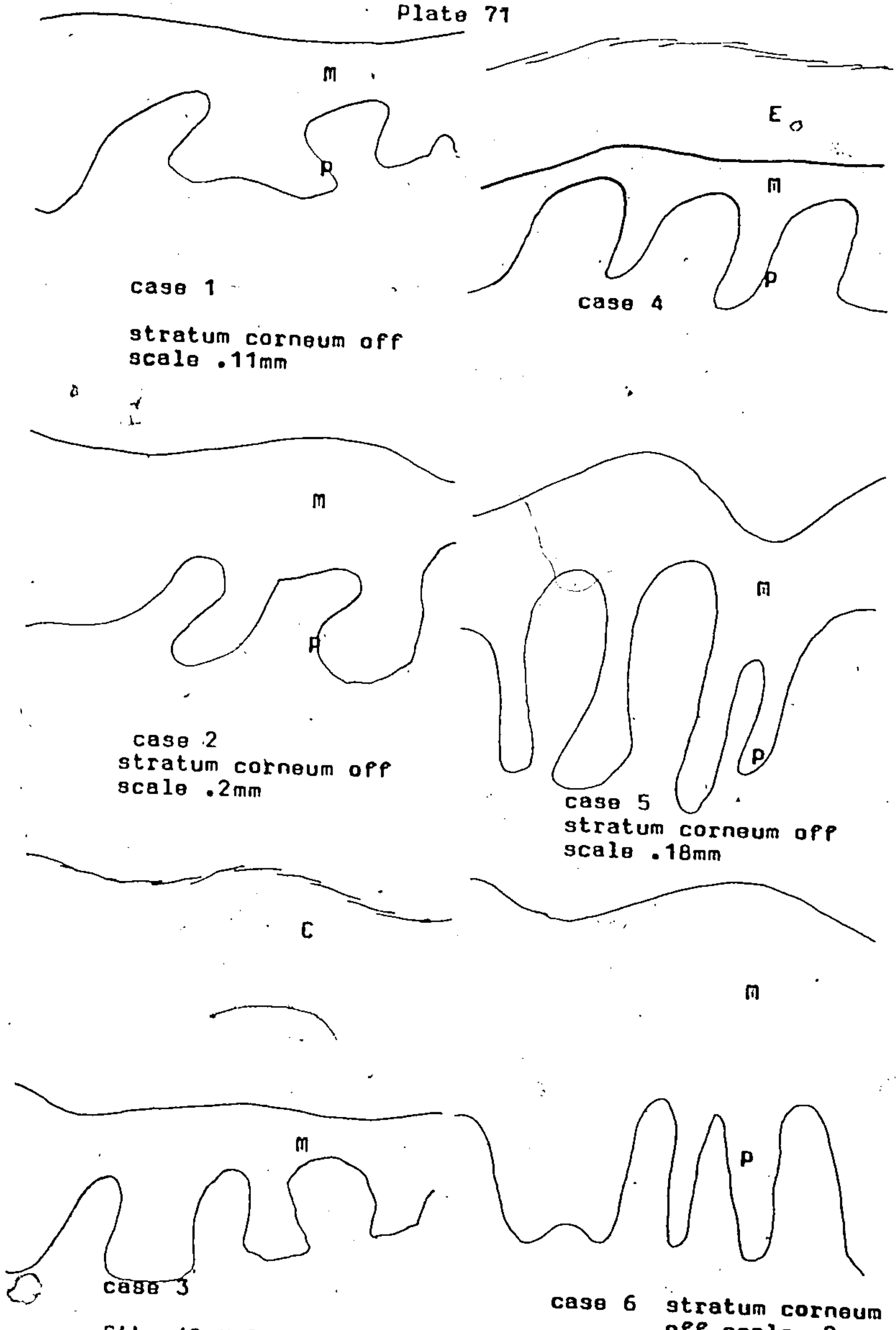




case 3

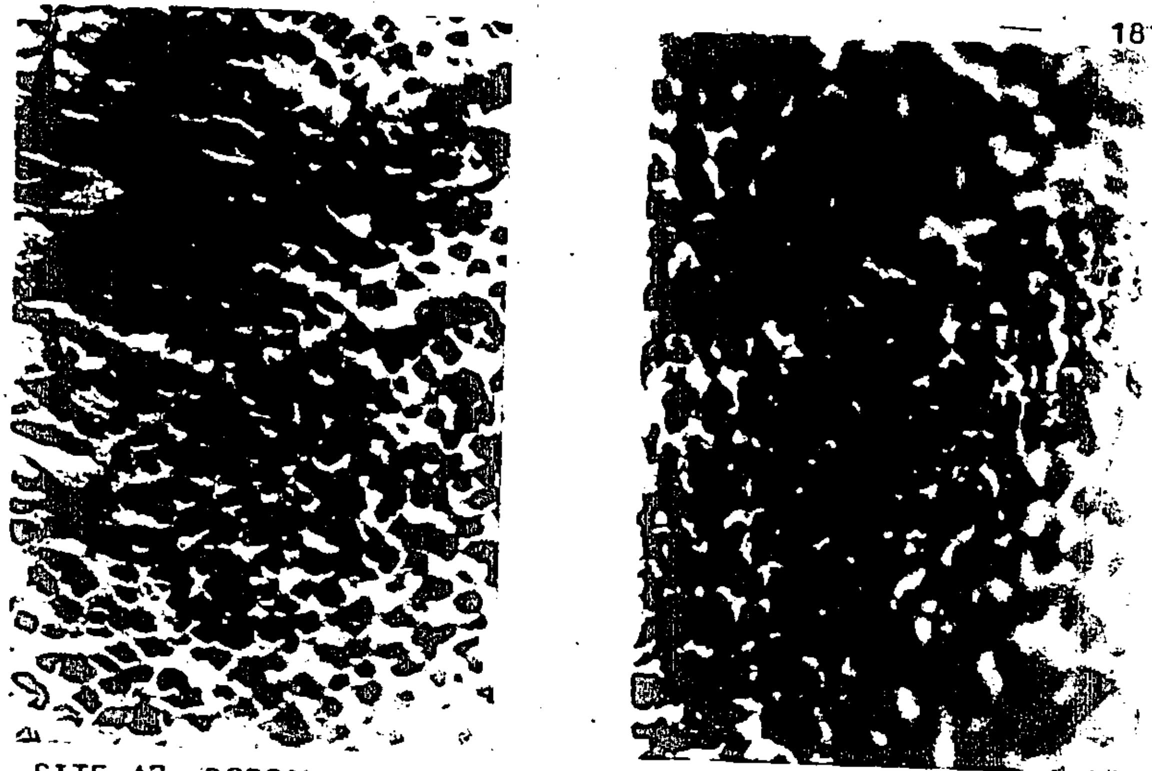
case 6 (stratum corneum .25mm)

Site 47, Dorsal Interphalangeal Joint of the Hand

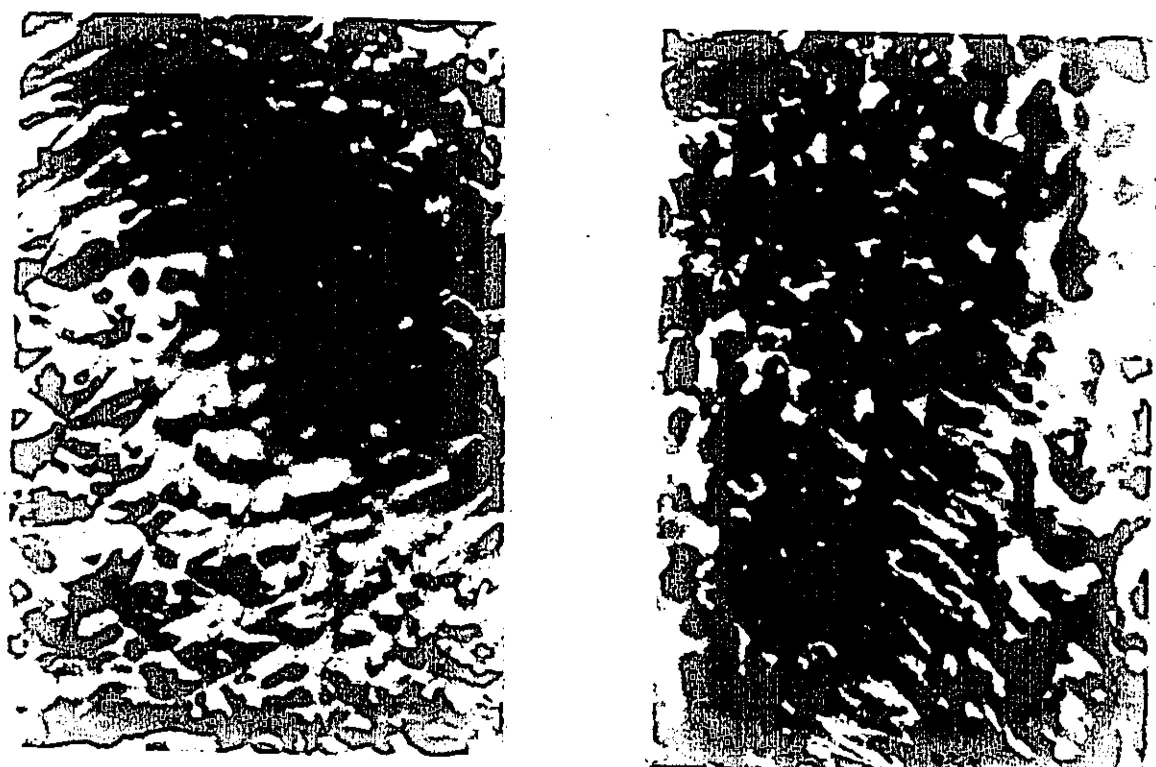
Plate 71




Site 48 Volar Interphalangeal Joint of the Hand



SITE 47, DORSAL INTERPHALANGEAL REGION, THE FINGER



SITE 48, VOLAR INTERPHALANGEAL REGION, THE FINGER

Epidermal Characteristics - The total epidermal thickness ranges from .13 to .58 mm with .31 the median. This tissue is among the upper 10% in thickness of all sites studied with the stratum dominating with 70% of the total. Rete peg numbers from 9 to 11 with 10 per mm the mean. The length of rete pegs varies from .07 to .09 mm with .08 mm the mean.

Interface Characteristics - The sine interface is characterized by deep elongate finger like rete pegs which are slanted in several instances. The epidermal interface reflects the superficial whorls of the skin in that curving parallel continuous ridges are present. Craters formed by the rete ridges are numerous and well formed between the whorls. The dermal interface has papillae formed in parallel along the lines of the whorls. They are elongate and finger-like. The structure of the epidermal-interface is characteristic to the individual and is genetically determined. The ridging in parallel of the structures does, however, suggest that the morphology is in response for tactile activities of the finger tip.

Case 50, Interdigital Finger

Functional Anatomy - The appositional thumb has enabled man to perform manual tasks that only he among all species is able to do. As the thumb is flexed and extended, or abducted and adducted, the skin is caused to stretch and fold. In order to accomplish these movements, reciprocally concavo-convex opposing joint surfaces are employed (saddle joint). Underlying the flexible skin, the metacarpal phalangeal joint is found. Fleshy muscles (adductor pollicus, obliquis and adductor pollicis transversus) are present to draw the thumb toward the mid line of the hand.

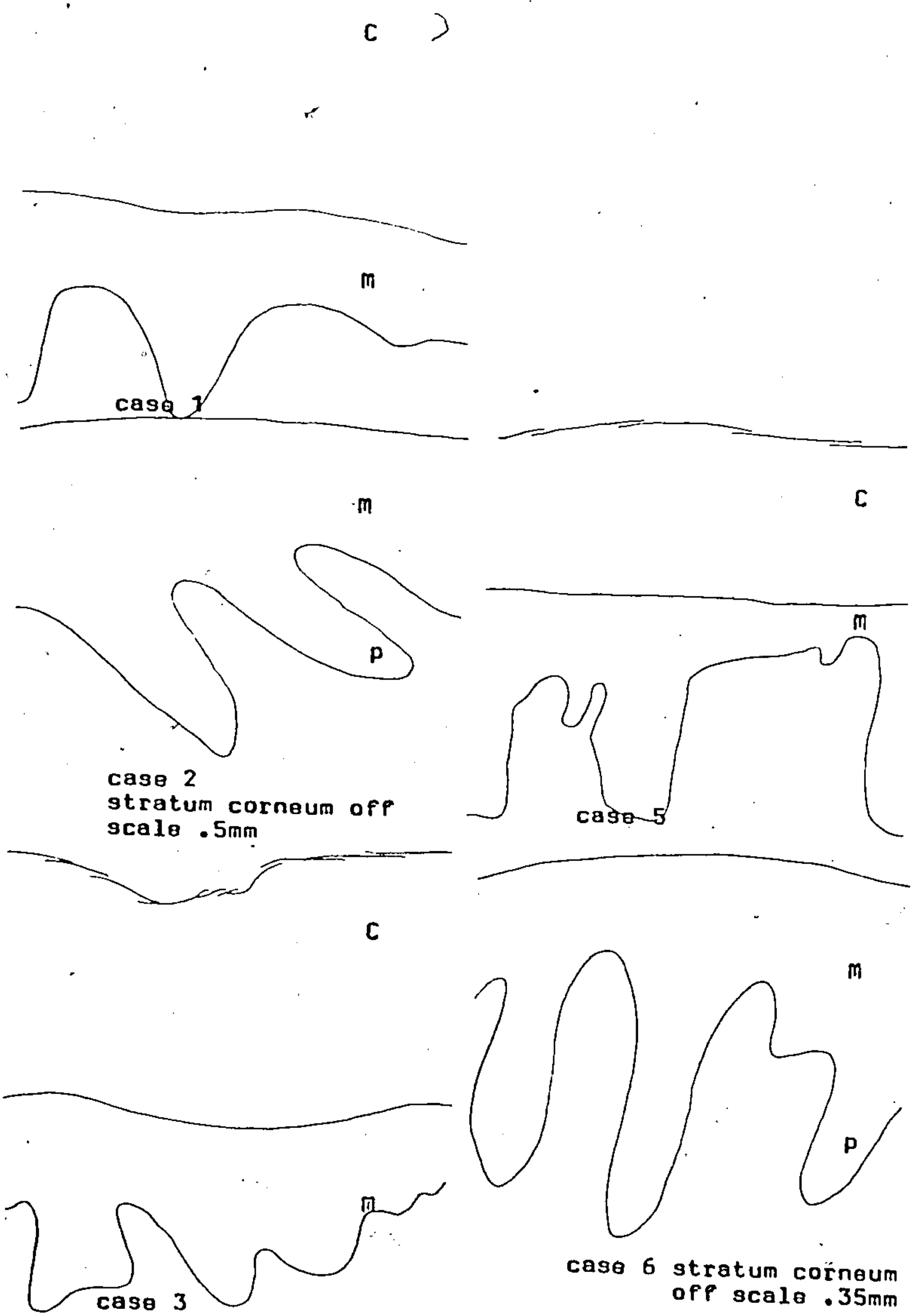
Epidermal Characteristics - The epidermal thickness of the skin of the web between the thumb and index finger ranges from .11 to .30 mm with .21 mm the mean. The tissue is among the upper 10% in thickness of all sites studied and the stratum corneum constitutes 70% of the total: Rete pegs number 8 to 12 per mm with 8 the mean. Rete peg length ranges from ..04 to .10 mm with .07 mm the mean.

Interface Characteristics - The sine interface demonstrates variously formed rete pegs. Case 6 has elongate finger like rete pegs, but the other cases have more broadened flat rete. The epidermal interface has numerous structureless continuous folds. They have an essentially parallel orientation but they tend to fan in response to the variable stresses placed on the web skin. A central structureless region at the apex of the web were underlying connective tissue dominates can be seen. Craters formed by the rete ridges are rounded and deep as a more peripheral position to the apex is taken. As the craters form closer to the apex, they tend to become more elongate. The dermal interface has numerous well formed large papillae oriented in parallel curving gently about the folds. The web of the thumb has a varied function which is reflected by the epidermal-dermal interface morphology. The lines of stress as the part rotates, abducts and adducts, flexes and extends in the grasping activity directs the formation of folds with variable epidermal-dermal structures firmly anchoring the intervening tissues.

Epidermal-dermal Interface of Volar and Dorsal Finger as a Continuous Skin Plane

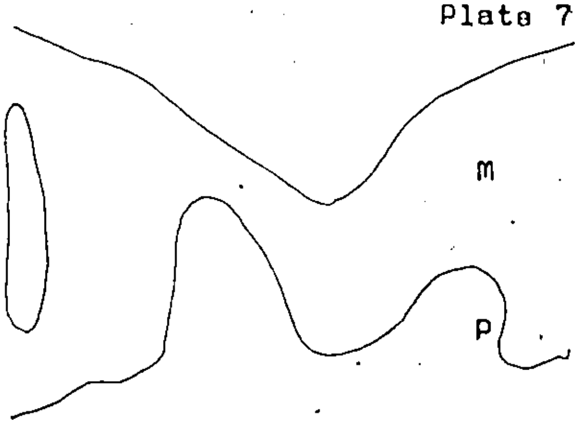
Epidermal-dermal interface preparations from numerous sites of the

Plate 73

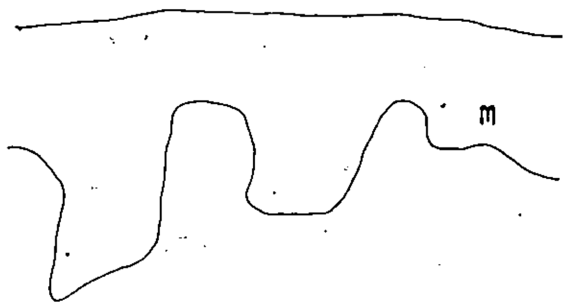



Site 49, Distil Aspect of the Index Finger

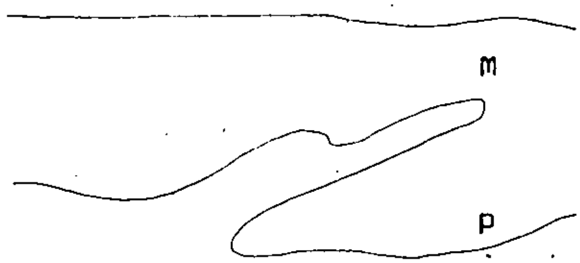
Plate 74



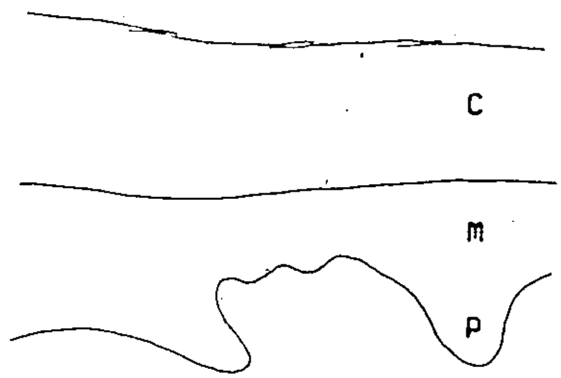

case 1 stratum corneum
off scale .15mm



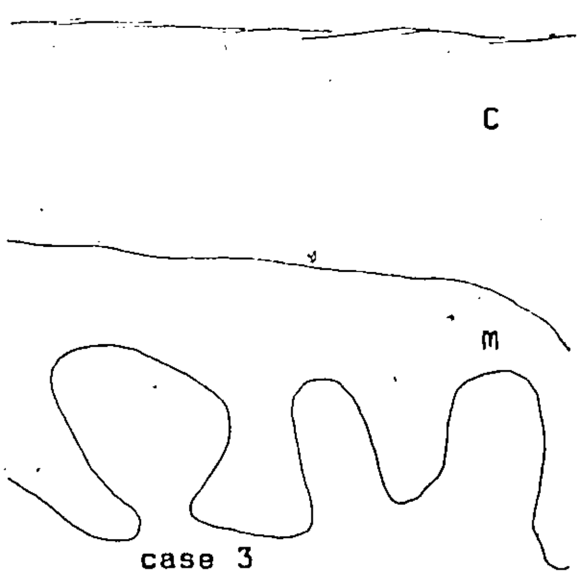

case 4 stratum corneum
off scale .20mm



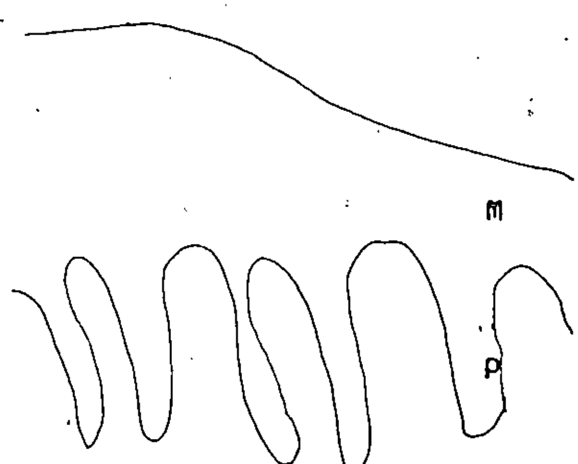

case 2 stratum corneum
off scale .25 mm




case 5

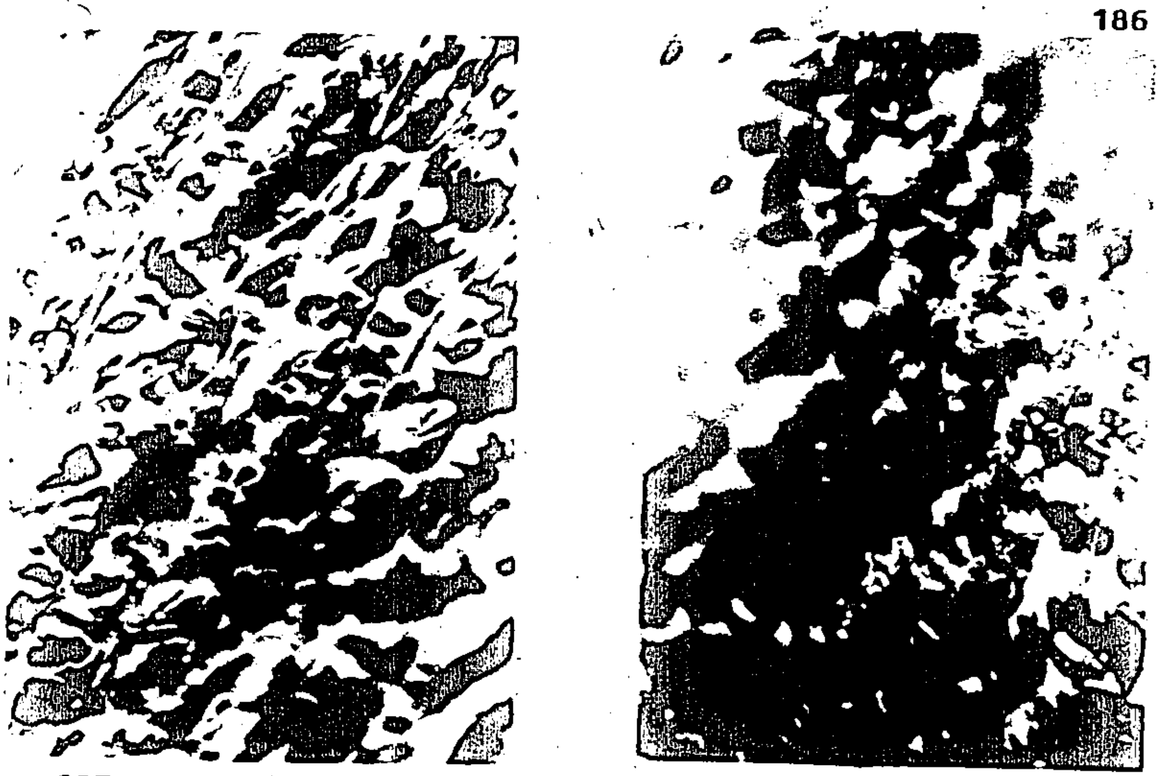



case 3

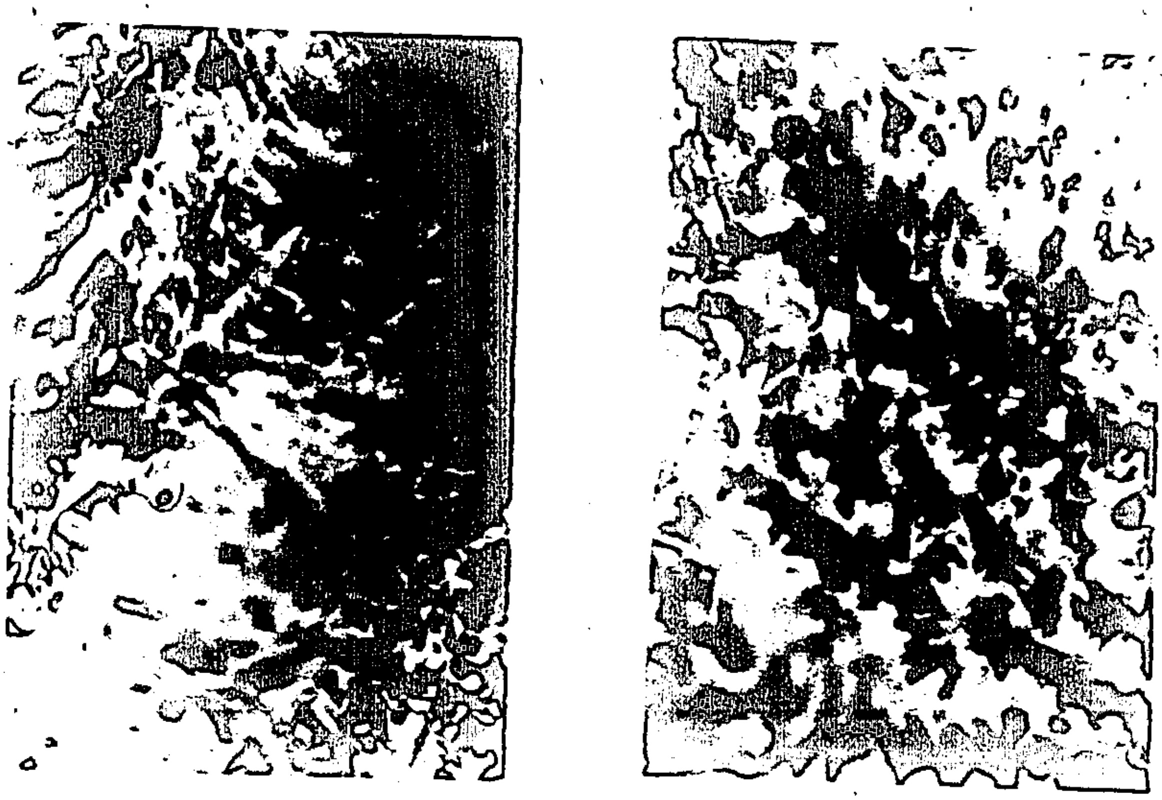



case 6 stratum corneum
off scale .20mm

Site 50, Interdigital Web Between Thumb, Index Finger



SITE 49, DISTIL AND VOLAR ASPECT, THE FINGER



SITE 50 THE INTERTRIGONAL ASPECT OF THE FINGER

human body with a variety of functions have been presented. Concluding this study, a more narrow anatomical examination is appropriate and was conceived. The finger is ideally suited for this purpose since it has a relatively small skin surface, but at the same time, it varies considerably in function within this limited space. The volar surface as a whole is adapted for grasping. The more proximal part of the finger is involved in gross powerful action, while the distil portion becomes adapted for fine tactile discrimination and the firm retension of small objects. The dorsal part of the finger is active in flexion and extension, but is comparatively passive in working when compared to the volar aspect of the finger from the standpoint of developing mechanical advantage. This variety of work is reflected in the epidermal-dermal interface preparations which follow.

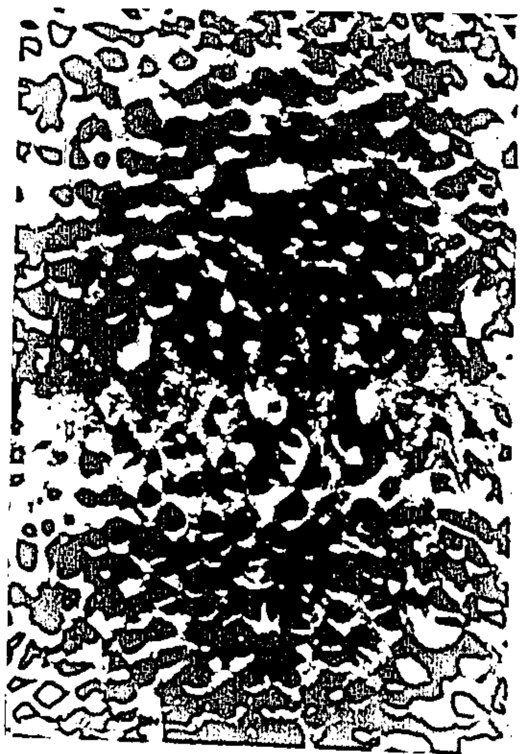
Finger, Dorsal Aspect, Epidermal Interface - The most proximal prepartion (Fig. 1) has several hair follicles. Craters formed by the rete ridges for the reception of dermal papillae are small but well formed, they are also more widely dispersed than in following preparations made from more distil portions of the finger. As the preparations are viewed from proximal to distil (interfaces 2, 3 and 4) the craters become more numerous and have greater depth and diameter. The flexor folds become narrower as the tip of the finger is approached and movements of the joints and the skin overlaying become more discrete and refined.

Finger, Dorsal, Dermal Interface - Dermal papillae interdigitate with the epidermal interface as finger-like projections. They become progressively larger from proximal to distil.

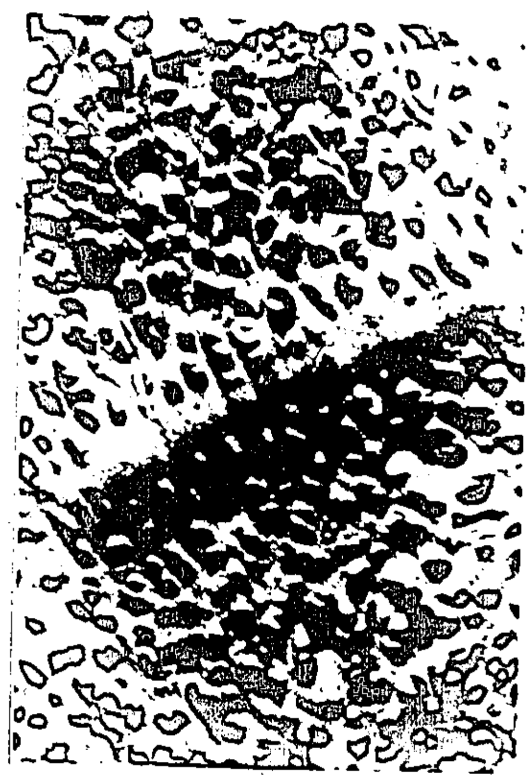
(1)

(2)

Epidermal portions of epidermal-dermal interface taken from proximal to distil (1 through 4) dorsal aspect of index finger of seventy four year old male. X35



(3)



(4)

(1)

(2)

Dermal portions of epidermal-dermal interface taken from proximal to distil (1 through 4), dorsal aspect of index finger of seventy four year old male. X35.

(3)

(4)

(1)

(2)

Epidermal portion of epidermal-dermal interface taken from proximal to distil (1 through 4) volar aspect of index finger of seventy four yoar old male. X 35.

(3)

(4)

(1)

(2)

Dermal portion of epidermal-dermal interface taken from proximal to distil (1 through 4) volar aspect of index finger of seventy four year old male. X35

(3)

(4)

<u>Finger, Volar Aspect, Epidermal Interface</u> - The volar aspect of the finger is active in grasping. The proximal interface (Fig. 1) has numerous well formed craters for the reception of dermal papillae. They have about the same depth and diameter of those of the most distil portion of the dorsal finger. As movement and tactile action becomes more discrete in the progressively distil interface (2, 3 and 4) the craters for reception of dermal papillae increasingly large and deep. The structureless bars of the rete ridges forming the whorls of the finger print are increasingly evident and suggest the intense mechanical advantage provided by the jaws of a plumber's wrench.

<u>Finger, Volar Aspect, Dermal Interface</u> - Dermal papillae interdigitate with the epidermal interface as finger-like projections. The volar surface of the finger is active in flexing and powerful in grasping, and the function is mirrored by progressively massive papillary structure from proximal portions where grasping movements are more broad and the papillae relatively small to the distil portions where great firmness is required and the structures are correspondingly larger. Grooves of the volar surface are also of a broader order and like those of the dorsal finger are relatively structureless. At these points, the subcutaneous tissues adhere the flexor folds with dense fibrous connective tissue and dermal papillae and rete ridges or pegs are not required.

## DISCUSSION AND CONCLUSIONS

In the present study, seven human cadavers were made available for dissection in order that comparisons could be made from 50 sites from well distributed locations. It was the intention to obtain as many sites from as many bodies as possible to demonstrate differences, if any, in epidermal morphology as skin function varied. Six functional groups were established: Weight bearing, flexing and extending, coverings, rounded and flat, special and anchoring types. The first two types were considered active as they were involved in receiving pressure or movement while the latter four were relatively passive.

Previous studies limited themselves to comparisons within a single cadaver. Pinkus (1964) made a compilation of several studies which compared total skin thickness, epidermis and/or dermis (all studies did not use all parameters). The results demonstrated extreme variability, and in light of recent electron microscopic studies concerned with human skin, a narrower range of study was conceived. The stratum germinativum stratum Malpighii and stratum granulosum reveal an orderly morphologically identifiable sequence of biochemical events as they undergo differentiating processes involved in keratinization. This was selected as one level of thickness measurements. The length of rete Malpighii below the suprapapillary plate was a second criterion since rete pegs allow for an additional source of cells committed to keratinization. The stratum corneum as the end product of keratinization constitutes yet another parameter for thickness evaluation. It was taken as a unit, but it does not represent the biochemical and morphological ultrastructural order of cells undergoing differentiation leading to the completed cornified layer. This is the first known use of this method of measurement and the reasons for its selection follows as the ultrastructure of epidermis is briefly outlined.

It would be helpful if future studies comparing components of epidermal thicknesses could be made with new born and individuals at different ages prior to adulthood. Restrictions of anatomical material made such a study impossible at this time, however. It has also been suggested that additional data could be obtained from a number of closely positioned points about a given site to demonstrate variability, if any, within a restricted region.

Ultrastructure of Human Skin

The early approach to skin biology made the assumption that only the most proximal basal epidermal cells were viable. According to this concept, these cells underwent deterioration, dehydration and cellular death as they pass peripherally toward the free surface of the skin (Zelickson, 1967).

During the past two decades, this view has been shown to be in error ( Matoltsy and Parakkal, 1967). Actually, from the stratum basale to the stratum corneum without, a well ordered and regular process of cellular differentiation is involved.

The stratum basals abuts the dermis itself with the basement membrane intervening, and its major function is cellular division (Odland and Read, 1967). However, these cells are by no means restricted to producing progeny. The basal cell role has been characterized as being pleuripotential (Pinkus and Mehregan, 1969). In incisive wounding, basal cells may migrate and divide to assist in the closure of defects, or they may modulate into a phagocytic cell to deal with wound contaminants (Ross, 1969). Generally, however, cells of the stratum basale move toward the free surface of the skin through the stratum spinosum and stratum granulosum and ultimately into the stratum corneum. During this migration, these cells are concerned with protein synthesis in the process of cellular differentiation called keratinization.

Evidence of protein synthesis first occurs at the level of the stratum basale where a small amount of rough endoplasmic reticulum and many free ribosomes can be observed (Odland, 1970). The fundamental feature of keratinization is the tonofibril composed of numerous thread-like tonofilaments having a diameter of 50 Å. They extend from the hemidesmosomes along the basement membrane border of the basal cell and course perpendicularly through the basal cell making a sling-like apparatus about the nucleus with attachment to the plaques of desmosomes ( Matoltsy and Parakkal, 1969). This organization was observed in normal interphalangeal skin and did not seem to differ from that noted by other investigators who worked on such less keratinized regions as the upper arm, sacrum and abdomen (Brody, 1960).

The stratum spinosum is composed of from two to four cell layers in the vast majority of sites studied. Since it is the principle component of the suprapapillary stratum Malpighii, its delineation marks the strata undergoing differentiation. Functionally, then, the stratum spinosum differs from the stratum germinativum which is undifferentiated epidermis and the stratum corneum which is differentiated tissue ( Matoltsy and Parakkal, 1969). The stratum spinosum is characterized by the frequent occurrence of desmosomes giving the typical "prickle cell" appearance. Ribosomal RNA is much in evidence along with larger vesicles and rough endoplasmic reticulum. The lamellar granules (Odland body) make their appearance for the first time in the stratum spinosum and are thought to contain phospholipids. The organelle migrates toward the periphery of the cell as it is displaced toward the free surface of the skin and ultimately appears to empty its vesicle-like contents into the intra-cellular space (Odland, 1960, Frithiof, Lagerlof and Wersall, 1963).

Along with the one or two cell layers of stratum germinativum and the several cell layers of the stratum granulosum, the stratum spinosum (stratum Malpighii collectively) is one of the epidermal features measured throughout this study for alterations. This cellular layer by its thickness indicates an increased number of cells committed to differentiation leading ultimately to keratinization. Acanthosis is marked in the heavily keratinized normal sites such as the heel or first metatarsal where it is much increased when compared to the bulk of tissues studied where the stratum Malpighii is .02 or .03 mm in thickness (Part I, Tables I through VI).

The stratum granulosum is easily delineated from other cell layers of the stratum Malpighii by the occurrence of keratohyaline granules which form upon the tonofibrils. As the masses of keratohyalin coalesce, they may nearly fill the cytoplasm of this stratum and the nucleus may dis-integrate (Brody, 1960). This condition is expressed in the extreme situation of keratinization. While the relative amount of intracellular keratohyalin may vary, the thickness of the stratum granulosum is limited to 2 to 4 layers of cells and did not provide sufficient latitude to establish the strata as one of epidermal features subject to comparison. Since it is still a part of the differentiation process of keratinization (the last phase leading to complete cornification) it is appropriate that it be included in the stratum Malpighii.

In sharp contrast to the nucleated layer of the stratum Malpighii is the stratum corneum which is the end product of the differentiating process and which is without nuclei. As the cells pass from the stratum granulosum to the stratum corneum above, the plasma membrane thickens and anabolic processes related to formation of differentiation products cease. Catabolic processes predominate in the stratum corneum and partial or complete degradation of nuclear remnants, mitochondria, keratohyaline granules, ribosomes, endoplasmic reticulum and Golgi occurs at a rapid rate. Dehydration also contributes to the horny nature of the stratum corneum ( Matoltsy and Parakkal, 1967).

The stratum corneum is the most varied of all parameters of the epidermal elements studied in this thesis. Thin scalp epidermis could be limited to .01 mm (case 1) while the thick heel occurred as .75 mm (case 6) in thickness. In the thinner range of thickness of the stratum corneum, mercury bromophenol blue testing for protein revealed a homogeneous quality of the differentiated strata. The stratum granulosum below had the capability to complete the keratinization process with essentially similar proteins constituting the stratum corneum. However, as the thicker ranges of stratum corneum were tested, a heterogeneous reaction to the stratum suggested incomplete biochemical conversion of the protein precursors of keratinization from the underlying strata (Part II, Fig. 23): Parakeratosis, then, is concomitant with an increased thickness of stratum corneum (Pinkus and Mehregan, 1969).

Biochemical variability can be attributed to fibrillar elements seen in the stratum corneum as well (Brody, 1970b). Number, type and orientation of the fibers provide strength and elasticity to the tissue and are important to the mechanical integrity of skin which is reflected in this study. Three types of fibrils are identified: Type one fibrils have only a faint keratin pattern; type two is the intermediate expression and type three demonstrates a definite keratin pattern throughout the whole fibrillar substance. Fibrils may also be densely-packed within the cells of the stratum corneum (type A) or the cytoplasm of the cells of the stratum corneum may have an essentially nonfibrous structure (Brody, 1970a). No predetermined order or arrangement of either fibers or cell types appears to exist at the ultrastructural level of the stratum corneum cell and it is not likely that they are a factor in influencing the overall morphology of the epidermal features of interest in this study.

Fibrous proteins are lacking in sulfur, while the amorphous proteins contain abundant sulfur (Zelickson, 1967). These cell constituents are responsible, together with the thickened plasma membrane, for the protective function of the stratum corneum. The filamentous constituents usually orient parallel with the free surface of the skin and provide cohesion, flexibility and elasticity (Maloltsy and Parakkal, 1967).

The filamentous network is stabilized by relatively few disulfide bonds and hence is not responsible for the insoluble character of the layer. Cell contents are stabilized mainly by amorphous components moderately rich in disulfide linkages. The plasma membrane is the component most resistant to keratinolytic agents and is a sulfur rich phospholipid. The plasma membrane surrounds and provides integrity to the cells of all epidermal strata, but is particularly in evidence in the stratum corneum of heavily cornified skin.

Statistical Evaluation of Epidermal Variability

The literature on biology of the skin and the examination of histologic slides in thickly cornified skin, attest to an essentially morphologic and functional similarity at the cellular level. The cells, however, are grouped into a wide variety of expressions of the epidermal features. The thickness of stratum corneum and the underlying supra-papillary stratum Malpighii and the length of the rete ridges are measurable.

When skin as a whole is considered, there is close correlation among the measurements of the respective epidermal features. The length of rete Malpighii is essentially directly related to the thickness of the stratum corneum. The heel (site 30) and plantar first metatarsal head (site 34) of the foot have the greatest length of rete pegs and they also express the greatest thickness of stratum corneum. Conversely, the scalp (site 1) in the wall-haired specimen studied had the fewest and lowest profile of rete pegs together with the thinnest stratum corneum. The stratum corneum (and to a lesser degree, the stratum Malpighii) varies directly with the thickness of the overall epidermis. The length and number of occurrence of rete pegs together with the interdigitating dermal papillae are demonstrated by epidermal-dermal interface preparations in two and three dimension fashions.

The close inter-relationship of the epidermal features is evidenced by the consistency of the observations that an increase in any one dimension produces an increase in the others. Aggressive functional demands made upon the skin particularly in weight bearing or pressure sites and in flexion or extension of a part would seem to be a principle factor in exaggeration of any and all of the epidermal features of interest to this study. The increased dimension of the rete ridges provides greater surface area for the epidermis to relate to the dermis. The interdigitation at the epidermal-dermal interface also mechanically locks the two layers more securely particularly in weight bearing regions, as the heel and first metatarsal heads. The epidermis and dermis interlock by the deflexion of dermal papillae parallel to the free surface of skin into the rete ridges of the epidermis. This morphogic alteration appears to be in response to external pressure against the papillae. It is a phenomenon seen only at skin sites receiving pressure.

Causal Factors of Morphological Variability in Epidermis

No two sites examined within the same individual or among the seven cadavers were exactly the same and relative thickness of epidermal strata or their respective epidermal-dermal interface structure all exhibited individuality. It is known that human skin is responsive to factors such as nutrition, age, hormone activity and gene control, but one seldom mentioned factor is the mechanical forces to which skin is subjected. This study categorized skin into six functional groups and comparisons were made. Characteristically, the weight bearing sites demonstrated the greatest range of development of the epidermal features. Skin surfaces involved in flexion and extension of a body member demonstrated a lesser, but still accentuated expression of interface characteristics and epidermal stratification. Coverings, both rounded and flat, skin involved in anchoring and special integumentary types had distinct interface characteristics, yet they seemed to have similar thickness of the epidermal strata. How the external mechanical operation of the skin could conceivably direct (in part) its morphological characteristics and modulations follows.

Morphologic Variability of Skin

Morphologic and functional polymorphism characteristic of mammalian epidermis is specific for a given body location (Billingham and Sivers, 1967) but may be structurally altered. The epidermis must "inform" the dermis of external conditions such as weathering, stress, wear and tear against the part, persistent abrasion, and we might add weight bearing and flexion ( Cohen, 1969). In responding to external factors, modulations of the epidermis are directed by the dermis. These involve overall or relative thickness of the various layers of the epidermis, epidermal-dermal interface, presence and condition of the stratum granulosum and indeed, the histology of the total skin (Cohen, 1969). This interaction of external stimuli, epidermis and dermis constitutes a true biological feedback mechanism.

Dermal Factors Influencing Skin Morphology

Interactions within the dermis itself may of themselves influence epidermal morphology. Vitamins and hormones have been shown to have the capacity to shift the developmental pathway of the equipotential epidermal basal cell diffusing from the dermis (McLoughlin, 1963). Aggressive forces acting against the free surface of the skin in such forms as trauma and physical or chemical irritation produces a dermal elaboration of histamine which can influence the activity of the basal cells of the stratum germinativum. An extension of the notion of cellular elaboration of histamine on the basis of trauma applies to heloma durum, an extreme response of the hyperkeratinization process. All epidermal features hypertrophy in reacting to external pressure which in turn invokes a dermal response.

In a similar way, the function of the skin, particularly as it is involved in weight bearing and to a lesser degree in the flexion of parts, could influence an elaboration of histamine in the dermis which in turn could be the mechanism for modulating of epidermal morphology. It is of interest for this study that histamine values vary in a predictable way in different parts of the body: Highest levels are found in the sole of the foot where this study has shown the greatest degree of interface expression and thickest cornification. Lowest levels, on the other hand, occurred where little motion or support is demanded of the skin such as on the abdomen (Feldberg, 1956).

The structural characteristics of epidermis require dermis for their maintainence (Briggaman and Wheeler, 1968). Recombinant grafts of guinea pig epidermis of the sole of the foot, the ear or the trunk region assumed the characteristics expected to develop over the underlying dermis and did not assume the features of the donor site epidermis (Dodson, 1963). The inductive capacity of the dermis varies considerably in different regions of the body. Induction is a localized, specific and chronically active dermal function which may or may not act in concert with external stimuli. Because of the intrinsic inductive dermal capacity, for example, no amount of dermabrasion can obliterate the human fingerprint.

The dermis provides a physical substrate for attachment and orientation of the epidermal basal cells as they form the epidermal-dermal interface (Wessels, 1967). The morphological response of the skin depends partly on the mechanical characteristics of the dermal collagen fiber network (Carr, 1969). If sufficient load is applied, uni-axial stress-strain relationships approach linearity. In this instance, collagen normally lies obliquely and under load becomes angularly displaced, but elastin content of the dermis remains unaltered under stress. Morphological alterations of collagen are accompanied by biochemical changes. When stained by the trichrome method, collagen which is normally stained green and oxyphilic becomes acidophilic and red staining when the skin is placed under load (Evan and Siesennop, 1967). In this thesis, weight bearing sites in normal human skin as well as hyperkeratinized heloma durum tissue demonstrated concentrations of fibroblasts about the tips of the dermal papillae with an increased amount of collagenic fibers in the ground substance of the dermis nearby. Briggaman and Wheeler (1968) felt that the increase of collagen reflects a firmer matrix upon which the increases of epidermal strata might rest since collagen by itself cannot support epidermal differentiation in tissue culture.

The Diffusable Dermal Factor

Successive stratification of germinativum, spinosum, granulosum and corneum requires the presence of some diffusable dermal factor according to in vitro tissue studies employing tritiated histamine as a labeling agent (Briggaman and Wheeler, 1968) and in in vivo studies with embryonic chick (Dodson, 1967).

Epidermal cells grown in tissue culture stratify properly even if dermis is freeze dried or powdered and the light microscopic characteristics of dermis are lost (electron microscopic features remain recognizeable). Supernatant cell free solutions from fibroblast cultures (as yet not chemically defined) are able to influence reconstruction of an organized epidermis in tissue cultures in which a suspension of epidermal cells is being grown. Chemically diffusable noncellular elaborations of dermis have been implicated in abnormalities of skin differentiation including psoriasis, ichthyosis and epidermal cancers (Karasek, 1969).

Tendon, tendon sheath and fascia, all non-dermal connective tissues are competent to produce a diffusable substance which influences epidermal differentiation similar to the dermal agent. The substance(s) withstand temperatures of 56°C (Briggaman and Wheeler, 1971). This coincides with values established for the "dermal influence".

The dermal influencing factor initiates mitosis in the basal cell of the stratum germinativum. An increase in cell division produces crowding and thus an increase in epidermal-dermal interface surface area. A greater depth and/or number of rete ridges is achieved. This effect has been studied as the sine interface and epidermal-dermal interface in the three dimension photomicrographs. Some of the cells push toward the free surface of skin entering the differentiating activity of the stratum Malpighii and finally complete the process of keratinization in the stratum corneum, both strata forming two measurable epidermal features reflecting the efficiency of epidermal proliferation and differentiation initiated by basal cell response to dermal influences which in turn are directed by external mechanical forces.

The Cell Cycle Concept

Reproductive or cell cycle time is defined as that period between the completion of mitosis in a cell and the completion of mitosis in a daughter cell (Malkinson, 1972). Epidermal skin growth is accretionary since only a limited population of cells is mitotically dividing, while the rest lose this ability and enter upon another pathway of differentiation (Balinsky, 1970). In skin, the cell cycle is limited to the stratum germinativum and almost entirely to the basal layer. The G-1 phase is crucial to the control of cell reproduction since it is during this period that the course of differentiation is determined. Commitment to mitosis has been made once the cell enters the S phase. During G-1, preparation for DNA synthesis takes place. Enzymes needed to produce the immediate DNA precursors (deoxynucleoside triphosphates and DNA polymerases)are synthesized. RNA and protein synthesis are required for cells to progress through the G-1 phase. If tissue is not involved with cellular renewal, the differentiated cell is permanently arrested in a prolonged G-1 state (Malkinson, 1972). Prior to DNA synthesis an initiator protein, which is itself under the control of a messenger RNA, must be produced. The messenger RNA is repressed by a complex between repressor protein and a co-repressor which is highly specific to any given cell line (Prescott, 1968). The repressor protein is intracellular, but the co-repressor equilibrates with the extracellular micro-environment.

Cell reproduction and DNA synthesis may be increased if either factor is altered. Cell damage or loss after injury would quickly alter the labile co-repressor substance in the extracellular environment. Increased cellular demand could effectively reduce the intracellular concentration of co-repressor favoring cell reproduction and DNA synthesis. In the weight bearing sites, which have an increased expression of rete ridges with a parallel increase of epidermal-dermal interface surface along with acanthosis of the stratum spinosum and increased thickness of stratum corneum, such a mechanism could be postulated for increased cell turnover (Cohen, 1969).

As cells proliferate toward the free surface of the skin from the basal layer of the stratum germinativum, they enter a course of differentiation. Other basal cells remain in situ for replication. Migration of single cells to more superficial layers seems to occur in a random fashion, and time-wise, is independent of mitosis from which the migrating cell originated (Malkinson, 1972).

Regional variations in epidermal thickness which are of importance to this study are accounted for by variability peculiar to differentiation rates rather than in proliferative activity of the germinal layers (Christophers and Petzgold, 1969).

In epidermal tissue the period of DNA synthesis (S) takes from 6 to 8 hours. The period separating the end of chromosomal replication from the onset of cellular division (G-2) extends from two to three hours. Actual mitosis (M) is limited to 30 to 60 minutes in basal cells of the stratum germinativum. RNA synthesis ceases (Taylor, 1960) and protein synthesis is maximal (Baserga, 1962). This short M period characteristic of the basal cell and the comparatively slow rate of cell turnover accounts for the very few mitotic figures which occur in the skin slides studied.

Factors Influencing Cell Cycling in Epidermis

The variable epidermal features central in this thesis owe their wide range of variation to feedback mechanisms involving the internal and external environment of the skin. Internal mitogenic substances which could alter basal cell proliferation and hence epidermal structure have been postulated and include intrinsic factors which result in increased cell production of fibroblast, parenchyma and connective tissue (Knospe et al., 1970). Humoral levels, hormonal levels, body temperature differentials and the general state of nutrition should also be considered (Bucher, 1963). Actively moving parts of the body and weight bearing activity would doubtless increase local tissue temperature and oxygen gradient resulting in altered proliferation of cells, and ultimately affect morphology.

<u>Epidermal Cell Transit Time</u>

The average transit time of epidermal cells from the basal layer to the site of desquamation in the uppermost stratum corneum varies from 20 to 50 days, with 26 days average as demonstrated by tritiated thymidine autoradiography in human epidermis (LeBlond and Wallen, 1956, Weinstein and Van Scott, 1965). Passage of cells to the stratum granulosum requires 12 to 14 days with passage through the stratum corneum requiring an additional 12 to 14 days. Personal observations of this author indicate that tissues which conserve the stratum corneum such as the weight bearing sites at the heel and first metatarsal head do not desquamate cells from the free surface of skin as readily as other sites since an increase in thickness of the cell boundaries is common providing adhesion along with mechanical compression and dehydration. This conservation would be reflected in the marked increases in thickness of this strata observed in this study.

Overt trauma and more subtle inflammatory changes increase mitotic and labeling indices with a decrease in cell transit time (Weinstein and Van Scott, 1965). This concept can be extended to the minimal traumatic situations of weight-bearing and flexion-extension of the epidermis and additional support to the argument that function may affect the morphology of the epidermis is provided.

Psoriasis in its inflammatory phase increases the basal cell population to three rather than the usual one layer of mitotically active cells in the stratum basale. Cells are produced 8 or 9 times faster than usual and cell cycle time is reduced (Weinstein and Van

Scott, 1965). This alteration is evident in a large group of other inflammatory skin diseases (Frost, 1966).

Since injuries of diverse types (wounding, adhesive cellophane tape stripping) are followed by inflammatory changes (a dermal event) with a parallel increase in the rate of cell division, it has been assumed that epidermal mitosis in this instance is secondary to inflammation (Malkinson, 1972). Whether the inflammation is marked as in disease states or minimal in situations in which additional demands are placed on the epidermis by weight bearing or flexion is only a matter of degree. Increased vascularization provides additional explanation for the hypertrophies of the epidermal feature measured in weight bearing and flexing skin surfaces as opposed to the passive covering, anchoring and special categories chosen in this study.

Epidermal Controls on Proliferation

External environmental factors influence epidermal morphology through initiating one or several dermal events. Recent studies have shown, moreover, that the epidermis itself is also involved in its own morphological destiny (Cohen, 1969). Factors within the stratum Malpighii regulate the proximo-distal arrangement of the upper layers of the epidermis.

Mitotic activity (hence, accretionary growth and morphological diversity so central to the measurement comparisons made in this study) is inhibited by three diffusable substances first extracted from the epidermis of mouse ear. The term, epidermal chalone, was coined to designate these substance in the initial investigations (Bullough, Hewett and Lawrence, 1964). Each body tissue may produce its own particular chalone inhibiting mitotic activity by feed-back inhibition as in the case of the epidermal tissues. The epidermal chalone functions only when complexed with epinephrine as a co-factor and in certain instances it interacts with glucocorticoids (Bullough, Hewett and Lawrence, 1964).

Chemically, the epidermal chalone is a protein (molecular weight 35,000) and while it is tissue specific, it is not species specific (Voorhees and Marris, 1971). Psoriasis is characterized by twelve fold acceleration in the rate of epidermal basal cell division. It is an inflammatory polygenically and environmentally controlled skin condition which responds favorably to the administration of glucocorticoids. Since mitotic acceleration can be inhibited by beta adrenergic stimulation, Voorhees and Duell (1971) have concluded that the epinephrine dependent chalone mechanism described by Bullough et al. (1964) is identical to a cascade of events in which epidermal basal cells can be inhibited by increasing intra-epidermal adenosine 3' 5' monophosphate. An increase in cyclic AMP is accompanied by an increase in phosphorylase activity and a breakdown of glycogen. In psoriasis, with its much increased mitotic index, there is low phosphorylase activity and a build up of glycogen. Consequently, the increase of epidermal basal cell division noted in psoriasis and by implication, other situations characterized by a proliferation of basal cells,could well be due to defective adenyl cyclase-cyclic AMP dependent protein kinase activity. When mitotic activity of the epidermal basal cell becomes wild and irregular as in melanomas and squamous cell carcinomas (skin cancers) some control can be re-established by use of extracts of epidermal chalone (Caron, 1969).

Stratum corneum, the differentiated product of keratinization, and the suprapapillary stratum Malpighii which is the differentiating nucleated cell mass involved in precursor synthesis leading to cornification are the principle epidermal features involved in this study. Differences as they relate epidermal morphology and thickness to epidermal function in the mechanics of interacting of skin have been documented. The conclusion that epidermal morphology is variable with respect to its mechanical function has been drawn. It can be hypothesized on the basis of the observations presented in this thesis and what is presently known concerning skin biology that morphological variability results from interaction of skin in a series of feedback events which involve external mechanical stimulation, mitogenic diffusable substances arising from within the dermis to activate mitotis in the stratum basale and the counterbalancing epidermal chalone. The interaction produces variable responses in cell cycling which in turn influences the characteristics of the interface between dermis and epidermis by increasing or decreasing the number of basal cells or by committing them into proliferative activity which would be reflected in changes of thickness of the epidermal features, stratum corneum and/or stratum Malpighii.

The Epidermal-dermal Interface

The interface of the two epidermal features may be regarded as a reflection of the biological activity of skin, namely, keratinization. The light microscope demonstrates the interface as a sine wave-like structure in two dimensions. On this basis, the epidermal-dermal interface has been interpreted as a series of elongated troughs and ridges which fit into one another since the structures may be seen occurring on many succeeding sections (Ham, 1969). Pinkus (1971) points out, however, that the two dimensional treatment of skin is often misleading, as can be recognized when epidermis and dermis are macerated and studied in three dimensions. The dermal papillae in these preparations are seen as cones fitting snugly into reciprocating depressions between the epidermal (rete) ridges. The apparent conflicts in these points of view have been resolved in this study.

The more or less regularly occurring well formed dermal papillae of high profile interdigitating with rete ridges were best demonstrated by hard working hairless skin. The plantar surface of the heel (site 30), plantar aspect of the first metatarsal head of the foot (site 34), plantar aspect of the arch of the foot (site 33), and the region of the Achilles tendon (site 21) provided the best support for the Pinkus view.

Well formed but lower profiled epidermal-dermal interfaces included regions of the chest (sites 7 and 8), the back (sites 12 and 13) and the dorsal arch of the foot (site 39).

Occasionally, the interface of epidermis and dermis proved to be essentially flat with ridges predominating on both the epidermis and dermis which presumably lie side by side, but which, in section appear very much like cone shaped papillae or rete ridges. Such regions included the anterior and posterior neck (sites 3 and 6), gluteal fold (site 16), elbow (site 20), popliteal space (site 23), inner arm (site 41), and the infra patella skin (site 37). All of these sites were involved in the activity of flexion of a body part.

The penis (site 17) representing the only hairless contractile skin type demonstrated a unique ridge structure which presumably permitted alteration in size and shape of the organ.

Intermediate between the cone and ridge types of interface was a large group of mixed tissues which were partly flat, occasionally ridged with patchy occurrences of papillae on the dermal interface. Among this group were the axilla of the arm (site 9), groin (site 11), posterior thigh (site 22), and malleolar skin (site 31).

Again, the weight-bearing sites demonstrated an epidermal-dermal interface adapted to their function. Other interface regions were less well defined, often due to an overlap of function.

The strip examination of the finger provided suitable comparisons of the alteration of structures within a relatively small surface area with respect to function. Wherever deep folds of the articular skin occurred, an especially tight relationship of skin to the underlying joint was required. In these instances, the underlying dense fibrous connective tissue became dominant and the epidermal-dermal interface structures were entirely lost. Between these structureless folds, however, were numerous well formed rete ridges on the epidermal interface and equally well formed cone shaped papillae on the dermal portion. Characteristically, the structures become larger in a proximo-distal manner as the work reflected by the finger becomes more discriminating.

When hair follicles are more numerous, all of the measureable epidermal features considered in this study become reduced. Stratum corneum and the stratum Malpighii are reduced and rete ridges are few (if any) and are very short when they do occur. It is interesting to note that in becoming bald, where a permanent loss of hair follicles occurs, numerous dermal papillae and rete ridges replace the loss (Pinkus, 1973, personal communication). This suggests that the hair follicle is strongly dominant in the induction processes within the epidermis and dermis. The wall of the hair follicle is of epidermal origin and relates positionally to the adjacent dermis. The dermis, at the lower third of the bulb is thought to diffuse out a substance preventing the formation of additional dermal papillae destined to become involved in the formation of other hair follicles (Cohen, 1969). The mesenchyme controlling matrix cell division diffuses out a controlling "dermal factor" identified as a mucopolysaccharide on the basis of histochemical staining tests (Cohen, 1969). If the distal third of the whisker bulb is removed, a new dermal papillae precursor to the formation of a new whisker bulb forms. An increase of dermal vascularization is noted at anagen of the hair follicle, and is at least in part a response to the physical factor of the loss of the whisker bulb. These events parallel the dermal activities involved in the induction of epidermis (Cohen, 1969).

PART II

# THE EXAMINATION OF EPIDERMIS IN NORMAL AND HYPERKERATINIZING SKIN USING NORMAL INTERPHALANGEAL SKIN AND INTERPHALANGEAL SKIN FORMING HELOMA DURUM (HUMAN CORN OR CLAVUS)

## OBJECTIVES

The human corn (heloma durum) provides an experiment in nature for comparison of thin skin such as that normally found at the interphalangeal joint of the toes and a highly keratinized atypical occurrence at the same site responding to altered function: That of being subjected to an increase in pressure. The gross hypertrophy of the epidermis and its component parts makes this extreme expression of hyperkeratinization ideal for observations of histochemical and ultrastructural changes. Comparisons on the basis of morphology and the relative thickness shifts incident to hyperkeratinization can also be made.

## REVIEW OF THE LITERATURE

The literature on heloma durum is limited. A historical review indicates that the lesion has plagued humanity from antiquity (Feigenbaum and Schreiber, 1964).

The lesion is a circumscribed cup-shaped thickening of the epidermis with a central core of parakeratotic stratum corneum with a reduced granular layer (Pinkus and Mehregan, 1969). Occasionally, there exists a pressure atrophy of the epidermis, although sweat ducts are preserved and may be observed winding about the central core of the clavus. Bonavilla (1968) observed that the projections of the dermal papillae are less conspicuous at the central portion of the lesion than about the periphery. Pinkus and Mehregan (1969) noted the flattening of rete ridges at the center of the lesion.

Hyperplasia of bone is the immediate underlying cause for the formation of the hyperkeratotic changes, if there is an external intermittant pressure (as from foot wear) against the enlarged bone (Freed, 1969). The thickened epidermis found in human heloma durum will modulate to the normal state if either causal factor (bone or external pressure) is permanently removed.

## MATERIALS AND METHODS

### Specimen Preparation

Ten patients were prepared for surgery utilizing a fifteen minute pre-surgical scrub using hexachlorophene soap and several applications of acetone. Local anesthesia was induced by regional digital block using xylocaine without epinephrine. The ultrastructure of skin specimen excised with local infiltration of anesthetic agents does not differ from those taken from patients under general narcosis (Brody, 1960 ).

Patients selected were caucasian females in the fourth and fifth decades and in good state of nutrition.

For studies involving the heloma durum itself, conjoined and elliptical incisions of 1.5 x .8 cm dimensions were made from the longitudinal axis of the digit. The tissues thus isolated were sharply and quickly dissected *in toto* and the lesions hemisected.

### Histology and Maceration Technique

The tissues were fixed in Bouin's and Zenker's fixatives for morphologic or histochemical study, but tissues destined for epidermal-dermal interface study were placed in aqueous 1 N sodium bromide solution and processed as reported earlier (Part I).

Heloma durum was excised from 10 patients. The specimen were identified by consecutive numbers. Normal interphalangeal skin (control tissue) was obtained from 8 patients with heloma durum on the lateral aspect of the digit but noncornified tissue available just dorsal and lateral to the lesion by making a narrow arc of conjoined and elliptical incisions on the longitudional axis of the toe measuring 1.5 x .4 cm. Excision of either helomatous or normal dorsal tissue was possible without adversely affecting the outcome of the surgery as long as the offending bone was eliminated thus providing control and hyperkeratotic tissue for study. Control tissues were identified consecutively by number in "N" series (for normal).

Staining: Hematoxylin and Eosin - Standard methods of staining were used for comparison of control and heloma durum interphalangeal skin (Pearse, 1961).

Heidenhain Iron Hematoxylin - Nuclear chromatin was demonstrated in control and hyperkeratotic tissue (heloma durum) by this procedure (Armed Forces Institute of Pathology, 1960).

Histochemical Analysis of Control and Hyperkeratotic Skin

Mucopolysaccharides - Periodic Acid - Schiff technique was employed for demonstration of mucopolysaccharides which stain purplish-red (Pearse, 1961).

Protein - The mercury-bromphenol blue method (Pearse, 1961) was used to demonstrate proteinaceous material.

Collagen - Mallory phosphotungstic acid procedure (Armed Forces

Institute of Pathology, 1960) was used for the demonstration of collagen and elastic fibers in the dermis.

DNA and RNA - Toluidine Blue O technique (Pearse, 1961) was employed to demonstrate DNA and RNA within cells.

DNA - Fuelgen reaction (Pearse, 1961) was used as a specific stain for DNA.

Measurement Techniques

Measurements of thickness of stratum corneum, stratum Malpighii and total epidermis as well as rete peg length were measured as described in Part I.

Cell circumferences were delineated with ink on photomicrographs and measured with a plenimeter, an engineering device moved over a small wheel which in turn is attached to a scale indicating distance travelled (Wetzlar, Germany). The device was calibrated against an enlarged photomicrograph of a stage micrometer. Only well formed cells of the stratum germinativum were selected for analysis. The mitotically active layer is cube shaped, but as the cells proliferate toward the free surface of skin, they increase in size and flatten out making their measurement less reliable (Pinkus, 1971).

These findings were subject to statistical analysis including determination of mean, standard deviation, variance and "t" testing for significant differences.

Electron Microscopy

The ultrastructure of hyperkeratinizing skin of heloma durum was studied in a lesion excised in toto from a male patient in the third decade of life and in good nutritional state.

This lesion was minced into 1 mm squares in cooled Dalton's fixative. Subsequently, a small refined dermatologic punch biopsy tool was developed at the University of Windsor Central Research Shop. The punch was made of hollow stainless steel tubing with an inside diameter of 0.4 cm which gives a tissue mass optimal for subsequent fixation and infiltration procedures. The biopsy tool was attached to a high speed hand drill (Mototool, Chicago) and a core of skin taken at right angles to the free surface of skin and immediately extruded from the punch tool by means of a metal plunger passed into the central hollow of the biopsy instrument.

Tissues were fixed in Dalton's fixative, dehydrated and embedded in an epon-araldite mixture (Kay, 1965).

The blocks were trimmed and then sectioned using glass knives prepared with an LKB Knife Maker Type 7801 A and a Reichert automatic ultramicrotome Model OmU2.

Sections were stained with uranyl acetate and lead citrate (Kay, 1965), and examined in the RCA EMU - 3H electron microscope.

Epidermal-dermal Interface

The interfaces of normal control interphalangeal skin and that of the hyperkeratinized heloma durum tissue were examined and compared following the methods outlined in Part I.

RESULTS

Morphology

The hyperkeratinized lesion, heloma durum, varies considerably in size and shape. Figs. 19 and 20 demonstrate variability both within the lesion (peripheral proximal portion and the thickest mid part) and the entire sample. It appears that morphological differences between heloma durum from the numerous patients studied are as varied as the morphological differences noted between the different anatomical sites examined in Part I of this thesis. The line drawings demonstrate greatly thickened stratum corneum. The stratum Malpighii developes rete pegs angled in all directions. Dermal papillae invade the stratum Malpighii and are often deflected by pressure forming the islands which have been included in the drawings.

Fig. 21 shows normal interphalangeal skin with regular interface characteristics and the usual 3 or 4 layers of spinous cells. Notice that the enlargement is x 250 allowing cytological evaluation of the strata. Fig. 22 demonstrates the heloma durum with broad coalesced rete pegs and the presence of dermal islands within the stratum Malpighii. The stratum corneum is greatly thickened. Indeed, all epidermal features are hypertrophied to the extent that the photomicrograph must be reduced to x 80 enlargement in order to demonstrate all epidermal features. Consequently, the three fold difference should be taken into account when comparing the normal and hyperkeratinized interphalangeal skin.

Measurement of Epidermal Features

Thickness measurements of normal interphalangeal skin and 10 cases

VARIATION IN EPIDERMAL COMPONENTS AMONG TEN CASES OF HUMAN HELOMA DURUM

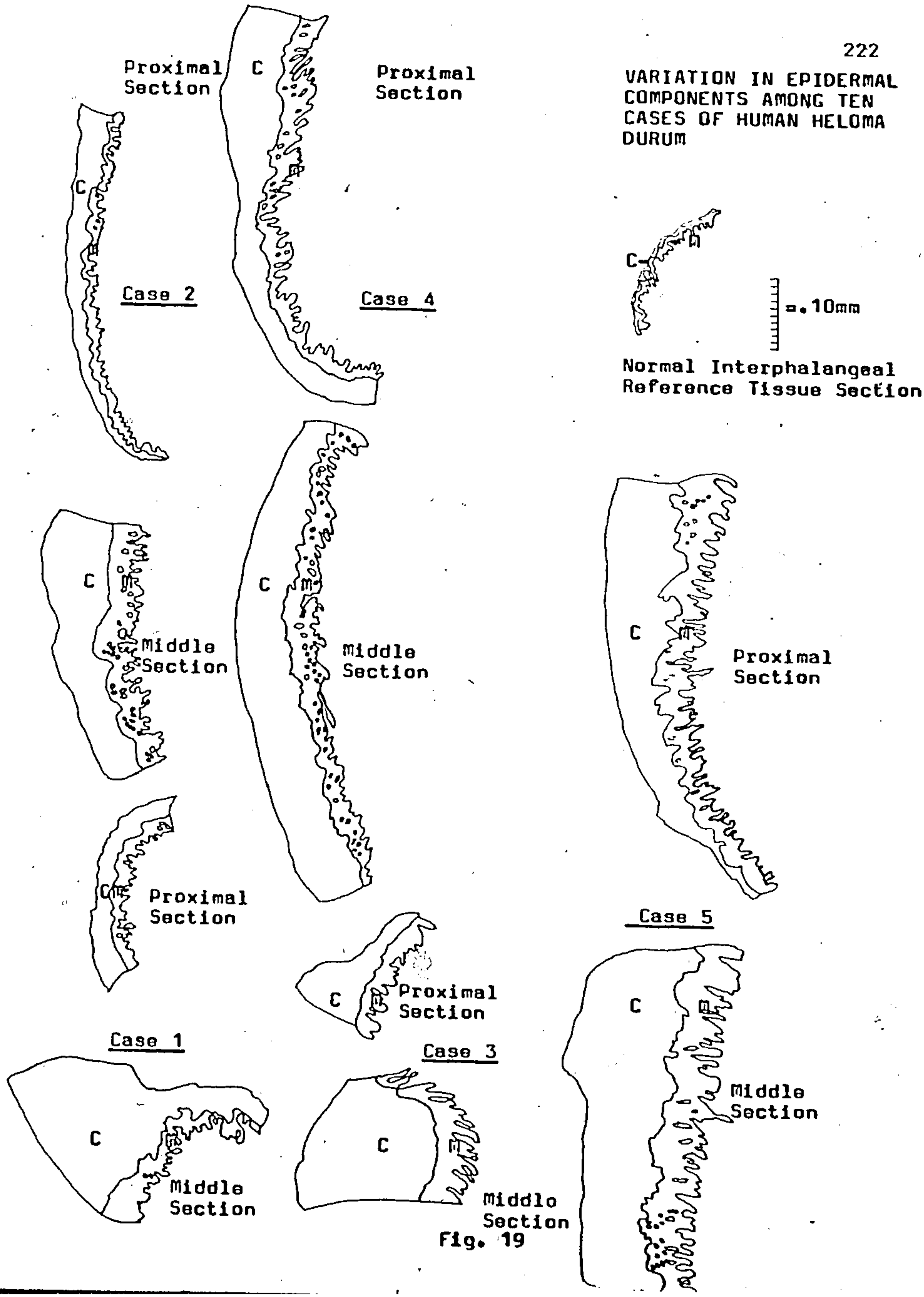
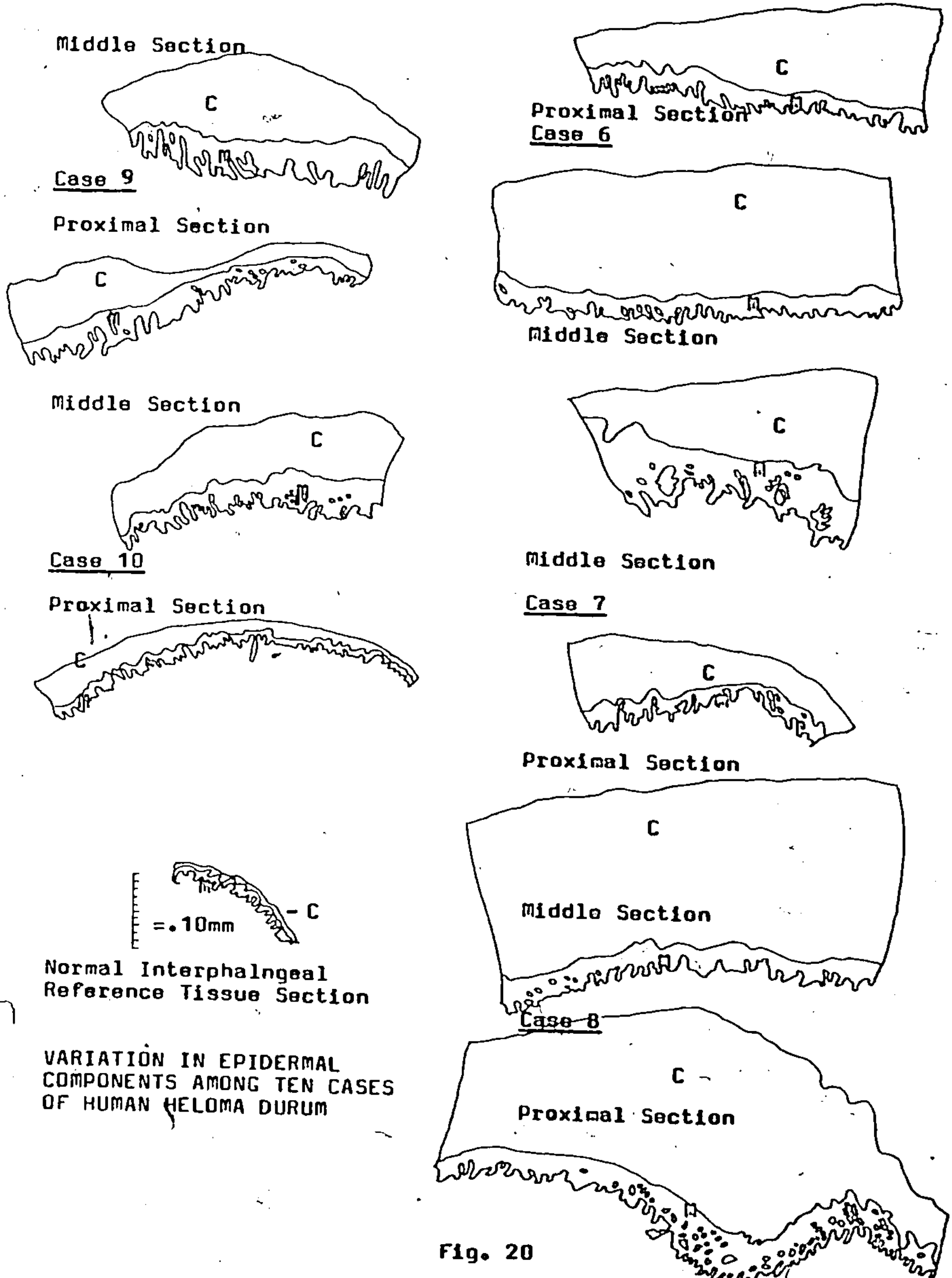



Fig. 19




VARIATION IN EPIDERMAL
COMPONENTS AMONG TEN CASES
OF HUMAN HELOMA DURUM

Fig. 20

Figure 21. Normal interphalangeal skin with reduced stratum corneum, little or no parakeratosis, much reduced rete ridging, the usual 4 or 5 layers of stratum spinosum and 1 or 2 layers of stratum granulosum. H and E X 250

Figure 22. Central cross section of the lesion, heloma durum showing hypertrophy of stratum cornoum acanthosis of stratum malpighii, increased density of stratum granulosum and elongation with flattoning of rete malpighii and dermal islands. Hand E X 80

Table XI

| Portion of Epidermis Under Study | Total Epidermis | Stratum Corneum | Stratum Malpighii | Number of Papillae | Length of Papillae |
|---|---|---|---|---|---|
| NORMAL INTER-PHALANGEAL REFERENCE $\bar{X}$ | .126mm($\pm$.008) | (57% total) .076mm ($\pm$.009) | (43% total) .050mm ($\pm$.003) | 11.62 ($\pm$42) | .061 mm($\pm$.005) |
| $S^2$ | .00137 | .00157 | .00016 | 1.410 | .00018 |
| S | .037 | .0386 | .0125 | 1.188 | .0136 |
| HELOMA DURUM MEAN OF TEN CASES $\bar{X}$ | 1.831mm($\pm$.19) | (83% total) 1.513mm ($\pm$.17) | (17% total) .370mm($\pm$.03) | 9.50 ($\pm$.37) | .205mm($\pm$.01) |
| $S^2$ | .3756 | .3067 | .0096 | 1.3889 | .00145 |
| S | .6128 | .5538 | .0979 | 1.1785 | .0381 |

Comparison of Mean Values of Epidermal Components in Heloma Durum and Normal Interphalangeal Reference Tissue of heloma durum are found in Appendix C and D. The results are statistically summarized in table X. In heloma durum, the total epidermal thickness is increased 15 fold with respect to values observed for normal control interphalangeal skin. The stratum Malpighii increases by 7 fold. Despite the acanthosis of the stratum Malpighii, the stratum corneum predominates in forming 83% of the total epidermis. The length of the rete pegs increases by 3 fold in heloma durum. The number of rete pegs decreases because of the coalescence of the structures.

Histochemical Studies on Normal Interphalangeal Skin and Hyperkeratinized Epidermis of Heloma Durum

For the most part, only subtle changes could be observed in histochemical tests for comparison of the control and hyperkeratinized skin. Cell replication and biosynthetic activity were tested for by toluidine blue-O (DNA and RNA) and Fuelgen (DNA) methods. In control interphalangeal epidermis, biosynthetic and cell replicative activity was uniformly indicated along the basal cell layer of the stratum germinativum. In hyperkeratinized heloma durum replicative and biosynthetic activity was especially marked at the epidermal juncture with the crown of the dermal papillae. The crowding of these basal cells of the stratum germinativum resulting from increased replicative activity was in association with large numbers of fibroblasts in the dermis just below. The Heidenhain iron hematoxylin stain for nuclear chromatin demonstrated that the long axis of the fibroblasts tended to orient at right angles to the free surface of skin in the heavily keratinized tissue of heloma durum, and that cells of the stratum basale crowded upward from the crown region of the dermal papillae. However, the nuclei were pyknotic and did not stain for DNA above the stratum germinativum.

Collagen (demonstrated by Mallory's phosphotungstic acid stain) is markedly increased and the fibers often are degraded as indicated by the increase of yellow staining material in the dermis of heloma durum.

PAS positive substances were demonstrated in increased amounts in heloma durum along the basement membrane and in the cell boundaries of the stratum corneum.

Proteinaceous compounds are homogeneous in the stratum corneum of control tissue, but in heloma durum, a wide variation of colorations indicating differing end products of protein synthesis during hyperkeratinization were observed (Fig. 23).

Parakeratosis is noted in hyperkeratotic skin (Pinkus and Mehregan, 1969) and it involved not only protein content of the stratum corneum, but the rapid proliferation of cells upward from the lower layers of epidermis in such a way that pyknotic nuclei may be observed. Figs. 24 and 25 show this streaming phenomenon at epidermal levels close to the stratum granulosum and proliferating outward toward the free surface of the skin almost to the point of desquamation of the stratum corneum.

Epidermal-dermal Interface in Heloma Durum and Control Interphalangeal Skin

The dermal portion of the epidermal-dermal interface from normal interphalangeal skin demonstrates papillae which are regularly spaced and more or less equal in height (Fig. 26). Similarly, the epidermal portion shows rete ridges interconnected in an orderly fashion to receive the

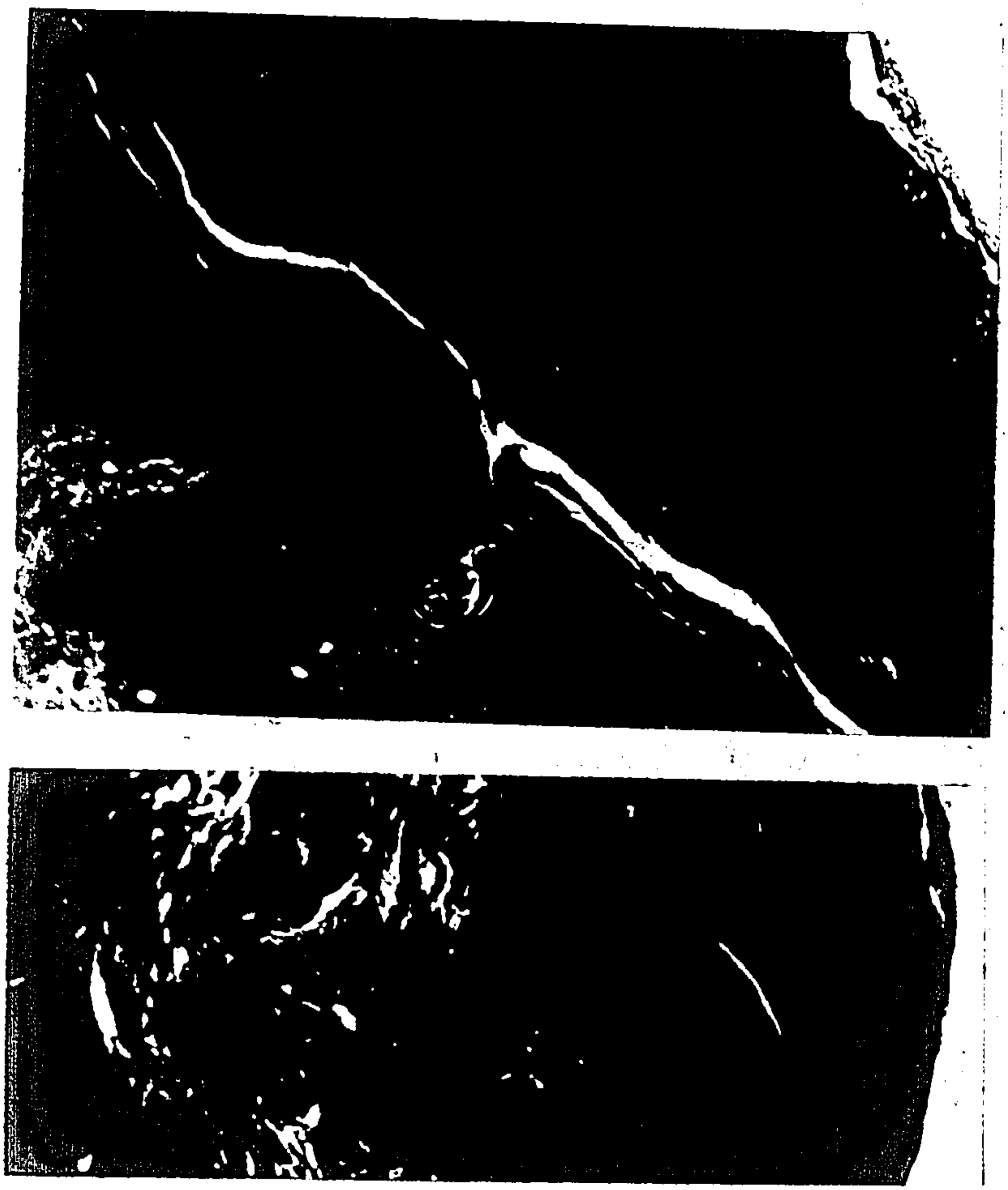


Figure 23. Top illustration demonstrates patchy parakeratosis of stratum corneum typical of hyperkeratinized skin as found in heloma durum. Lower picture demonstrates the more homogeneous stratum corneum of normal interphalangeal skin. Mercury bromphenol blue stain, X 80

Figure 24. Stratum granulosum in the lesion, heloma durum showing increased keratohyaline granules with cells from the granular layer erupting into the stratum corneum with pyknotic nuclei being displaced peripherally. H and E X 250

Figure 25. The stratum corneum in the lesion, heloma durum, and example of extreme hyperkeratinization showing numerous pyknotic nuclei being displaced peripherally within the horney layer. H and E X 250

regularly placed dermal papillae.

Dermal papillae of heloma durum show considerable hypertrophy, and often several seem to coalesce leaving foot-like projections distally. Papillae orient in several directions, as opposed to smaller and more regularly structured papillae in control tissue. The epidermal part complementary to the dermal portion indicates a widening of the rete ridges receiving the much hypertrophied and variably shaped dermal papillae. A bizarre disorientation of the epidermal ridges is apparent.

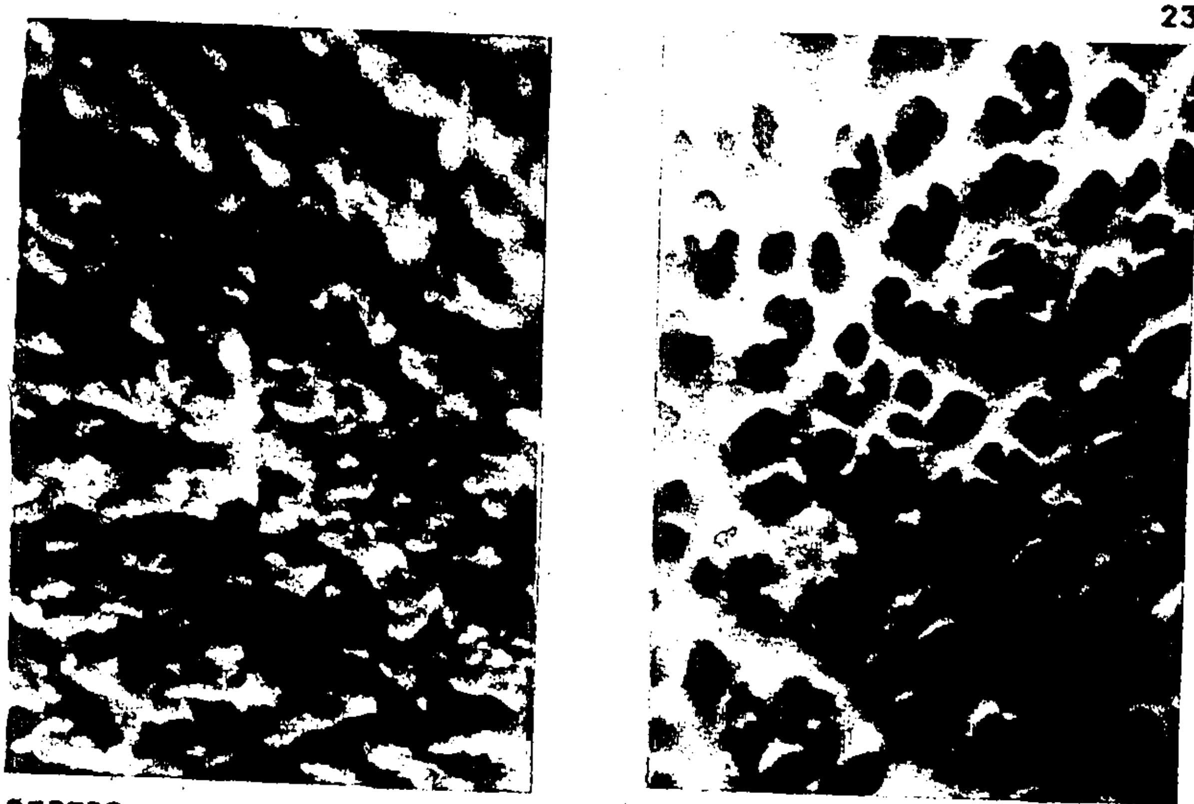
Electron Microscopy

Electron micrographs of heloma durum tissue demonstrated actively synthesizing fibroblasts with densely packed collagen in the adjacent ground substance. Stratum basale, stratum spinosum and stratum granulosum cells showed qualitative similarity to cells from control tissue. Quantitative analysis of ultrastructural similarity or dissimilarity must await more thorough study.

Cell Circumference Measurements of Control and Heloma Durum Interphalangeal Skin

Striking alterations in morphology of the stratum Malpighii and its rete ridging as well as marked increase in thickness and mass of the stratum corneum have been noted in heloma durum when compared with control interphalangeal skin (Appendix C and D).

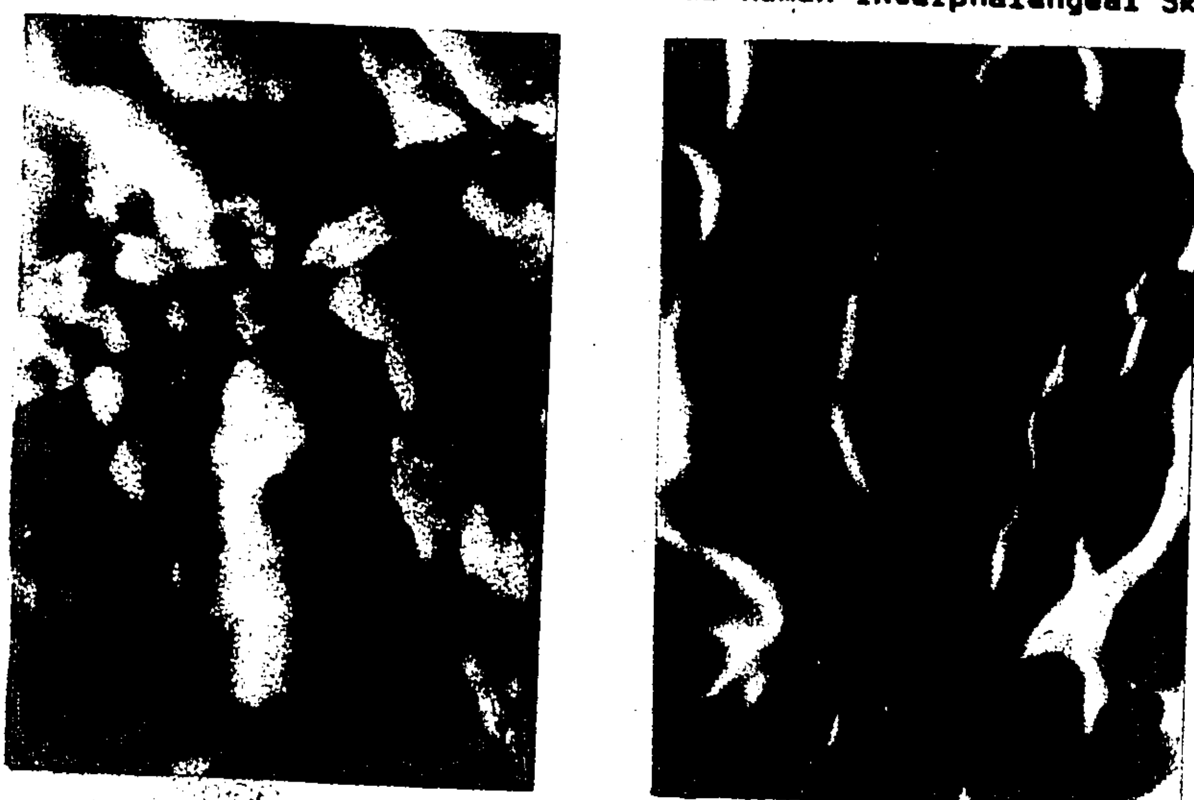
However, noticeable changes at the cellular level were not readily detected when histochemical and electron microscopic studies were made. Measurements of cell circumference in control and heloma durum interphalangeal skin from the mitotically active stratum basale did not differ



DERMIS

EPIDERMIS

Epidermal-Dermal Interface of Normal Human Interphalangeal Skin



DERMIS

EPIDERMIS

Epidermal-Dermal Interface of Human Heloma Durum

(X 60)

significantly from one another, nor did measurements of the relative height of the cells. It may be inferred, then, that striking alterations in morphology and thickness of epidermal strata is accomplished without altering cellular dimensions and without crucial biochemical changes.

Cell measurements and their statistical evaluations are summarized in Table XII.

| Stratum Basale Cell Height | $\bar{X}$ * | $S^2$ | S | N |
|---|---|---|---|---|
| Normal Control Interphalangeal Epidermis | .014mm | 5.52 | 2.35 | 4 |
| Heloma Durum Interphalangeal Epidermis | .015mm | 4.04 | 2.01 | 27 |

| Stratum Basale Cell Circumference | | | | |
|---|---|---|---|---|
| Normal Control Interphalangeal Epidermis | .035 | .000025 | .00499 | 7 |
| Heloma Durum Interphalangeal Epidermis | .036 | .000078 | .00846 | 24 |

*Significant variation between control interphalangeal epidermis and that of heloma durum was determined by "t" testing of the data. No significant difference between the two variables was found:

Stratum Basale Cell Height "t" = .649, p = < .5 (not significant)

Stratum Basale Cell Circumference

"t" = .2778, p = < .9 (not significant)

Normal Control Interphalangeal Epidermis and Heloma Durum Compared for Cell Height and Circumference

Table XII

## DISCUSSION AND CONCLUSIONS

### Alterations in Thickness of Epidermal Strata in Heloma Durum

The range of total epidermal thickness of interphalangeal skin of the digits of living subjects (a total of eight cases were analysed) ranged from .09 to .20 mm with a mean thickness for all specimens examined of .13 mm. The stratum corneum ranged in thickness from .04 to .15 mm a mean of .08 mm. The length of rete ridges ranged from .04 to .08 mm and a mean of .06 mm.

For heloma durum (a total of ten cases were examined), total epidermal thickness ranged from 1.12 to 2.85 mm with the mean of 1.83 mm. The stratum corneum ranged from .88 mm to 2.40 mm with the mean of 1.51. The length of rete ridges varies from .14 to .27 mm and a mean .21 mm.

If normal skin sites as revealed in the present study are taken into account, total epidermal thickness may be as thin as .02 mm (site 17, the penile shaft, case 1) and as thick as .85 mm (site 30, the plantar heel, case 6) and the rete ridge length demonstrates a maximum length of .30 mm in the plantar heel (site 30).

Due to the extreme alteration of total epidermal thickness, principally due to thickening of the stratum corneum with a parallel lengthening of rete ridges, it may be said that heloma durum provides a unique natural situation demonstrating modulation of the epidermal features. Essentially similar dermal inductive competence exists at the interphalangeal joint when unaltered by heloma durum. When mechanical irritation from outside is applied to the skin, total epidermal thickness increases fifteen fold and the stratum corneum assumes 83% of the total epidermal thickness whereas in the control suprapapillary stratum Malpighii and stratum corneum are about equally divided. The length of rete ridges increases over three fold from averages of .06 mm to an .21 mm equalling the mean for the length of rete ridges of the heel where they are more pronounced than any of the fifty normal sites examined.

If the external irritation is removed from the digits as may occur in prolonged bed rest or by the surgical removal of the underlying head of the phalangeal bone, the thickened stratum corneum will return to normal thickness and the skin of the digit appears flexible. This modulation provides further credence to the notion that epidermal morphology is at least partly due to mechanical activity demanded of the skin.

These considerable changes of epidermal features do not appear to be the result of obvious ultrastructural or histochemical alterations within the limits of the available methodology.

Ultrastructure of Hyperkeratinized Interphalangeal Skin

Electron microscopic analysis of skin in normal interphalangeal skin and that found in the hyperkeratinizing situation, exemplified by heloma durum, revealed no obvious ultrastructural changes. It is, however, possible that sutble changes do occur, particularly with respect to the lamellar granules (Odland bodies) which contribute mucopolysaccharides to the intercellular boundaries, since histochemical tests show an increased PAS reaction accompanied by broadening of the space between cells in the hyperkeratinizing situation. Greater production of mucopolysaccharides for distribution in the intercellular spaces could account for tighter adherence of the cells with the result of least desquamation, and in this way conserving cells in the stratum corneum and adding to the thickness consistently seen in both weight bearing tissues and most especially in heloma durum.

Histochemical Analysis of Hyperkeratinized Interphalangeal Skin

Histochemical analysis of the stratum germinativum and stratum spinosum demonstrated little if any alteration in the cytochemical make up of the individual cells. Several nuclear and DNA staining methods demonstrated an increase in the number of cells committed to mitosis at the crowns of the dermal papillae. These were in close association with fibroblasts which were likewise increased in numbers in the hyperkeratinizing situation. Their position was altered to one orienting them at right angles to the free surface of skin. An increased number of cells can be observed proliferating upward in a stream toward the free surface of the skin. Skin involved in formation of heloma durum demonstrated a marked increase in collagen in the dermis, but experimental evidence cited earlier indicates that collagen has no competence to initiate mitosis of basal cells. This function has been attributed to an undefined "diffusable dermal influencing factor." Since extracts of tendon sheaths and connective tissue (both formed by fibroblast activity) as well as pulverized fibroblasts in extract form can act as the "dermal influencing factor" it seems reasonable to assume that the fibroblast is elaborating substances which induce the increased mitosis observed from their close association with basal cells at the crowns of dermal papillae seen in heloma durum.

Parakeratosis with numerous pyknotic nuclei characterize the stratum corneum in both heloma durum and heavily cornified weight bearing sites. This is due to the apparent acceleration in cell transit time discussed in Part I and the inability of the stratum granulosum to complete protein synthesis. Dehydration within the thickened stratum corneum is doubtless another factor in parakeratosis of the stratum corneum in grealty thickened normal locations as well as in heloma durum.

Tissue Dynamics in Hyperkeratinization

It has been observed that vasodilitation precedes the formation of heloma durum (Bonavilla, 1968) which is accompanied by an elaboration of histamine within the dermis. The increase in fibroblast numbers in the crown of the dermal papillae is doubtless an inflammatory response with the result that basal cell mitosis is stimulated much as would occur in wounding of the epidermal tissues (Ross, 1969). The increased mitotic activity would have a double effect. First, the increased number of cells would produce crowding along the basement membrane which in turn would increase the length of rete ridges. Some basal cells would be committed to keratinization and would proliferate upward with the result that the suprapapillary stratum Malpighii would also thicken to the point of acanthosis. The increased number of cells would in turn produce a thicker stratum corneum. In hyperkeratinization, the present study shows, however, that the percent of stratum corneum in terms of thickness of the layer is far more increased as compared to the Malpighiian layer.

The role of the cell cycle and epidermal transit time has not been resolved by this study. The morphological events suggest an acceleration in these phenomena. Autoradiographic studies would resolve this problem. However, the medical-legal obstacles make such attempts difficult at best.

Modulation of thickness of stratum corneum and suprapapillary stratum Malpighii and the length of rete ridges arise from changes in the balance of the epidermal chalone, which inhibits basal cell mitosis and the "diffusable dermal influencing factor" (Cohen, 1969) which in turn are responsive to factors discussed above. In general, the increased length and thickness of dermal papillae of the epidermal dermal interface of heloma durum parallel the increased thickness of suprapapillary stratum Malpighii and stratum corneum. Since the sizes of cells do not increase in accretionary growth (Part II, Table XI) the increases in demand for protein synthesis during keratinization in the Malpighiian layer are met by increasing the number of cells committed to this process.

Epidermal-Dermal Interface of Heloma Durum

Dermal papillae increase in length and often coalesce forming greatly thickened papillae. Pressure often deflects the papillae in various directions so that in cross section, islands of dermis appear within the stratum Malpighii.

Rete ridges form more thickly and the crater-like depressions for the reception of the much increased dermal papillae are much broader and deeper. These structures in heloma durum are three and four fold greater than those found in normal interphalangeal skin and where the structures are much more regularly positioned.

Aside from their morphological interest, they suggest an increase in cellular activity as the cells aggregate to form the whole.

SUMMARY

Two basic methods were employed in the evaluation of human skin in order that the variations with respect to thickness and/or area of epidermal features of stratum corneum and stratum Malpighii as well as the morphologic and dimensional difference of rete ridging, could be inter-related with the mechanical functioning of skin isolated from many points throughout the body. Measurements from cross section preparation were first investigated for all of the epidermal features of interest. Secondly, three dimensional representations of epidermal-dermal interface following maceration technique of all sites examined were prepared and presented in atlas form as microphotographs. Supplementary studies involving histochemistry and electron microscopy of normal and hyper-keratinized skin were also made.

The investigation was approached in two ways. Part I reports measurements of epidermal features from fifty different functional sites from widely spaced regions of the body. Seven human cadavers were allocated for these studies. A narrower parameter of study involving a single finger is included to develop the principle that morphological variation can exist as more discrete functional changes occur. Epidermal-dermal interface preparations accompany the measured date.

Part II employs the heloma durum (human corn) as experiment of nature in which normally thin skin from the interphalangeal skin of the digits of man is radically modulated as the result of external pressure, to produce hypertrophy of all epidermal features. The extreme modulation

seemed a reasonable basis for comparisons of normally keratinized skin and the hyperkeratinized situation found in heloma durum using histochemistry and electron microscopy.

Explanations for the biological basis for these modulations are postulated from the current literature.

PART I

1. Human epidermis is distinctive to various regions of the body. The strata are biologically inter-related as they are involved in the differentiating process of keratinization. Measurements of these features are more meaningful for this reason rather than gross examination of the total skin (epidermis and dermis). The following variables examined are:

a. The thickness of the stratum corneum: the end product of keratinization. This layer is readily delineated from the cell layers below due to the absence of nuclei. Additional evaluation can be provided as to relative area of the strata by weight comparisons. The stratum corneum is responsive to weight bearing and to a lesser degree flexion of a body member by increasing its thickness. More passive skin surfaces remain at a constant thickness with stratum corneum and stratum Malpighii about evenly divided.

b. The thickness of the suprapapillary stratum Malpighii: The cellular layer involved in differentiating in protein synthesis in orderly sequence beginning with the stratum basale of the stratum germinativum and continuing toward the free surface of the skin through stratum spinosum and stratum granulosum at which point cornification is completed.

The thickness of stratum Malpighii increases with demand also, but not nearly to the extent that the stratum corneum does.

c. Length of the rete ridges: Increases in length and/or number results in an increase in surface area exposed to the dermis and this parameter is directly proportional to keratinization activity. Again, its greatest expression in length is noted in weight bearing sites and to a lesser degree for skin involved in the flexion and extension.

When analysed statistically, positive correlations between variables can be shown.

2. An atlas of human skin has been prepared providing comparisons of the interface structures both in terms of size and number and demonstrating the highly variable nature of the epidermal-dermal interface characterizing the 50 sites all of which have a degree of functional difference.

3. The Horstmann view relating epidermal-dermal interface has been expanded upon. Dermal papillae do not occur in direct relationship to hair follicles, but as they escape the powerful over-riding inductive effects of the hair follicle. When hair follicles are absent, inductive forces of the dermis can be directed toward the development of a more expressive epidermal-dermal interface with rete ridges and dermal papillae occurring in greater number and length. The interface of epidermis and dermis reaches its highest development where weight bearing is the principle function of the body part.

4. An attempt has been made to organize the skin into functional categories. Passive skin types such as those involved in coverings, rounded and flat, special types as penis and eyelid and anchoring sites showed the least expression of thickness of stratum corneum, supra-

papillary stratum Malpighii and the number and/or length of rete ridges. As more work is demanded of the skin, all parameters tend to increase in direct proportion.

5. It has long been known that alterations in the function of muscle and bone result in changes in the morphology of these tissues. On the basis of the observations made in this thesis, it is reasonable to state that the function to which the skin is put is a determining factor in the morphology of the epidermis and its component features. Mechanical action of the skin operates not at the exclusion of genetic influences, humoral effects or hormonal levels, age, or nutrition, but rather in addition to these factors, thus contributing to the complexity of the biology of the skin.

## PART II

Heloma durum (common human corn) presents an excellent example in support of the premise that altered function (in this case, a marked increase in external irritation or pressure against the skin of the interphalangeal joints of the digits of man) alters the morphology of the several epidermal features studied throughout this thesis.

a. The thickness of the stratum corneum increases proportionally to a degree observed no where else in the skin of man.

b. The stratum Malpighii undergoes marked acanthosis (an increase in thickness of the stratum due to a greater number of spinous cells) in response to pressure.

c. The number and length of rete ridges and interdigitating dermal papillae are grossly increased,

1. Electron microscopy: Superficial examination of cells involved in the hyperkeratinization process in heloma durum and in normal interphalangeal skin show qualitative similarities of all organelles. Quantitative analysis must await a more thorough study.

2. Cell measurement: Although all epidermal features are greatly expanded, cell dimensions remain constant in normal interphalangeal skin and that involved in hyperkeratinization (heloma durum). The alterations of morphology, then, are the result of accretionary growth.

3. Histochemical studies of normal interphalangeal skin and the hyperkeratinized epidermis of heloma durum: Little alteration in histochemistry was detectable. There was a noticeable increase in PAS positive material at the basement membrane (inductive dermal influence has been shown to be a mucopolysaccharide) and in the cell boundaries of the stratum corneum (ultrastructural studies suggest that the lamellar granule contributes a mucopolysaccharide to the intercellular boundaries).

Hyperkeratinized skin as noted in the heloma durum presents marked parakeratosis with evidence that proteinaceous compounds are incompletely developed in passage through the stratum granulosum. Pyknotic nuclei pass rapidly from the stratum granulosum and are observable in large numbers to the level of the free surface of the skin involved in heloma durum. Parakeratosis is also a feature of weight bearing sites as they are found from place to place in the human body.

GLOSSARY

## Terminology as Used in this Study

Human integument is comprised of an underlying dermis and an overlying conrifying layer, the epidermis. This study involves alterations in the morphology of epidermis and the character of the epidermal-dermal interface, but the functional relationship of the dermis demands it be considered as well.

### THE DERMIS

The dermis is of mesodermal origin, a portion of which is from the somites (Pinkus, 1971). The predominant cell is the fibroblast found within the ground substance together with fibers of several types (Ham, 1969).

The fibroblast is characterized by a basophilic cytoplasm and a nucleus which often is ovoid or elongate. Cytoplasmic processes extend noticeably from the cell body. Fibroblasts are active in synthesis of most dermal structures - ground substance, collagenic, elastic and reticular fibers.

Ground substance is an amorphous mucopolysaccharide in which the cellular and formed elements of dermis are found.

Elastic fibers seen as wavy bands of collagen, a protein formed by the hydroxylation of proline and lysine.

Reticular fibers are networks of collagenic fibers seen in loose connective tissue of the dermis where epidermis and basement membrane are adjacent.

### BASEMENT MEMBRANE

The basement membrane seems to be a nonliving, permeable layer formed probably by both the epidermis above and the dermis below. The epidermis contributes amorphous carbohydrate macromolecules which provide the PAS-positive reaction. The dermis contributes the reticular fibers (Midgely and Pierce, 1963; Zelickson, 1967)

THE EPIDERMIS

The epidermis is derived from primary ectoderms except for the melanocytes which are migratory and are neuro-ectodermal in origin (Balinski, 1970). It is composed of vertically arranged clones of epidermal cells or keratinocytes (Pinkus, 1958) in five layers. The strata become progressively flattened and broad as they push upward toward the free surface of skin. Epidermis and dermis separated by the basement membrane between collectively make up what is termed the total skin.

Rete ridges or interpapillary pegs project into the dermis away from the free surface of the skin and are composed of cells of the stratum germinativum and stratum spinosum. They interdigitate with and surround the dermal papillae. Dermal papillae are cone shaped projections of the dermis consisting of thin collagen fibers and bundles in the ground substance matrix (Pinkus, 1971). Often the projections occur as ridges since they occur consistently in successive cross sections (Ham, 1969).

Stratum germinativum is the innermost of the five layers of epidermis and is the only stratum mitotically active (Pinkus, 1958). Nuclei are large and the cell has a mean diameter of 6 $\mu$. Progeny of the germinativum are pushed up as stratum spinosum.

Stratum spinosum has cells which are irregular and polyhedral in shape and are characterized by numerous attachment sites or desmosomes. Several layers are present with diameters varying from 10 to 15 $\mu$. Acanthosis designates a thickening resulting from an increased number of cells in the stratum spinosum (hyperplasia).

Stratum granulosum is named on the basis of granular appearance when stained with hematoxylin indicating the presence of keratohyalin granules. The cells have a diamond shape with the nuclei showing degeneration. Cell diameters are on the order of 30 $\mu$.

Stratum lucidum, if visible, is a thin homogeneous zone above the stratum granulosum and below the stratum corneum.

Stratum corneum is the outermost horny layer of skin rich in keratin. The stratum is composed of a variable number of cells without nuclei or only remnants thereof. Cell diameters are on the order of 30 $\mu$ (Pinkus, 1958).

Suprapapillary stratum Malpighii is the nucleated cell mass above an imaginary line drawn through the tips of the dermal papillae.

THE EPIDERMAL-DERMAL INTERFACE

In order to avoid confusion in the interpretation of this study when the interface area formed by the juncture of dermis with epidermis is mentioned, two entities should be recognized:

1. Epidermal-dermal Interface - This expression shall be restricted in this thesis to the three dimensional representation as revealed by incident light microscopy after the tissue was separated by maceration technique, fixed, dehydrated, cleared and treated by resin infiltration.

The lower (surface adjacent to the dermis) epidermis interface may be examined, or the dermis interface as it has been separated from the epidermis, can be studied. This is the only way to appreciate the hand in glove relationship of dermis with epidermis.

2. Sine Interface - The term sine interface has been coined for use in this thesis to differentiate it from the three dimensional preparation described above. When skin is sectioned and mounted on glass slides for examination by light microscopy, a two dimensional representation is obtained. The juncture of dermis with epidermis is seen as a continuous line, usually in the form of a sine wave or curve; for this reason the term was selected. It provided the means for measurement of the rete pegs and the counting of rete pegs.

APPENDIX A

# APPENDIX A

## EPIDERMAL-DERMAL INTERFACE PREPARATION

MACERATION:

24 hour immersion in aqueous 1 N sodium bromide

FIXATION:

12 hours immersion in 10% neutral formalin

DEHYDRATION AND CLEARING:

| | |
|---|---|
| 1 hour | 50% ethanol |
| 1 hour | 70% ethanol |
| 1 hour | 80% ethanol |
| 1 hour | 95% ethanol |
| 1 hour | absolute ethanol |
| 1 hour | absolute ethanol |
| 1 hour | absolute ethanol-xylene |
| 1 hour | xylene |
| 12 hours | 1% beeswax in turpentine |

AIR DRY, 3 DAYS

MOUNT, INTERFACE UP, ON GLASS SLIDES AFFIXING WITH "ELMER'S GLUE" (BORDEN CO.) STORE AWAY FROM DUST

APPENDIX B

LINEAR MEASUREMENT

| ANATOMIC LOCATION | CASE NO. 1 C | M | E | %C | %M | CASE NO. 2 C | M | E | %C | %M |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 scalp | .01 | .02 | .03 | 43 | 57 | .05 | .02 | .07 | 78 | 22 |
| 2 eyelid | .01 | .03 | .04 | 25 | 75 | .01 | .03 | .04 | 25 | 75 |
| 3 post.neck | .02 | .02 | .04 | 50 | 50 | .02 | .02 | .04 | 50 | 50 |
| 4 cheek | .02 | .03 | .05 | 40 | 60 | .01 | .03 | .04 | 25 | 75 |
| 5 chin | .01 | .02 | .03 | 33 | 67 | .02 | .03 | .05 | 40 | 60 |
| 6 ant.neck | | | | | | .03 | .03 | .06 | 50 | 50 |
| 7 chest,midline | .02 | .02 | .04 | 50 | 50 | .02 | .02 | .04 | 50 | 50 |
| 8 mid chest | .01 | .03 | .04 | 25 | 75 | .04 | .02 | .06 | 67 | 23 |
| 9 axillar arm | .05 | .03 | .08 | 63 | 37 | .08 | .02 | .10 | 80 | 20 |
| 10 linea alba | .02 | .02 | .04 | 50 | 50 | .02 | .02 | .04 | 50 | 50 |
| 11 groin | .03 | .03 | .06 | 50 | 50 | .03 | .03 | .06 | 50 | 50 |
| 12 mid line, back | .01 | .01 | .02 | 50 | 50 | | | | | |
| 13 mid line,back L | .01 | .03 | .04 | 25 | 75 | .02 | .01 | .03 | 67 | 33 |
| 14 buttox | .01 | .02 | .04 | 25 | 75 | .02 | .02 | .04 | 50 | 50 |
| 15 u.l. back | .01 | .01 | .02 | 50 | 50 | .01 | .01 | .02 | 50 | 50 |
| 16 gluteal fold | .01 | .01 | .02 | 50 | 50 | | | | | |
| 17 penile shaft | .01 | .01 | .02 | 50 | 50 | .03 | .03 | .06 | 50 | 50 |
| 18 mid lat. ear | .01 | .03 | .04 | 25 | 75 | .01 | .04 | .05 | 20 | 80 |
| 19 ear lobe | .01 | .02 | .03 | 33 | 67 | .01 | .02 | .03 | 33 | 67 |
| 20 inner elbow | .02 | .02 | .04 | 50 | 50 | .02 | .02 | .04 | 50 | 50 |
| 21 achilles tendon | | | | | | | | | | |
| 22 post.thigh | .03 | .02 | .05 | 60 | 40 | .02 | .01 | .03 | 66 | 34 |
| 23 popliteal space | .02 | .02 | .04 | 50 | 50 | .03 | .01 | .04 | 75 | 25 |
| 24 ant. thigh | .03 | .03 | .06 | 50 | 50 | .03 | .02 | .05 | 60 | 40 |
| 25 superior patella | .03 | .03 | .06 | 50 | 50 | .07 | .02 | .09 | 80 | 20 |

## LINEAR MEASUREMENT

| ANATOMIC LOCATION | CASE NO.3 C | M | E | %C | %M | CASE NO.4 C | M | E | %C | %M |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 scalp | .02 | .04 | .06 | 42 | 59 | .03 | .03 | .06 | 50 | 50 |
| 2 eyelid | .02 | .03 | .05 | 40 | 60 | .01 | .03 | .04 | 25 | 75 |
| 3 post.neck | .02 | .03 | .05 | 40 | 60 | .01 | .02 | .03 | 33 | 67 |
| 4 cheek | .01 | .03 | .04 | 25 | 75 | .02 | .02 | .04 | 50 | 50 |
| 5 chin | .03 | .04 | .07 | 43 | 57 | .03 | .01 | .04 | 75 | 25 |
| 6 ant.neck | .03 | .03 | .06 | 50 | 50 | .02 | .02 | .04 | 50 | 50 |
| 7 chest,mid line | .02 | .02 | .04 | 50 | 50 | .02 | .02 | .04 | 50 | 50 |
| 8 mid chest | .01 | .02 | .03 | 33 | 67 | .02 | .03 | .05 | 40 | 60 |
| 9 axillar area | .02 | .02 | .04 | 50 | 50 | .04 | .02 | .06 | 67 | 33 |
| 10 linea alba | .01 | .02 | .03 | 33 | 67 | .02 | .02 | .04 | 50 | 50 |
| 11 groin | .01 | .01 | .02 | 50 | 50 | .02 | .04 | .06 | 33 | 67 |
| 12 mid line, back | .02 | .02 | .04 | 50 | 50 | .01 | .02 | .03 | 33 | 67 |
| 13 mid line,back l | .02 | .02 | .04 | 50 | 50 | .02 | .02 | .04 | 50 | 50 |
| 14 buttock | .02 | .01 | .03 | 67 | 33 | .02 | .02 | .04 | 50 | 50 |
| 15 u.l. back | .01 | .03 | .04 | 25 | 75 | .02 | .02 | .04 | 50 | 50 |
| 16 gluteal fold | .02 | .02 | .04 | 50 | 50 | .02 | .01 | .03 | 70 | 30 |
| 17 penile shaft | .01 | .02 | .03 | 33 | 67 | .02 | .03 | .05 | 40 | 60 |
| 18 mid lat. ear | .01 | .02 | .03 | 33 | 67 | .01 | .03 | .04 | 25 | 75 |
| 19 ear lobe | .01 | .02 | .03 | 33 | 67 | .02 | .02 | .04 | 50 | 50 |
| 20 inner elbow | .02 | .02 | .04 | 50 | 50 | .03 | .04 | .07 | 40 | 60 |
| 21 achilles tendon | | | | | | .13 | .02 | .15 | 88 | 12 |
| 22 post.thigh | .02 | .03 | .05 | 40 | 60 | .03 | .03 | .06 | 50 | 50 |
| 23 popliteal space | .01 | .02 | .03 | 33 | 67 | .02 | .02 | .04 | 50 | 50 |
| 24 ant. thigh | .02 | .02 | .04 | 50 | 50 | | | | | |
| 25 superior patella | .05 | .03 | .08 | 60 | 40 | .04 | .03 | .07 | 60 | 40 |

LINEAR MEASUREMENT

| ANATOMIC LOCATION | CASE NO. 5 C | M | E | %C | %M | CASE NO. 6 C | M | E | %C | %M |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 scalp | .02 | .03 | .05 | 45 | 55 | .03 | .03 | .06 | 50 | 50 |
| 2 eyelid | .01 | .03 | .04 | 25 | 75 | .01 | .04 | .05 | 20 | 80 |
| 3 post. neck | .02 | .02 | .04 | 50 | 50 | .02 | .04 | .06 | 33 | 67 |
| 4 cheek | .03 | .03 | .06 | 50 | 50 | .03 | .04 | .07 | 43 | 57 |
| 5 chin | .03 | .04 | .07 | 43 | 57 | .04 | .04 | .08 | 50 | 50 |
| 6 ant. neck | .06 | .04 | .10 | 60 | 40 | .03 | .02 | .05 | 60 | 40 |
| 7 chest, midline | .02 | .02 | .04 | 50 | 50 | .01 | .03 | .04 | 25 | 75 |
| 8 mid chest | .02 | .02 | .04 | 50 | 50 | .03 | .03 | .06 | 50 | 50 |
| 9 axillar arc | .04 | .04 | .08 | 50 | 50 | .06 | .02 | .08 | 75 | 25 |
| 10 linea alba | .02 | .05 | .07 | 30 | 70 | .02 | .04 | .06 | 33 | 67 |
| 11 groin | .02 | .04 | .06 | 33 | 67 | .02 | .02 | .04 | 50 | 50 |
| 12 mid line, back | .03 | .02 | .05 | 60 | 40 | | | | | |
| 13 mid line, back L | .02 | .02 | .04 | 50 | 50 | .03 | .04 | .07 | 40 | 60 |
| 14 buttock | .01 | .01 | .02 | 50 | 50 | .02 | .05 | .07 | 30 | 70 |
| 15 u.l. back | .02 | .02 | .04 | 50 | 50 | .05 | .03 | .08 | 60 | 40 |
| 16 gluteal fold | .02 | .02 | .04 | 50 | 50 | .02 | .03 | .05 | 40 | 60 |
| 17 penile shaft | .02 | .02 | .04 | 50 | 50 | .02 | .03 | .05 | 40 | 60 |
| 18 mid lat. ear | .08 | .04 | .12 | 66 | 34 | .07 | .07 | .14 | 50 | 50 |
| 19 ear lobe | .02 | .02 | .04 | 50 | 50 | .01 | .02 | .03 | 33 | 67 |
| 20 inner elbow | .04 | .03 | .07 | 60 | 40 | .05 | .06 | .11 | 45 | 55 |
| 21 achilles tendon | .10 | .15 | .25 | 40 | 60 | .23 | .10 | .33 | 70 | 30 |
| 22 post. thigh | .02 | .02 | .04 | 50 | 50 | .04 | .03 | .07 | 60 | 40 |
| 23 popliteal space | .02 | .04 | .06 | 33 | 67 | .02 | .04 | .06 | 33 | 67 |
| 24 ant. thigh | | | | | | .04 | .05 | .09 | 45 | 55 |
| 25 superior patella | .04 | .04 | .08 | 50 | 50 | .07 | .05 | .12 | 58 | 42 |

# LINEAR MEASUREMENT

| ANATOMIC LOCATION | CASE NO. 1 C | m | E | %C | %m | CASE NO. 2 C | m | E | %C | %m |
|---|---|---|---|---|---|---|---|---|---|---|
| 26 lat. thigh | .02 | .02 | .04 | 50 | 50 | .02 | .01 | .03 | 67 | 33 |
| 27 med. thigh | .02 | .03 | .05 | 40 | 60 | .03 | .01 | .04 | 75 | 25 |
| 28 tibial crest | .01 | .02 | .03 | 33 | 67 | .02 | .01 | .03 | 67 | 33 |
| 29 post. leg | .03 | .02 | .05 | 60 | 40 | .03 | .02 | .05 | 60 | 40 |
| 30 plantar heel | .43 | .07 | .50 | 86 | 14 | .53 | .05 | .58 | 91 | 9 |
| 31 malleolus | .02 | .05 | .07 | 30 | 70 | .04 | .03 | .07 | 57 | 43 |
| 32 infra malleolus | .03 | .04 | .07 | 40 | 60 | .09 | .04 | .13 | 70 | 30 |
| 33 mid p.arch | .09 | .05 | .14 | 65 | 35 | .40 | .03 | .43 | 93 | 7 |
| 34 p. met head I | .11 | .04 | .15 | 73 | 27 | .42 | .04 | .46 | 91 | 9 |
| 35 oe fold | .11 | .05 | .16 | 70 | 30 | .15 | .03 | .18 | 83 | 17 |
| 36 J. great toe | .05 | .05 | .10 | 50 | 50 | .05 | .03 | .08 | 63 | 37 |
| 37 infra patella | .03 | .02 | .05 | 60 | 40 | .03 | .02 | .05 | 60 | 40 |
| 38 mid ankle | .03 | .03 | .06 | 50 | 50 | .05 | .05 | .10 | 50 | 50 |
| 39 d. arch | .04 | .02 | .06 | 66 | 34 | .05 | .02 | .07 | 70 | 30 |
| 40 supra-deltoid | .03 | .03 | .06 | 50 | 50 | .02 | .02 | .04 | 50 | 50 |
| 41 inner arm | .04 | .03 | .07 | 60 | 40 | .04 | .02 | .06 | 67 | 33 |
| 42 elbow | .03 | .04 | .07 | 43 | 57 | .06 | .04 | .10 | 60 | 40 |
| 43 wrist | .06 | .05 | .11 | 55 | 45 | .18 | .03 | .21 | 85 | 15 |
| 44 dorsal hand | .03 | .06 | .09 | 35 | 65 | .07 | .03 | .10 | 70 | 30 |
| 45 volar hand | .10 | .05 | .15 | 67 | 33 | .26 | .10 | .36 | 70 | 30 |
| 46 knuckle | .02 | .04 | .06 | 33 | 67 | .10 | .03 | .13 | 75 | 25 |
| 47 d.interphalangeal | .10 | .06 | .16 | 60 | 40 | .18 | .03 | .21 | 85 | 15 |
| 48 v.interphalangeal | .10 | .04 | .14 | 70 | 30 | .02 | .07 | .09 | 78 | 22 |
| 49 distil finger | .14 | .05 | .19 | 75 | 25 | .50 | .08 | .58 | 85 | 15 |
| 50 interdigital finger | .15 | .04 | .19 | 80 | 20 | .25 | .05 | .30 | 85 | 15 |

C=stratum corneum (mm)
M=stratum malpighii (mm)
E=total epidermal thickness (mm)
%C= percent of total epidermis represented by stratum corneum
%M= percent of total epidermis represented by stratum malpighii

# LINEAR MEASUREMENT

| ANATOMIC LOCATION | CASE NO. 3 C | M | E | %C | %M | CASE NO. 4 C | M | E | %C | %M |
|---|---|---|---|---|---|---|---|---|---|---|
| 26 lat. thigh | .03 | .03 | .06 | 50 | 50 | .01 | .03 | .04 | 25 | 75 |
| 27 med. thigh | .02 | .01 | .03 | 67 | 33 | .02 | .03 | .05 | 40 | 60 |
| 28 tibial crest | .02 | .02 | .04 | 50 | 50 | .02 | .02 | .04 | 50 | 50 |
| 29 post. leg | .03 | .03 | .06 | 50 | 50 | .01 | .02 | .03 | 33 | 67 |
| 30 plantar heel | .60 | .03 | .67 | 90 | 10 | .50 | .13 | .63 | 80 | 20 |
| 31 malleolus | .01 | .03 | .04 | 25 | 75 | .02 | .02 | .04 | 50 | 50 |
| 32 infra malleolus | .05 | .04 | .09 | 55 | 45 | .02 | .02 | .04 | 50 | 50 |
| 33 mid p.arch | .04 | .03 | .07 | 57 | 43 | .02 | .02 | .04 | 50 | 50 |
| 34 p. met head I. | .37 | .05 | .42 | 88 | 12 | .45 | .03 | .48 | 94 | 6 |
| 35 toe fold | .10 | .06 | .16 | 62 | 38 | .03 | .02 | .05 | 60 | 40 |
| 36 d. great toe | .02 | .02 | .04 | 50 | 50 | .07 | .02 | .09 | 78 | 22 |
| 37 infra patella | .02 | .02 | .04 | 50 | 50 | .08 | .03 | .11 | 73 | 27 |
| 38 mid ankle | .02 | .03 | .05 | 40 | 60 | .09 | .03 | .12 | 75 | 25 |
| 39 d. arch | .03 | .03 | .06 | 50 | 50 | .03 | .03 | .06 | 50 | 50 |
| 40 supra-deltoid | .02 | .03 | .05 | 40 | 60 | .02 | .01 | .03 | 67 | 33 |
| 41 inner arm | .02 | .02 | .04 | 50 | 50 | .02 | .02 | .04 | 50 | 50 |
| 42 elbow | .04 | .05 | .09 | 45 | 55 | .02 | .02 | .04 | 50 | 50 |
| 43 wrist | .15 | .03 | .18 | 83 | 17 | .05 | .05 | .10 | 50 | 50 |
| 44 dorsal hand | .03 | .04 | .07 | 40 | 60 | .05 | .02 | .07 | 70 | 30 |
| 45 volar hand | .17 | .05 | .22 | 75 | 25 | .02 | .02 | .04 | 50 | 50 |
| 46 knuckle | | | | | | .26 | .04 | .30 | 87 | 13 |
| 47 d.interphalangeal | .12 | .03 | .15 | 80 | 20 | .16 | .03 | .19 | 85 | 15 |
| 48 v.interphalangeal | .14 | .04 | .18 | 78 | 22 | .17 | .06 | .23 | 75 | 25 |
| 49 distil finger | .14 | .05 | .19 | 75 | 25 | .06 | .02 | .08 | 75 | 25 |
| 50 interdigital finger | .11 | .04 | .15 | 75 | 25 | .20 | .04 | .24 | 80 | 20 |

C=stratum corneum (mm)
M=stratum malpighii (mm)
E=total epidermal thickness (mm)
%C= percent of total epidermis represented by stratum corneum
%M= percent of total epidermis represented by stratum malpighii

## LINEAR MEASUREMENT

| ANATOMIC LOCATION | CASE NO. 5 C | M | E | %C | %M | CASE NO.6 C | M | E | %C | %M |
|---|---|---|---|---|---|---|---|---|---|---|
| 26 lat. thigh | .01 | .01 | .02 | 50 | 50 | .06 | .05 | .11 | 55 | 45 |
| 27 med. thigh | | | | | | .02 | .04 | .06 | 33 | 67 |
| 28 tibial crest | .02 | .02 | .04 | 50 | 50 | .05 | .03 | .08 | 60 | 40 |
| 29 post. leg | .03 | .02 | .05 | 60 | 40 | .03 | .05 | .08 | 40 | 60 |
| 30 plantar heel | .55 | .06 | .61 | 90 | 10 | .75 | .10 | .85 | 88 | 12 |
| 31 malleolus | .05 | .02 | .07 | 70 | 30 | .06 | .03 | .09 | 67 | 33 |
| 32 infra malleolus | .05 | .04 | .09 | 55 | 45 | .04 | .04 | .08 | 50 | 50 |
| 33 mid p.arch | | | | | | .11 | .05 | .16 | 70 | 30 |
| 34 p. met head I | .15 | .05 | .20 | 75 | 24 | .95 | .10 | 1.05 | 90 | 10 |
| 35 toe fold | .06 | .05 | .11 | 55 | 45 | .15 | .07 | .22 | 70 | 30 |
| 36 d. great toe | .02 | .02 | .04 | 50 | 50 | .15 | .05 | .20 | 75 | 25 |
| 37 infra patella | .02 | .02 | .04 | 50 | 50 | .09 | .06 | .15 | 60 | 40 |
| 38 mid ankle | .03 | .03 | .06 | 50 | 50 | | | | | |
| 39 d. arch | .03 | .03 | .06 | 50 | 50 | .08 | .05 | .13 | 60 | 40 |
| 40 supra-deltoid | .02 | .02 | .04 | 50 | 50 | .05 | .03 | .08 | 60 | 40 |
| 41 inner arm | .01 | .02 | .03 | 33 | 67 | .03 | .04 | .07 | 43 | 57 |
| 42 elbow | .12 | .03 | .15 | 80 | 20 | .07 | .06 | .13 | 53 | 47 |
| 43 wrist | .06 | .02 | .08 | 75 | 25 | .05 | .05 | .10 | 50 | 50 |
| 44 dorsal hand | .06 | .04 | .10 | 60 | 40 | .04 | .05 | .09 | 45 | 55 |
| 45 volar hand | .07 | .03 | .10 | 70 | 30 | .14 | .05 | .19 | 75 | 25 |
| 46 knuckle | .04 | .03 | .07 | 57 | 43 | .15 | .07 | .22 | 68 | 32 |
| 47 d.interphalangeal | .04 | .02 | .06 | 65 | 35 | .25 | .10 | .35 | 70 | 30 |
| 48 v.interphalangeal | .18 | .05 | .23 | 78 | 22 | .20 | .13 | .33 | 60 | 40 |
| 49 distil finger | .10 | .03 | .13 | 75 | 25 | .35 | .06 | .41 | 85 | 15 |
| 50 interdigital finger | .07 | .04 | .11 | 64 | 36 | .20 | .08 | .28 | 70 | 30 |

C stratum corneum (mm)
M stratum malpighii (mm)
E total epidermal thickness (mm)
%C percent of total epidermis represented by stratum corneum
%M percent of total epidermis represented by stratum malpighii

APPENDIX C

NORMAL RANGE ANALYSIS

| Identific-ation | Overall Depth | Stratum Corneum | | Suprapapillary Stratum malpighii | | Papillae Number/mm | Well Formed Papillae (Mean Length) |
|---|---|---|---|---|---|---|---|
| | mm | mm | % | mm | % | | mm |
| Normal Thin Skin | .04 | .02 | 50 | .02 | 50 | 11 | .06 |
| | .06 | .04 | 66 | .02 | 33 | | |
| | .04 | .02 | 50 | .02 | 50 | | |
| Normal Thick Skin | .30 | .18 | 60 | .12 | 40 | 11 | .65 |
| | .22 | .18 | 81 | .04 | 19 | | |
| | .20 | .14 | 70 | .06 | 30 | | |
| INTERPHALANGEAL NORMAL SKIN | | | | | | | |
| 2 | .16 | .08 | 50 | .08 | 50 | 12 | .05 |
| | .11 | .06 | 55 | .05 | 46 | | |
| | .10 | .05 | 50 | .05 | 50 | | |
| 5 | .11 | .06 | 55 | .05 | 45 | 10 | .07 |
| | .14 | .07 | 50 | .07 | 50 | | |
| | .10 | .04 | 40 | .06 | 60 | | |
| 10 | .09 | .05 | 55 | .04 | 45 | 13 | .04 |
| | .12 | .09 | 75 | .03 | 25 | | |
| | .12 | .08 | 67 | .04 | 23 | | |
| 12 | .11 | .08 | 73 | .03 | 27 | 12 | .06 |
| | .09 | .05 | 56 | .04 | 44 | | |
| 8n2(3) | .08 | .03 | 38 | .05 | 62 | 10 | .08 |
| | .10 | .04 | 40 | .06 | 60 | | |
| 8n2(4) | .20 | .15 | 75 | .05 | 25 | 13 | .07 |
| | .16 | .12 | 75 | .04 | 25 | | |
| 8n2(5) | .12 | .07 | 58 | .05 | 42 | 11 | .07 |
| | .10 | .04 | 40 | .06 | 60 | | |
| 8n2(6) | .18 | .13 | 73 | .05 | 27 | 12 | .05 |
| | .20 | .15 | 75 | .05 | 25 | | |

APPENDIX D

# INTEGRATED ANALYSIS OF PATHOLOGICAL TISSUE

| Identification | Overall depth Range in mm | Stratum Corneum Range thin mm (%) | Stratum Corneum thick mm (%) | Stratum Corneum Average thin (%) | Stratum Corneum Average thick (%) | Suprapapillary Stratum Malpighii Range thin mm (%) | Suprapapillary Stratum Malpighii thick mm (%) | Suprapapillary Stratum Malpighii Average thin (%) | Suprapapillary Stratum Malpighii Average thick (%) | Papillae Average Number/mm | Well Formed Papillae Average Length-mm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Case 1 | .25 - 2.68 | .20(80) | 2.28(85) | 72 | 82 | .05(20) | .42(27) | 28 | 18 | 10 | .21 |
| Case 2 | .28 - 1.15 | .17(57) | .88(79) | 69 | 72 | .09(18) | .25(22) | 31 | 29 | 12 | .14 |
| Case 3 | .24 - 2.16 | .08(33) | 1.85(86) | 77 | 88 | .06 (12) | .40(22) | 23 | 12 | 10 | .20 |
| Case 4 | .36 - 1.12 | .26(72) | .92(82) | 77 | 77 | .05(13) | .35(36) | 23 | 23 | 8 | .21 |
| Case 5 | .29 - 1.80 | .14(48) | 1.55(86) | 66 | 80 | .07(11) | .40(23) | 24 | 20 | 9 | .26 |
| Case 6 | .52 - 1.95 | .37(69) | 1.75(90) | 77 | 88 | .10(19) | .26(15) | 23 | 12 | 9 | .19 |
| Case 7 | .42 - 1.93 | .32(32) | 1.38(72) | 82 | 83 | .04(19) | .28(55) | 18 | 17 | 9 | .20 |
| Case 8 | .26 - 2.85 | .08(31) | 2.40(94) | 84 | 86 | .10(10) | .59(31) | 16 | 14 | 10 | .20 |
| Case 9 | .30 - 1.45 | .23(77) | 1.19(82) | 77 | 81 | .07(23) | .40(28) | 23 | 19 | 8 | .27 |
| Case 10 | .18 - 1.22 | .09(64) | .93(76) | 75 | 76 | .05(36) | .33(28) | 25 | 24 | 10 | .17 |

CASE 1

| Identification | Overall depth thin (mm) | Overall depth thick (mm) | Stratum Corneum thin (mm) | Stratum Corneum thick (mm) | Stratum Corneum thin (%) | Stratum Corneum thick (%) | Suprapapillary Stratum Malpighii thin (mm) | Suprapapillary Stratum Malpighii thick (mm) | Suprapapillary Stratum Malpighii thin (%) | Suprapapillary Stratum Malpighii thick (%) | Papillae (number/mm) | Well formed papillae (mean length) (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | .47 | .64 | .27 | .32 | 48 | 50 | .20 | .32 | 42 | 50 | 8 | .15 |
| 8 | .33 | .39 | .21 | .30 | 64 | 77 | .09 | .12 | 23 | 36 | 13 | .14 |
| 9 | .25 | .57 | .20 | .48 | 80 | 84 | .05 | .09 | 20 | 16 | 11 | .21 |
| 16 | .46 | 1.36 | .34 | 1.13 | 74 | 90 | .12 | .13 | 26 | 10 | 8 | .22 |
| 31 | .45 | 2.68 | .38 | 2.28 | 85 | 85 | .07 | .40 | 15 | 15 | 14 | .17 |
| 37 | .49 | 2.36 | .31 | 2.07 | 63 | 88 | .18 | .29 | 37 | 22 | 9 | .18 |
| 42 | .59 | 2.55 | .33 | 2.13 | 56 | 83 | .26 | .42 | 44 | 27 | 9 | .18 |
| 45 | .72 | 2.18 | .37 | 1.84 | 51 | 84 | .35 | .34 | 49 | 16 | 11 | .18 |
| 48 | .51 | 1.85 | .28 | 1.58 | 56 | 85 | 23 | .27 | 45 | 15 | 11 | .20 |
| 50 | .92 | 2.25 | .72 | 1.92 | 78 | 86 | .20 | .28 | 22 | 14 | 12 | .22 |
| 52 | .57 | 1.96 | .42 | 1.64 | 74 | 84 | .15 | .32 | 26 | 16 | 11 | .25 |
| 55 | .44 | 2.03 | .27 | 1.71 | 61 | 84 | .17 | .32 | 39 | 16 | 8 | .24 |
| 58 | .43 | 1.86 | .30 | 1.53 | 70 | 81 | .13 | .33 | 30 | 33 | 8 | .23 |
| 64 | .84 | 1.85 | .77 | 1.60 | 92 | 86 | .07 | .25 | 8 | 14 | 7 | .20 |
| 68 | .95 | 1.58 | .68 | 1.45 | 72 | 92 | .27 | .13 | 28 | 8 | 9 | .23 |
| 72 | .86 | 1.05 | .72 | 1.46 | 84 | 95 | .14 | .10 | 16 | 5 | 9 | .35 |
| 76 | 1.36 | 1.61 | 1.05 | 1.40 | 81 | 87 | .31 | .21 | 19 | 13 | 11 | .19 |
| 80 | 1.35 | 1.59 | 1.10 | 1.32 | 82 | 83 | .25 | .27 | 18 | 17 | 7 | .21 |
| 84 | 1.32 | 1.68 | 1.08 | 1.38 | 83 | 82 | .23 | .30 | 17 | 18 | 5 | .32 |
| 87 | 1.06 | 1.83 | .88 | 1.48 | 83 | 81 | .18 | .35 | 17 | 19 | 7 | .28 |
| 90 | .54 | .84 | .41 | .69 | 76 | 82 | .13 | .15 | 24 | 18 | 10 | .25 |

CASE 2.

| Identification | Overall depth thin (mm) | Overall depth thick (mm) | Stratum Corneum thin (mm) | Stratum Corneum thick (mm) | Stratum Corneum thin (%) | Stratum Corneum thick (%) | Suprapapillary Stratum Malpighii thin (mm) | Suprapapillary Stratum Malpighii thick (mm) | Suprapapillary Stratum Malpighii thin (%) | Suprapapillary Stratum Malpighii thick (%) | Papillae (number/mm) | Well formed Papillae (mean length) (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DISTIL. | | | | | | | | | | | | |
| B6 (4) | .30 | .43 | .17 | .33 | 57 | 77 | .13 | .10 | 43 | 23 | 12 | .15 |
| B6 (9) | .32 | .53 | .23 | .40 | 72 | 77 | .09 | .12 | 18 | 23 | 12 | .16 |
| B6 (26) | .28 | .46 | .18 | .36 | 64 | 78 | .10 | .10 | 36 | 22 | 10 | .09 |
| B6 (30) | .32 | .33 | .22 | .18 | 69 | 55 | .10 | .05 | 31 | 45 | 10 | .05 |
| MIDDLE | | | | | | | | | | | | |
| B5 (11) | .43 | .48 | .30 | .33 | 70 | 69 | .13 | .15 | 30 | 31 | 10 | .12 |
| B5 (31) | .49 | .58 | .37 | .36 | 75 | 62 | .12 | .22 | 25 | 38 | 12 | .14 |
| B5 (39) | .51 | .59 | .38 | .77 | 74 | 80 | .13 | .19 | 26 | 20 | 14 | .23 |
| B5 (39) | .55 | 1.04 | .35 | .81 | 64 | 78 | .20 | .23 | 36 | 22 | 13 | .18 |
| B5 (46) | .72 | 1.15 | .50 | .88 | 80 | 79 | .14 | .25 | 20 | 22 | 15 | .15 |
| PROXIMAL | | | | | | | | | | | | |
| B4 (4) | .57 | .72 | .34 | .52 | 60 | 72 | .23 | .20 | 40 | 28 | 10 | .15 |

CASE 3

| Identification | Overall depth thin (mm) | Overall depth thick (mm) | Stratum Corneum thin (mm) | Stratum Corneum thick (mm) | Stratum Corneum thin (%) | Stratum Corneum thick (%) | Suprapapillary Stratum Malpighii thin (mm) | Suprapapillary Stratum Malpighii thick (mm) | Suprapapillary Stratum Malpighii thin (%) | Suprapapillary Stratum Malpighii thick (%) | Papillae (number/mm) | Well formed papillae (mean length) (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B8 | .24 | 1.19 | .08 | 1.01 | 33 | 85 | .16 | .18 | 67 | 15 | 9 | .16 |
| B18 | .56 | 1.35 | .45 | 1.05 | 80 | 78 | .11 | .30 | 20 | 22 | 15 | .18 |
| B23 | .63 | 1.13 | .45 | .83 | 72 | 73 | .18 | .30 | 28 | 27 | 9 | .16 |
| B33 | 1.32 | 1.51 | 1.16 | 1.18 | 88 | 78 | .16 | .33 | 22 | 22 | 10 | 23 |
| B38 | 1.32 | 1.54 | 1.18 | 1.32 | 90 | 85 | .14 | .22 | 10 | 15 | 12 | .18 |
| B48 | .66 | 1.43 | .48 | 1.24 | 73 | 87 | .18 | .19 | 27 | 13 | 8 | .25 |
| B53 | .63 | 1.41 | .45 | 1.23 | 71 | 87 | .18 | .18 | 29 | 13 | 7 | .28 |
| B58 | .60 | 1.10 | .48 | .90 | 80 | 82 | .12 | .20 | 20 | 18 | 8 | .20 |
| B68 | .45 | 1.85 | .38 | 1.46 | 84 | 79 | .07 | .39 | 16 | 21 | 12 | .30 |
| B73 | .52 | 1.76 | .45 | 1.50 | 87 | 85 | .07 | .26 | 23 | 26 | 10 | .35 |
| B78 | .51 | 1.82 | .45 | 1.51 | 88 | 83 | .06 | .31 | 12 | 17 | 10 | .40 |
| B83 | .56 | 1.84 | .34 | 1.44 | 61 | 78 | .22 | .40 | 37 | 22 | 10 | .40 |
| B88 | .54 | 2.16 | .41 | 1.85 | 87 | 86 | .07 | .31 | 13 | 14 | 8 | .35 |

CASE 4 (Rheumatoid arthritic patient with heloma durum)

| Identification | Overall depth | | Stratum Corneum | | | | Suprapapillary Stratum Malpighii | | | | Papillae (number/mm) | Well formed papillae (mean length) (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | thin (mm) | thick (mm) | thin (mm) | thick (mm) | thin (%) | thick (%) | thin (mm) | thick (mm) | thin (%) | thick (%) | | |
| 3 | .87 | .88 | .70 | .53 | 80 | 60 | .17 | .35 | 20 | 40 | 7 | .25 |
| | .85 | .97 | .53 | .83 | 62 | 85 | .32 | .14 | 38 | 15 | 9 | .28 |
| 5 | .66 | 1.06 | .48 | .80 | 73 | 75 | .18 | .26 | 27 | 25 | 7 | .20 |
| | .60 | .90 | .44 | .75 | 73 | 83 | .16 | .15 | 27 | 17 | 8 | .25 |
| 9 | .37 | .97 | .32 | .77 | 87 | 80 | .05 | .20 | 13 | 20 | 10 | .22 |
| | .48 | 1.10 | .35 | .85 | 73 | 77 | .13 | .25 | 27 | 23 | 8 | .23 |
| 15 | .36 | .98 | .26 | .63 | 72 | 64 | .10 | .35 | 28 | 36 | 8 | .15 |
| | .40 | 1.11 | .35 | .88 | 87 | 88 | .05 | .23 | 13 | 21 | 9 | .19 |
| 20 | .50 | 1.06 | .35 | .96 | 70 | 90 | .15 | .10 | 30 | 10 | 10 | .15 |
| | .74 | 1.12 | .54 | .92 | 73 | 82 | .20 | .20 | 27 | 18 | 8 | .18 |
| 26 | .46 | 1.04 | .38 | .87 | 82 | 85 | .08 | .15 | 18 | 15 | 7 | .16 |
| | .68 | 1.00 | .60 | .92 | 88 | 92 | .08 | .08 | 12 | 8 | 6 | .20 |

CASE 5

| Identification | Overall depth | | Stratum Corneum | | | | Suprapapillary Stratum Malpighii | | | | Papillae (number/mm) | Well formed papillae (mean length) (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | thin (mm) | thick (mm) | thin (mm) | thick (mm) | thin (%) | thick (%) | thin (mm) | thick (mm) | thin (%) | thick (%) | | |
| 3 | 1.00 | 1.76 | .80 | 1.42 | 80 | 80 | .20 | .34 | 20 | 20 | 9 | .40 |
| | .67 | 1.69 | .52 | 1.53 | 78 | 90 | .15 | .16 | 22 | 10 | 10 | .25 |
| 5 | 1.00 | 1.76 | .60 | 1.41 | 60 | 80 | .40 | .35 | 40 | 20 | 9 | .20 |
| | .62 | 1.75 | .55 | 1.35 | 89 | 77 | .07 | .40 | 11 | 23 | 10 | .20 |
| 12 | .29 | 1.44 | .14 | 1.22 | 48 | 85 | .15 | .22 | 52 | 15 | 10 | .22 |
| | .68 | 1.80 | .42 | 1.55 | 62 | 86 | .26 | .25 | 38 | 14 | 9 | .27 |
| 14 | .30 | .97 | .15 | .77 | 50 | 79 | .15 | .20 | 50 | 21 | 10 | .25 |
| | .92 | .95 | .55 | .63 | 60 | 66 | .37 | .32 | 40 | 34 | 8 | .28 |

CASE 6

| Identif-ication | Overall depth | | Stratum Corneum | | | | Suprapapillary Stratum Malpighii | | | | Papillae (number/mm) | Well formed papillae (mean length) (θm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | thin (mm) | thick (mm) | thin (mm) | thick (mm) | thin (%) | thick (%) | thin (mm) | thick (mm) | thin (%) | thick (%) | | |
| 2 | .53 | 1.73 | .43 | 1.54 | 81 | 89 | .10 | .19 | 19 | 11 | 9 | .22 |
| | 1.46 | 1.88 | 1.28 | 1.12 | 88 | 92 | .18 | .16 | 12 | 16 | 9 | .22 |
| 5 | 1.01 | 1.81 | .83 | 1.56 | 82 | 86 | .18 | .25 | 18 | 14 | 8 | .22 |
| | .54 | 1.54 | .40 | 1.39 | 74 | 90 | .14 | .15 | 26 | 10 | 10 | .20 |
| 6 | .55 | 1.55 | .40 | 1.42 | 40 | 92 | .15 | .13 | 27 | 8 | 10 | .15 |
| | 1.30 | 1.74 | 1.10 | 1.60 | 85 | 92 | .20 | .14 | 15 | 14 | 8 | .18 |
| 8 | .54 | 1.72 | .37 | 1.53 | 69 | 89 | .17 | .19 | 31 | 11 | 8 | .17 |
| | 1.51 | 1.95 | 1.28 | 1.75 | 85 | 90 | .23 | .20 | 15 | 10 | 9 | .22 |
| 11 | .67 | 1.75 | .49 | 1.58 | 73 | 90 | .18 | .17 | 27 | 10 | 10 | .15 |
| | .52 | 1.86 | 1.30 | 1.69 | 85 | 90 | .22 | .18 | 15 | 10 | 9 | .15 |
| 13 | 1.45 | 1.86 | 1.30 | 1.58 | 90 | 85 | .15 | .28 | 10 | 15 | 8 | .18 |
| | .59 | 1.51 | .44 | 1.35 | 75 | 90 | .15 | .16 | 25 | 10 | 8 | .18 |
| 16 | .75 | 1.67 | .55 | 1.46 | 73 | 87 | .20 | .21 | 20 | 13 | 8 | .15 |
| | | 1.85 | | 1.60 | | 87 | | .25 | | 13 | 8 | .20 |
| 18 | .89 | 1.69 | .67 | 1.44 | 75 | 85 | .22 | .25 | 25 | 15 | 10 | .20 |

CASE 7

| Identification | Overall depth thin (mm) | Overall depth thick (mm) | Stratum Corneum thin (mm) | Stratum Corneum thick (mm) | Stratum Corneum thin (%) | Stratum Corneum thick (%) | Suprapapillary Stratum Malpighii thin (mm) | Suprapapillary Stratum Malpighii thick (mm) | Suprapapillary Stratum Malpighii thin (%) | Suprapapillary Stratum Malpighii thick (%) | Papillae (number/mm) | Well formed papillae (mean length) (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B1 (8) | 1.05 | 1.93 | .80 | 1.38 | 76 | 72 | .25 | .55 | 24 | 28 | 4 | .38 |
| B3 (7) | .42 | 1.17 | .38 | .95 | 91 | 81 | .04 | .22 | 9 | 22 | 8 | .22 |
| B1 (12) | 1.01 | 1.65 | .32 | 1.30 | 32 | 79 | .69 | .35 | 68 | 21 | 10 | .16 |
| B3 (11) | .59 | 1.10 | .51 | .95 | 87 | 95 | .08 | .15 | 13 | 15 | 8 | .18 |
| B3 (15) | .64 | 1.12 | .53 | 1.00 | 83 | 90 | .11 | .12 | 17 | 10 | 9 | .21 |
| B2 (16) | .72 | .77 | .65 | .7[illegible] | 90 | 91 | .07 | .17 | 10 | 9 | 11 | .18 |
| B2 (20) | .61 | .84 | .54 | .69 | 89 | 82 | .07 | .15 | 11 | 18 | 10 | .17 |
| BB (24) | .65 | .96 | .50 | .78 | 77 | 78 | .15 | .18 | 23 | 19 | 9 | .20 |
| B2 (29) | .81 | .93 | .71 | .81 | 88 | 87 | .10 | .12 | 12 | 13 | 9 | .18 |
| B2 (28) | .80 | .84 | .70 | .66 | 88 | 79 | .10 | .18 | 12 | 21 | 8 | .15 |
| B2 (34) | .78 | .84 | .68 | .80 | 87 | 85 | .10 | .14 | 13 | 15 | 9 | .16 |
| B2 (41) | .78 | 1.15 | .68 | 1.05 | 87 | 91 | .10 | .10 | 13 | 9 | 8 | .18 |

**CASE 0**

| Identification | Overall depth thin (mm) | Overall depth thick (mm) | Stratum Corneum thin (mm) | Stratum Corneum thick (mm) | Stratum Corneum thin (%) | Stratum Corneum thick (%) | Suprapapillary Stratum Malpighii thin (mm) | Suprapapillary Stratum Malpighii thick (mm) | Suprapapillary Stratum Malpighii thin (%) | Suprapapillary Stratum Malpighii thick (%) | Papillae (number/mm) | Well formed papillae (mean length) (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | .75 | 1.80 | .52 | 1.47 | 69 | 82 | .23 | .33 | 31 | 18 | 9 | .30 |
| 1b | 1.91 | 2.10 | 1.68 | 1.90 | 88 | 90 | .23 | .20 | 12 | 10 | 10 | .27 |
| 1c | 1.48 | 2.11 | 1.14 | 1.98 | 77 | 94 | .34 | .13 | 23 | 13 | 7 | .23 |
| 2a | 1.25 | 1.28 | 1.12 | 1.08 | 90 | 84 | .13 | .20 | 10 | 16 | 11 | .18 |
| 2b | .46 | 1.09 | .29 | .91 | 63 | 84 | .17 | .18 | 37 | 16 | 7 | .23 |
| 3a | .80 | 1.62 | .62 | 1.52 | 78 | 93 | .18 | .12 | 22 | 7 | 10 | .26 |
| 3b | 1.68 | 2.07 | 1.52 | 1.82 | 91 | 88 | .16 | .25 | 9 | 12 | 10 | .20 |
| 3c | 2.06 | 2.10 | 1.66 | 1.92 | 81 | 92 | .40 | .17 | 19 | 8 | 10 | .19 |
| 4a | .95 | 1.36 | .79 | 1.08 | 83 | 80 | .16 | .28 | 17 | 20 | 10 | .20 |
| 4b | 1.48 | 1.90 | 1.32 | 1.31 | 89 | 69 | .16 | .59 | 11 | 31 | 9 | .23 |
| 5a | .50 | 1.49 | .30 | 1.18 | 60 | 79 | .20 | .31 | 40 | 21 | 9 | .25 |
| 5b | .26 | 1.21 | .08 | .96 | 31 | 79 | .18 | .25 | 69 | 21 | 8 | .23 |
| 6a | .72 | 2.08 | .51 | 1.90 | 71 | 91 | .21 | .18 | 29 | 9 | 10 | .16 |
| 6b | 2.23 | 2.28 | 2.01 | 2.10 | 90 | 92 | .22 | .18 | 10 | 8 | 8 | .13 |
| 6c | 2.41 | 2.60 | 2.21 | 2.33 | 92 | 90 | .20 | .27 | 8 | 10 | 10 | .14 |
| 6d | .65 | 2.53 | .51 | 2.24 | 79 | 89 | .14 | .29 | 21 | 11 | 9 | .20 |
| 7a | .79 | 2.85 | .69 | 2.35 | 69 | 83 | .10 | .50 | 13 | 17 | 11 | .10 |
| 7b | 2.58 | 2.68 | 2.45 | 2.38 | 95 | 88 | .13 | .30 | 5 | 12 | 10 | .15 |
| 7c | 2.54 | 2.55 | 2.41 | 2.40 | 95 | 94 | .13 | .15 | 5 | 6 | 8 | .14 |
| 7d | 2.29 | 2.51 | 2.02 | 2.27 | 88 | 90 | .23 | .24 | 12 | 10 | 10 | .18 |
| 8a | .77 | 1.59 | .57 | 1.41 | 74 | 88 | .20 | .18 | 26 | 12 | 10 | .30 |
| 8b | 1.50 | 1.73 | 1.20 | 1.43 | 80 | 83 | .30 | .30 | 20 | 17 | 10 | .18 |
| 9a | .50 | 1.44 | .20 | 1.20 | 40 | 83 | .30 | .24 | 17 | 60 | 10 | .22 |
| 9b | .97 | 1.65 | .75 | 1.35 | 77 | 82 | .22 | .30 | 23 | 18 | 9 | .25 |
| 10a | .96 | 2.59 | .85 | 2.37 | 90 | 91 | .10 | .22 | 10 | 9 | 10 | .18 |
| 10b | 2.24 | 2.62 | 2.04 | 2.42 | 91 | 92 | .20 | .20 | 9 | 8 | 11 | .17 |
| 10c | 2.19 | 2.27 | 1.92 | 2.07 | 88 | 91 | .27 | .20 | 12 | 9 | 12 | .18 |
| 10d | .68 | 2.05 | .48 | 1.73 | 71 | 84 | .20 | .32 | 29 | 16 | 12 | .17 |

CASE 9

| Identification | Overall depth thin (mm) | Overall depth thick (mm) | Stratum Corneum thin (mm) | Stratum Corneum thick (mm) | Stratum Corneum thin (%) | Stratum Corneum thick (%) | Suprapapillary Stratum Malpighii thin (mm) | Suprapapillary Stratum Malpighii thick (mm) | Suprapapillary Stratum Malpighii thin (%) | Suprapapillary Stratum Malpighii thick (%) | Papillae (number/mm) | Well formed Papillae (mean length) (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B7(5) | .40 | 1.32 | .30 | 1.03 | 75 | 78 | .10 | .29 | 25 | 29 | 8 | .30 |
| B8(5) | .89 | 1.09 | .68 | .91 | 76 | 83 | .21 | .18 | 24 | 17 | 5 | .28 |
| B9 (5) | .50 | 1.07 | .40 | .93 | 80 | 87 | .10 | .14 | 20 | 12 | 8 | .28 |
| B7 (11) | .40 | .62 | .33 | .48 | 82 | 78 | .07 | .14 | 18 | 22 | 5 | .20 |
| B8 (9) | .88 | 1.22 | .80 | .97 | 91 | 97 | .08 | .25 | 9 | 20 | 9 | .26 |
| B9 (9) | .34 | .79 | .26 | .69 | 76 | 88 | .08 | .10 | 28 | 12 | 10 | .23 |
| B7 (15) | .76 | 1.43 | .68 | 1.18 | 90 | 82 | .08 | .25 | 10 | 18 | 8 | .25 |
| B8 (13) | .93 | 1.21 | .83 | .91 | 89 | 91 | .10 | .30 | 11 | 25 | 7 | .25 |
| B9 (13) | .30 | .55 | .23 | .45 | 77 | 82 | .07 | .10 | 23 | 18 | 9 | .10 |
| B8 (17) | .68 | 1.17 | .35 | .92 | 81 | 79 | .13 | .25 | 19 | 21 | 8 | .28 |
| B9 (17) | .47 | .55 | .37 | .37 | 79 | 67 | .10 | .18 | 21 | 33 | 9 | .18 |
| B8 (20) | .82 | 1.05 | .67 | .80 | 82 | 76 | .15 | .25 | 18 | 24 | 8 | .28 |
| B8 (24) | .76 | 1.31 | .59 | .98 | 78 | 75 | .17 | .33 | 22 | 25 | 8 | .28 |
| B9 (25) | .43 | 1.13 | .31 | .92 | 72 | 81 | .12 | .21 | 28 | 19 | 7 | .30 |
| B8 (28) | .95 | 1.34 | .82 | 1.12 | 86 | 84 | .13 | .22 | 14 | 16 | 7 | .23 |
| B9 (29) | .56 | 1.14 | .46 | 1.04 | 82 | 91 | .10 | .10 | 18 | 9 | 6 | .30 |
| B8 (32) | .85 | 1.23 | .52 | 1.05 | 61 | 85 | .33 | .18 | 39 | 15 | 9 | .30 |
| B8 (36) | .49 | 1.45 | .30 | 1.19 | 73 | 82 | .13 | .26 | 27 | 18 | 8 | .35 |
| B8 (40) | .59 | 1.27 | .34 | 1.13 | 60 | 89 | .23 | .14 | 40 | 11 | 8 | .37 |
| B8 (48) | .78 | 1.33 | .65 | 1.02 | 83 | 77 | .13 | .31 | 17 | 23 | 9 | .26 |
| B8 (48) | .53 | 1.40 | .35 | 1.17 | 66 | 84 | .18 | .23 | 34 | 16 | 8 | .32 |
| B (52) | .74 | 1.43 | .37 | 1.03 | 50 | 72 | .37 | .40 | 50 | 28 | 5 | .26 |
| B (56) | .62 | 1.22 | .38 | 1.07 | 61 | 88 | .24 | .15 | 24 | 12 | 8 | .37 |

CASE 10

| Identification | Overall depth thin (mm) | Overall depth thick (mm) | Stratum Corneum thin (mm) | Stratum Corneum thick (mm) | Stratum Corneum thin (%) | Stratum Corneum thick (%) | Suprapapillary Stratum Malpighii thin (mm) | Suprapapillary Stratum Malpighii thick (mm) | Suprapapillary Stratum Malpighii thin (%) | Suprapapillary Stratum Malpighii thick (%) | Papillae (number/mm) | Bell formed Papillae (mean length) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B5 (1) | .38 | .78 | .30 | .50 | 79 | 64 | .08 | .28 | 21 | 36 | 9 | .13 |
| B6 (1) | .32 | .56 | .22 | .44 | 69 | 79 | .10 | .12 | 31 | 21 | 8 | .12 |
| B4 (5) | .62 | .94 | .51 | .75 | 82 | 80 | .11 | .19 | 18 | 20 | 12 | .24 |
| B6 (5) | .26 | .59 | .20 | .47 | 77 | 80 | .06 | .12 | 23 | 20 | 11 | .10 |
| B4 (9) | .43 | 1.12 | .33 | .82 | 77 | 73 | .10 | .30 | 23 | 27 | 9 | .19 |
| B4 (5) | .55 | .98 | .43 | .81 | 78 | 81 | .12 | .17 | 22 | 17 | 10 | .20 |
| B6 (5) | .14 | .47 | .09 | .37 | 64 | 79 | .05 | .10 | 36 | 21 | 13 | .12 |
| B5 (8) | .33 | .60 | .17 | .43 | 51 | 72 | .16 | .17 | 49 | 28 | 10 | .15 |
| B6 (10) | .24 | .34 | .16 | .24 | 67 | 70 | .08 | .10 | 33 | 30 | 9 | .08 |
| B4 (13) | .42 | .78 | .32 | .68 | 76 | 87 | .10 | .10 | 24 | 13 | 7 | .20 |
| B5 (12) | .36 | .57 | .28 | .43 | 78 | 75 | .08 | .14 | 22 | 25 | 7 | .24 |
| B6 (14) | .18 | .47 | .11 | .40 | 61 | 85 | .08 | .07 | 39 | 15 | 13 | .13 |
| B5 (20) | .37 | .66 | .30 | .50 | 81 | 76 | .07 | .16 | 19 | 24 | 10 | .15 |
| B6 (19) | .18 | .36 | .14 | .22 | 78 | 61 | .04 | .14 | 18 | 39 | 11 | .10 |
| B5 (24) | .36 | .70 | .25 | .57 | 25 | 81 | .11 | .13 | 30 | 19 | 10 | .18 |
| B6 (23) | .31 | .61 | .28 | .51 | 90 | 83 | .03 | .10 | 10 | 17 | 8 | .16 |
| B5 (28) | .39 | .71 | .28 | .56 | 72 | 79 | .11 | .15 | 28 | 21 | 8 | .20 |
| B5 (33) | .54 | 1.22 | .46 | .93 | 85 | 76 | .08 | .29 | 15 | 24 | 11 | .20 |
| B6 (31) | .30 | .53 | .22 | .36 | 73 | 68 | .08 | .17 | 27 | 32 | 10 | .08 |
| B5 (36) | .46 | 1.06 | .36 | .76 | 78 | 72 | .10 | .33 | 22 | 28 | 11 | .18 |
| B5 (40) | .55 | 1.12 | .45 | .85 | 82 | 76 | .10 | .27 | 18 | 24 | 12 | .22 |
| B5 (47) | .62 | 1.10 | .47 | .77 | 76 | 70 | .15 | .33 | 24 | 30 | 12 | .21 |

## APPENDIX E

STATISTICAL FORMULATIONS AS USED IN THIS THESIS

The measure of central tendency is computed from the raw data as reported in Appendix B, C or D. The mean ($\overline{X}$) is computed as the sum total of all observed data divided by the number of occurrences: $\overline{X} = \frac{X}{n}$ . The mean ($\overline{X}$) for the rete peg number and length or thickness of the respective epidermal strata may fail to reveal individual characteristics which are important in this study. Extreme values departing from the average tend to alter the mean values.

STANDARD DEVIATION (s) is a test of the measure of dispersion away from the mean. If d is the deviation of each individual measurement from the mean, standard deviation of mass of raw data is computed as $\sqrt{\frac{\sum d^2}{n}}$

PEARSONIAN r (Correlation Coefficient). Given variables x and y, sc = standard score or Z.

$$\frac{\sum ScX \cdot ScY}{n} \quad \text{or} \quad \frac{\sum xy - \bar{X}_x \bar{X}_y}{\sigma x \; \sigma y}$$

+1 indicates a perfect positive correlation, - 1 a perfect negative correlation. One cannot assume causal relationship from high correlation coefficient.

STANDARD ERROR

$$\frac{\sigma}{\sqrt{n-1}}$$

p = Confidence Level: Possibility a given value could occur by chance alone. (.01 = 1 chance in 100.

SIGNIFICANT DIFFERENCE: The student "t" test

$$\frac{\bar{X}_{(a)} - \bar{X}_{(b)}}{\sqrt{\frac{N_a(S^2) + N_b(S^2)}{N_{(a)} - N_{(b)} - 2} \times \frac{N_{(a)} + N_{(b)}}{N_{(a)} \times N_{(b)}}}}$$

BIBLIOGRAPHY

Armed Forces Institute of Pathology, 1960. Manual of Histologic and Special Staining Technics. Blakiston Division of McGraw Hill Co., New York.

Balinsky, B. I., 1970. An Introducation to Embryology, 3rd Edition. W. B. Saunders Co., Philadelphia.

Baserga, R., 1962. Autoradiographic study of the uptake of C-14 leucine by tumor cells in deoxyribonucleic acid synthesis. Biochim et biophys. ACTA-61: 445-453.

Billingham, R. E. and Silvers, W. K., 1967. Studies on the conservation of epidermal specificities of skin and certain mucosas in adult mammals. J. Exp. Med. 125: 429 - 446.

Bonavilla, E. J., 1968. Histopathology of helom durum; some significant features and their implications. J.A.P.A. 50: 423 - 431.

Briggaman, R. A. and Wheeler, E. E., 1968. Epidermal-dermal interactions in adult human skin; role of dermis in epidermal maintainence. J. Invest. Derm. 51: 454 - 465.

Briggaman, R. A. and Wheeler, C. E., 1971. Epidermal-dermal interactions in adult human skin II: The nature of the dermal influence. J. Invest. Derm. 56: 18 - 33.

Brody, I., 1960. The ultrastructure of the tonofibrils in the keratinization process of normal human epidermis. J. Ultrastructural Research 4: 264-297.

Brody, I., 1970 (a). Variations in the differentiation of fibrils in the normal human stratum corneum as revealed by electron microscopy. J. Ultrastructural Research 30: 601 - 614.

Brody, I., 1970 (b) An electron microscopic study of the fibrillar density in the normal human stratum corneum. J. of Ultrastructural Research 30: 209-217.

Bucher, N. L., 1963. Regeneration of mammalian liver. Internat. Rev. of Cytology: 15: 245 - 300.

Bullough, W. S., 1960. The control of mitotic activity in mammalian tissues. Biol. Rev. 37: 307 - 330.

Bullough, W. S., 1962. The vertebrate epidermal chalone. London, Nature 193: 520 - 523.

Bullough, W. S., Hewett, C. L. and Laurence, E. B., 1964. the epidermal chalone. Exp. Cell Res. 36: 192 - 200.

Bullough, W. S. and Laurence, E. B., 1960. The control of epidermal mitotic activities in the mouse. Proc. Roy. Soc. B. 151: 517 - 536.

Caron, G. A., 1969. Chalone and cancer. Arch. of Derm. Vol. 99: 232 - 234.

Carr, E. E. and Millington, P. F., 1969. Load consequent changes in the microstructure of human skin. J. of Physiol. JulyVol203: 7 - 15.

Christophers, E. and Petzgold, V., 1969. Epidermal cell replacement; topographical variations in albino guinea pig skin. Brit. J. Derm. 81: 598 - 602.

Cohen, J., 1969. Interactions of the skin. Brit. J. Derm. 81 Supp 3: 46 - 59.

Cummins, H. and Midlo, C., 1943. Finger prints, palms and soles. Blakiston Division of McGraw-Hill Co., New York.

Davis, G. G., 1934. Applied Anatomy, The Construction of the Human Body Considered in Relation to its Functions, Disease and Injuries. W. B. Saunders Co., Philadelphia.

Dodson, J. W., 1963. On the nature of tissue interactions in embryonic skin. Experimental Cell Research 31: 233-235.

Dodson, J. W., 1967. Differentiation of epidermis - inter-relationships of epidermis and dermis in embryonic chicken skin. J. Embryol. Exptl. Morph. 17: 83 - 105.

Evan, J. H. and Siesenhop, W. W., 1967. Proc. 7th Int. Conf. Med. Electro and Bioengineering, Stockholm.

Evans, F. G., 1961. Biomechanical Studies of the Musculo-skeletal System. Charles C. Thomas Publ., Springfield.

Feigenbaum, A. and Schreiber, L., Jan 1964. A compend of helomata. Current Podiatry Vol 13, No. 1: 9-40.

Feldberg, W. 1956. Histamine. Ciba Symposium, Little Brown and Co., Boston.

Fitzpatrick, T. B., 1971. Dermatology in General Medicine. McGraw-Hill Co., New York.

Freed, J. B., 1967. Histologic post mortem evaluation of bone hyperplasia accompanying digital clavus. J.A.P.A. 59: 467 - 476.

Frithiof, L., Lagerlof, G. and Wersall, J., 1963. Electron microscopical observations of hypkeratinization of oral mucosa. Acta Oto-laryngologica Suppl. 188: 423 - 429.

Frost, P., Weinstein, G. D. and Van Scott, E. J., 1966 Autoradiographic studies of epidermal proliferation. J. Invest. Derm. 45: 561 - 570

Garn, S. M., 1955. Applications of pattern analysis to anthropometric data. Annals of New York Academy of Sciences, 63: 89 - 98.

Garn, S. M., 1958. Statistics, a review. The Angle Orthodontist, 28: No. 3 149 - 165.

Ham, A. W., 1969. Histology. J. B. Lippincott Co., Philadelphia.

Hell, E. A., 1970. A stimulant to DNA synthesis in guinea pig epidermis. Brit. J. Dermat. 83: 632-636.

Horstmann, E., 1952 (a) Zur morphologie der gesunden und kranken haut. Arch. Derm. and Syph. 194: 164 - 173.

Horstmann, E., 1952 (b). Ueber den Papillarkörper der Menschlichen haut und seine regionalen Unterschiede. Acta Anatomica XIV: 23-42.

Howard, A. and Pelc, S., 1953. Synthesis of deoxyribonucleic acid in normal and irradiated cells and its relation to chromosomal breakage. Heredity (supp.): 32 - 48.

Karasek, M., 1969. Induction of growth and differentiation in post embryonic epithelial cell cultures. J. Invest. Derm. 52: 377 - 378.

Kay, D. H., 1965. Techniques for Electron Microscopy. Blackwell Scientific Publications, Oxford.

Knospe, W. H., Fried, W. and Gregory, S. A., 1970. Effect of a noncellular spleen derived factor on recovery of hematopoietic stem cells from irradiation. J. Lab. Clin. Med. 76: 584 - 592.

LeBlond, E. P. and Walker, G. E., 1956. Renewal of cell populations. Physiol. Rev. 36: 255 - 263.

Malkinson, F., 1972. Epidermal cell kinetics in Yearbook of Dermatology. Year Book Medical Publishers, Chicago.

Marro, J. M. and Vorhees, J. J., 1971. Preliminary characterization of an epidermal chalone-like inhibitor. J. Invest. Derm. 56: 353-358.

Matoltsy, A. G. and Parakkal, P.F., 1967. Keratinization in Ultrastructure of Normal and Abnormal Skin. Zelickson, Lea and Febiger Co., Philadelphia.

McCarthy, D. J., and Habowsky, J.E.J.., 1972. A cytological survey by strata of skin in heloma durum using electron microscopy. J.A.P.A. 62: No. 7, 239-249.

McCarthy, D.J. and Habowsky, J.E.J., 1972. Alterations in skin morphology in heloma durum utilizing maceration technique for examination of epidermal-dermal interface. J.A.P.A., 62: No. 8, 303 - 307.

McLoughlin, C. B., 1963. Mesenchymal influences on epidthelial differentiation. Symp. Soc. Expt. Biol. 17: 359 - 366.

Midgley, A. R. and Pierce, C. B., 1963. Immunohistochemical analysis of the basement membrane of the mouse. Am. J. of Path. 43: 929 - 943.

Montagna, W., 1965. The Structure and Function of Skin. 2nd ed. Academic Press, Inc., New York.

Montgomery, H., 1967. Dermatopathology. Harper - Row Co., New York.

Morton, D. J., 1952. Human Locomotion and Body Form. Williams and Wilkins Co., Baltimore.

Oberste-Lehn, 1962. Dermoepidermal interface. Archives of Dermat. Vol 86: 770-778.

Odland, G. F., 1960. A submicroscopic granular component in human epidermis. J. Invest. Dermat. 34: 11 - 15.

Odland, G. F. and Reed, T. H., 1967. Epidermis in Ultrastructure of Normal and Abnormal Skin, Zelickson, Lea and Febiger Co., Philadelphia.

Parrot, J. L., 1956. Histamine. Ciba Symposium. Little Brown and Co., Boston.

Pearse, A. G. E., 1961. Histochemistry, Theoretical and Applied. J. and A. Churchill Ltd., London.

Pease, D. C., 1964. Histolcgical Techniques for Electron Microscopy., 2nd ed. Academic Press, New York.

Pinkus, H., 1958. Keratosis senilis. Amer. J. Clin. Path. 29: 193-215.

Pinkus, H., 1964. Makroskopische Anatomie der Haut. Handbuch der Haut und Geschlechtskrankheiten (J. Jadassohn) Ergänzungswerk, Marchionini Berlin-Springer Verlag.

Pinkus, H. and Mehregan, A., 1969. A Guide to Dermatohistopathology. Appleton-Century Crofts, New York.

Pinkus, H., 1971. The Skin. International Academy of Pathology, Monograph No. 10. The Williams and Wilkins Co., Baltimore.

Prescott, D. M., 1968. Biology of Cancer and the Cancer Cell; Normal and Abnormal Regulation of Cell Reproduction. Sixth National Cancer Conference Procedings. Lippincott Co., Philadelphia.

Ross, R., 1969. Wound Healing. Scientific American: 220, No. 6: 40 - 50. W. H. Freeman Co., San Francisco.

Szabo, G., 1959. Quantitative investigations on the melanocyte system of human epidermis. Pigment Cell Biology. Academic Press, Inc., New York.

Taylor, V. H., 1960. Nucleic acid synthesis in relation to cell division cycle. Ann. of New York Acad. of Sc. 90: 409 - 424.

Van Scott, E. J. and Reinerston, R. P., 1961. The modulating influence of stromal environment on epithelial cells studied in human auto-transplants. J. Invest. Derm. 36: 109 - 115.

Vorhees, J. J. and Duell, E. A., 1971. Psoriasis as a possible defect of the adenyl cyclase-cyclic AMP cascade. Archives of Dermat . 104: 352 - 358.

Weinstein, G. D. and Van Scott, E. J., 1965. Autoradiographic analysis of turnover time of normal and psoriatic epidermis. J. Invest. Derm. 45: 257 - 262.

Wessels, N. K., 1962. Tissue interactions during skin histodifferentiation. Develop. Biol. 4: 87 - 107.

Wessels, N. K., 1967. Differentiation of epidermis and epidermal derivatives. New Eng. J. Med. 277: 21 - 33.

Wolff, J., 1870. Üeber die innere Architektur des Knochen und ihre Bedeutung für die Frage vom Knochenwachstum. Virch. Ach. 50: 92 - 108.

Zelickson, A. J., 1967. Ultrastructure of Normal and Abnormal Skin. Lea and Febiger Co., Philadelphia.

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