J. Soc. Cosmetic Chemists, **18**, 537–547 (Aug. 19, 1967)

Keratin Replacement as an Aging Parameter

NORMAN ORENTREICH, M.D.* and NANCY J. SHARP, B.A.†

Presented September 20, 1966, Seminar, New York City

Synopsis—The rate of nail growth diminishes in a measurable, reproducible, predictable manner with increasing age. There is a diminution in this rate of almost 40% between the ages of 25 and 95, or about 4.5 μ/week for each year of age after maturation. Young men's nails grow faster than women's until middle age but grow more slowly after the seventh decade of life. The known factors that have no effect on or that alter nail growth are enumerated. The measurement of nail growth may be a useful method of screening cosmetic preparations that may influence the nail.

Introduction

The scarcity of techniques for measuring and evaluating physiologic age, both in humans and animals, has hampered the advance of the science of experimental gerontology. A useful aging parameter must fulfill the following criteria: ease of performance, valid predictability in relationship to aging and longevity, reproducibility, low variability in each age range, and known relationship to disease.

Studies performed on the rate of keratin replacement of hair, nails, and skin indicate that there is a definite relationship between this rate and the age of the individual. The earliest known quantitative evaluation of the rate of regeneration of epithelium was performed during World War I in France by Carrel and duNouy (1). While involved in the development of a better antiseptic for wounds, they developed

* Orentreich Medical Group, 909 Fifth Ave., New York, N. Y. 10021.
† Orentreich Foundation for the Advancement of Science, New York, N. Y. 10021

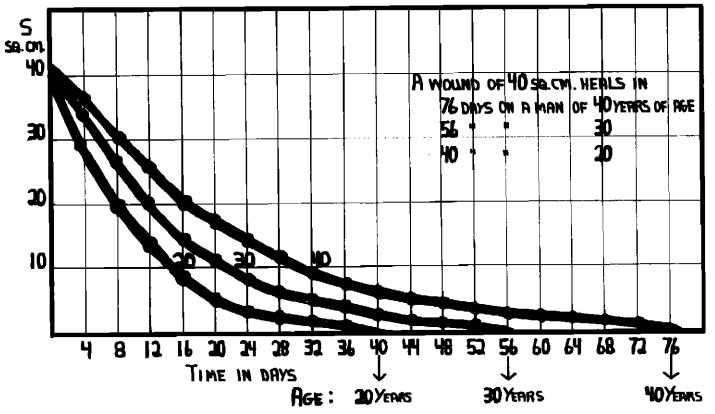

Figure 1. Index of epithelialization as a function of age

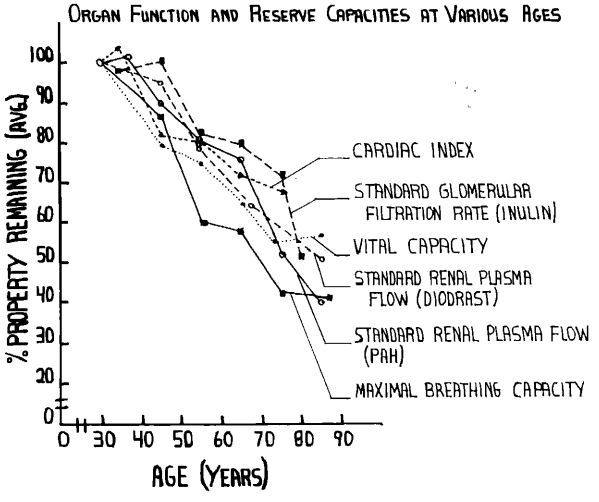

Figure 2. Per cent physical capacities remaining at various ages

a planimetric method for measuring the rate of epithelialization of a wound. For the first time, the generally accepted phenomenon that wounds heal more slowly in an aged person than in a younger one was measured in a quantitative fashion. The curve of the rate of epithelialization in wound-healing as a function of the age of the subject is presented in Fig. 1. By measuring the area of a wound under normal conditions, i.e., eliminating infected wounds, pathologic conditions, wounds which measured under 5 cm^2, etc., duNouy was able to calculate the "index of cicatrization" (which was actually the rate of epitheli-

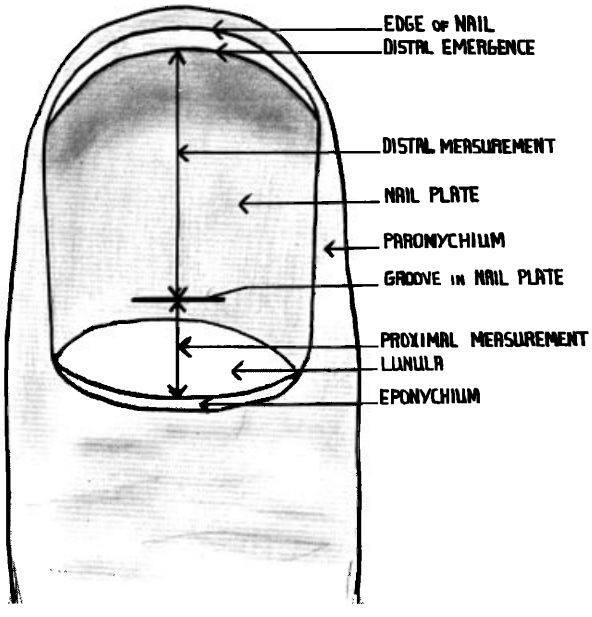

Figure 3. Method for nail growth measurement

alization as duNouy measured it) of a wound, with size of the wound and age of the individual as the only variables. The subjects were soldiers, healthy men between the ages of 20 and 40. This index of cicatrization formula enabled duNouy to calculate the time a wound would take to epithelialize, given only its dimensions and the age of the patient.

Shock (2) measured the decline in various physiologic functions with age in a large population segment. The graph in Fig. 2 represents a cross-sectional average of the per cent decline in performance of six functions which Shock measured in subjects of all ages. Although some functions, such as conduction velocity, decline only about 15% from age 30 to age 90 others (such as maximal breathing capacity) were found to retain only about 40% of their original capacity in 90-year-old individuals. Averaging all nine parameters, it appears that the decline in function of an individual is about 40% between the ages of 30 and 90, or that a 90-year-old retains, on the whole, about 60% of the reserve capacity of his youth.

Studies have been performed on the technique of measuring mitosis in the human epidermis, and the relation of keratin replacement to age (3–7). Barman (8, 9) and Rook (10) have studied changes in human

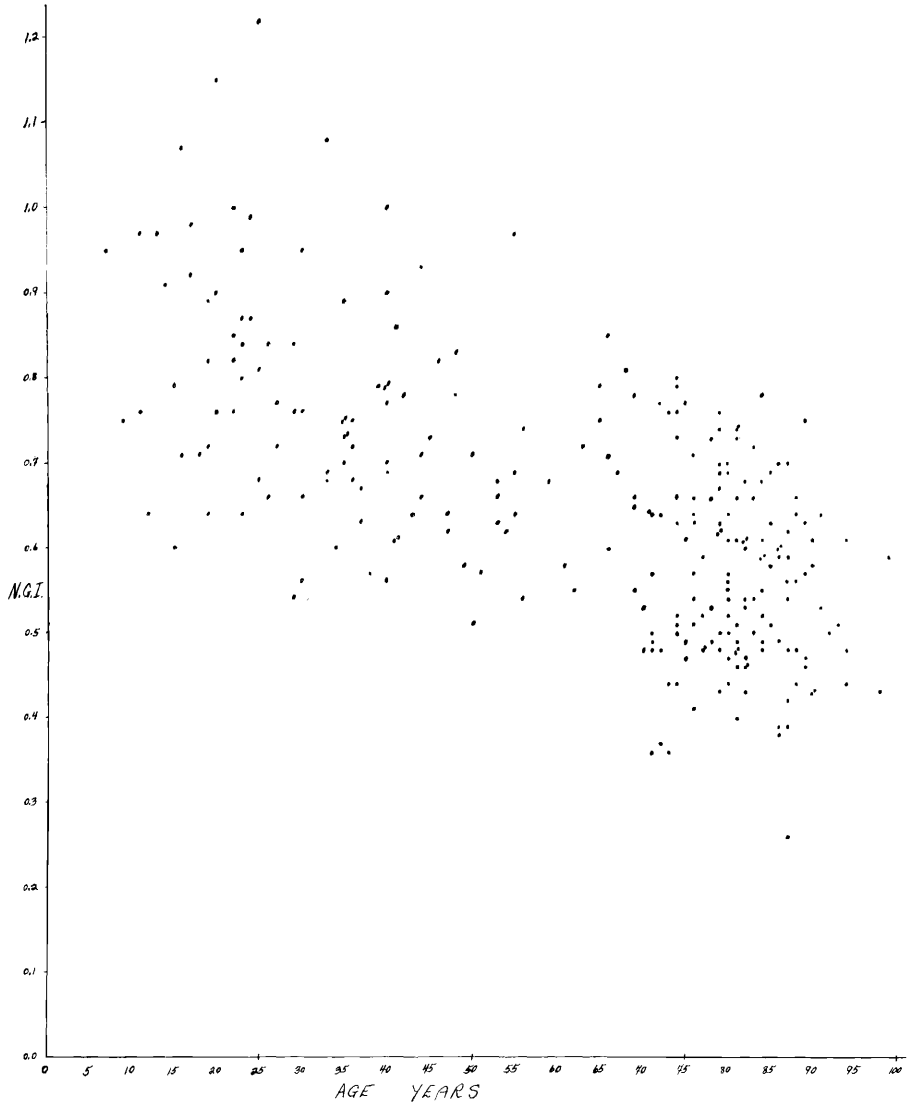

Figure 4. Scattergram of Nail Growth Index as a function of age

hair with age. Their experiments have shown that definite changes with age include a decrease in the density of hairs, a decrease in the percentage of coarse hairs with an increase in the percentage of fine hairs, and a decrease in the percentage of anagen (growing) hairs as compared to an increase in telogen (resting) hairs.

Table I
Age Distribution by Decade (257 Subjects)

Age (yr.)	Females	Males
10–19	8	8
20–29	16	8
30–39	10	11
40–49	17	6
50–59	12	1
60–69	12	2
70–79	45	12
80–89	55	21
90–99	10	3
Total	185	72

This paper concerns itself with changes in the rate of fingernail growth with age. The work is part of a research program to develop useful parameters of aging and to understand the significance of keratin replacement as a measure of physiologic function and reverse capacity.

Method

With the edge of a glass slide, a scratch was made transversely in the nail plate near the top of the lunula (Fig. 3). For this study only the thumbnails were measured. A calibrated micrometer built into a magnifying lens was used to measure the distance proximally from the scratch to the edge of the eponychium (cuticle) and distally from the scratch to the distal emergence (where the nail plate leaves the nail bed). Thus two values were obtained, distal and proximal, as a cross-check to prevent errors. Measurements were made at intervals, permitting the calculation of average growth in millimeters over a period of time as the transverse groove on the nail grew out. Measurements were generally taken at four- and at eight-week intervals; the total growth in millimeters was then divided by the time elapsed in weeks to yield the Nail Growth Index, or NGI, in millimeter growth per week.

Subjects were 257 normal males and females, selected among staff members and their families, patients with normal nails in a dermatologic practice, and residents of the Menorah Home for the Aged in Brooklyn. The ages of the 185 females and 72 males were distributed, by decade, as shown in Table I. Several studies were performed over a one-year period in order to determine seasonal changes in growth.

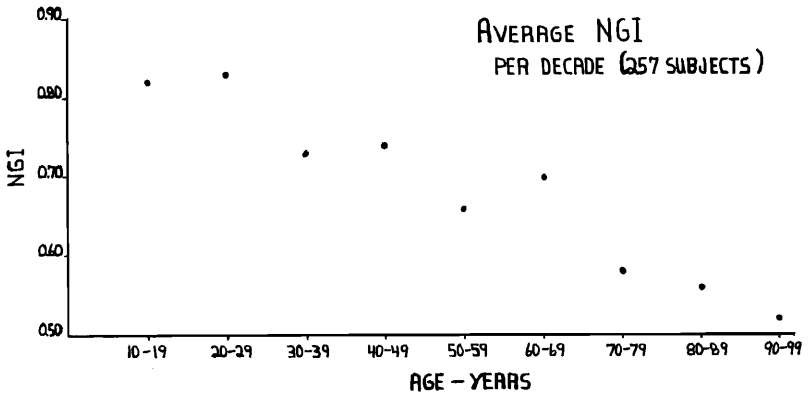

Figure 5. Average Nail Growth Index per decade of 257 subjects

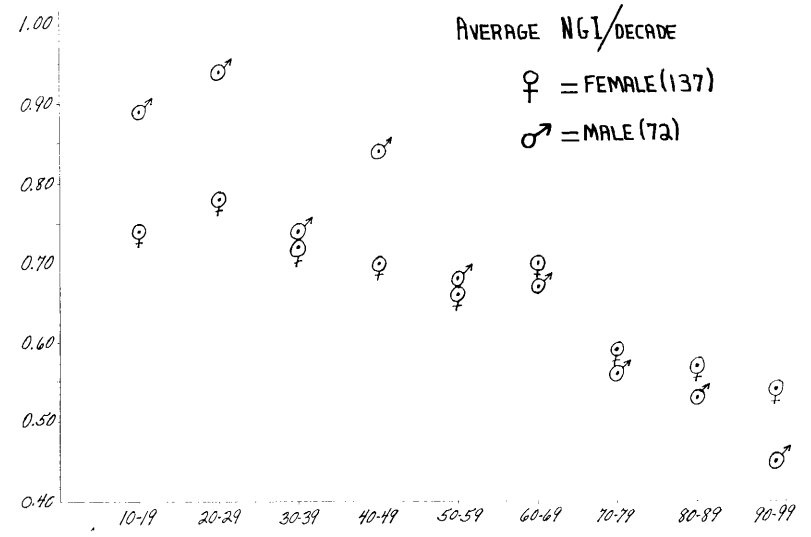

Figure 6. Average Nail Growth Index per decade, male *vs.* female

Results and Conclusions

The scattergram in Fig. 4 shows the average Nail Growth Index of 257 individuals in the study. Since right and left nails were found to grow at a similar rate in most individuals, the average of the two nails was used in computing the data. Broken down into decades, these figures were averaged, as plotted in Fig. 5. NGI's decreased from a

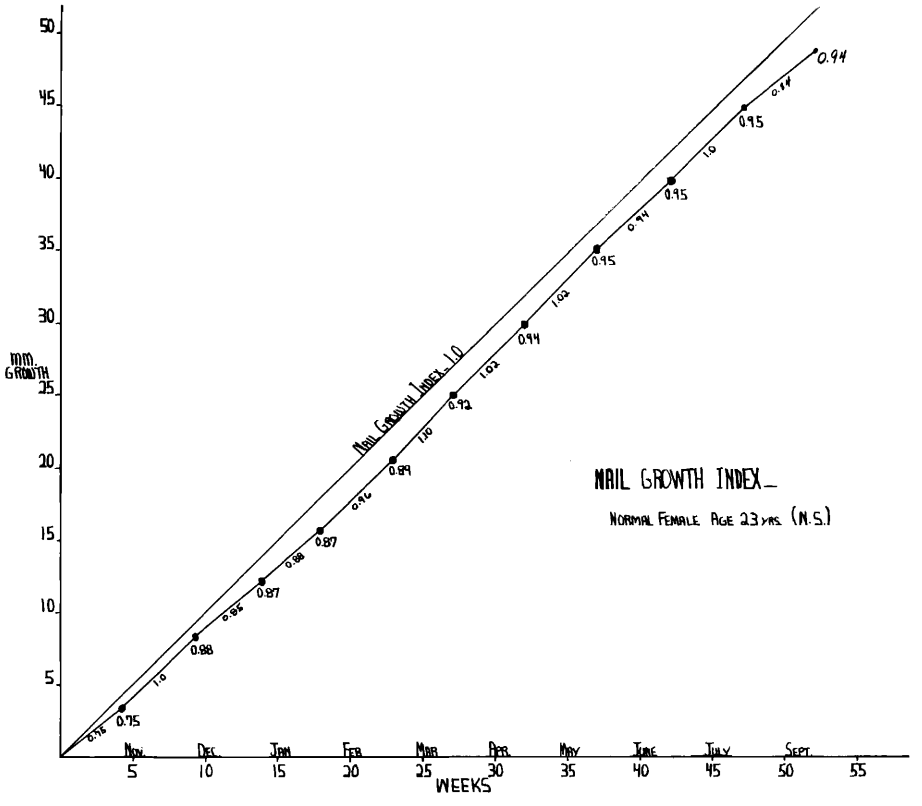

Figure 7. One year nail growth curve of twenty-three-year-old female

high value of 0.83 (average) for the third decade of life to 0.52 (average) in individuals between 90 and 99 years of age. This is a decrease of about 38% in rate of growth over a period of 70 years.

These averages per decade were also broken down by sex, as shown in Fig. 6. Males had a higher NGI until about the sixth decade, when the values for males and females are very close. By the eighth decade, growth rate of males begins to fall below that of females; in the tenth decade average NGI for males is 0.45, while that of females is 0.54.

One year studies of individuals indicated a linear rate of nail growth with little seasonal variation. Figure 7 shows the growth of a 23-year-old female over a one year period, measures every four to six weeks, plotted against the 45° slope of a Nail Growth Index of 1.0 mm/week. Average growth of this subject was 0.95 mm/week.

Table II
Nail Growth Factors

Faster	Slower	No Effect
Males	Females	Left- or right-handedness
Pregnancy	Lactation	Season
Third digit	First digit	Minor chronic illness
Piano playing	Aging	Occupation
Onychophagia	Severe cold	Dietary habits
	Acute infection	Moderate emotional stress
	Pneumonia	Minor surgery
	Mumps	Height and weight
	Malnutrition	Weight change
	Decreased circulation	Color
	Smoking	Nail polish and remover
	Congestive heart failure	
	Paralysis	
	Sleep	

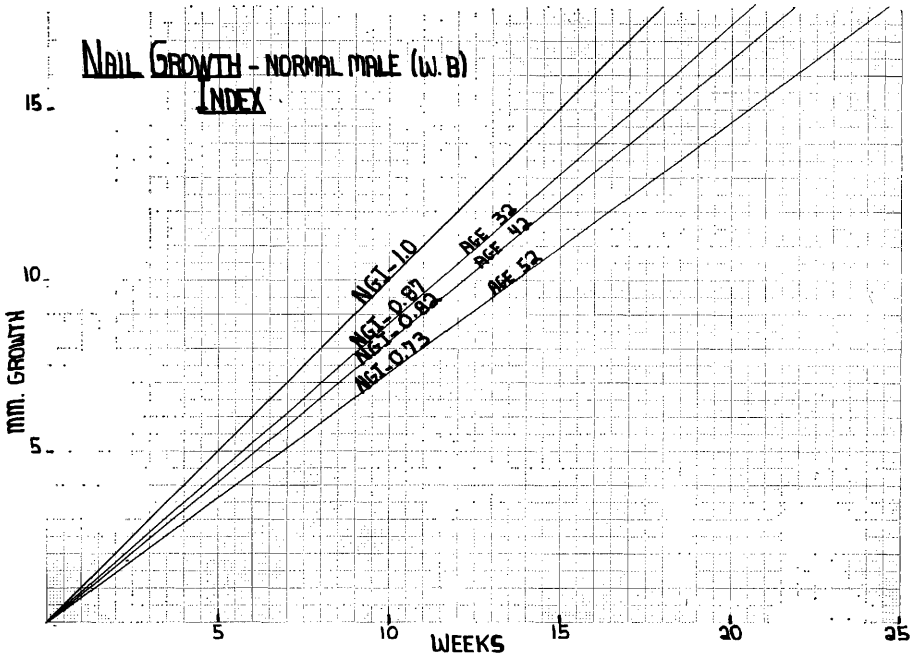

Figure 8. Nail Growth Index slope at ten-year intervals

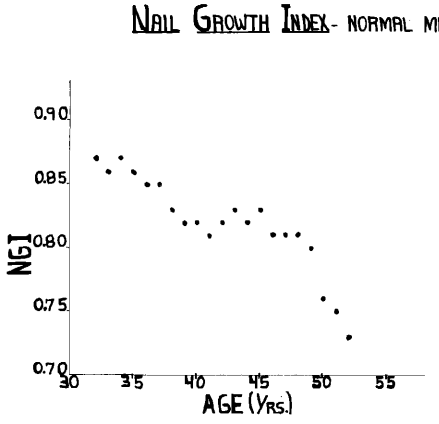

Figure 9. Yearly Nail Growth Index for twenty years

Discussion

A significant decline with age in the rate of nail growth was found in this study. Young males show faster growth rate than females; this difference diminishes toward middle age and reverses itself after the seventh decade of life. This may be correlated with the "male menopause." The rate of growth is not noticeably affected by mild climatic changes, although severe changes in temperature have been shown to alter this rate markedly (11). Table II is a summary of various factors which are reported to alter nail growth rate (11–17). The table also lists those factors that have already been shown to have no effect. This technique of measuring the rate of nail growth can be used to monitor the potential effects of nail cosmetics and of products alleged to influence nail growth.

The results of this study are in agreement with those of several previous experiments on the rate of linear nail growth. Bean (12, 13) performed a 20-year study of his own thumbnails, measuring the number of days which a scratch at the proximal edge of the nail plate took to grow out to the distal end. Converting his data into millimeter growth per week, his NGI decreased from 0.87 at age 32 to 0.82 at age 42 and to 0.73 at age 52 (Fig. 8). Figure 9 represents Bean's Nail Growth Index as measured each year from age 32 to age 52.

Cross-sectional studies of linear nail growth have been performed by Hillman (17), who measured 300 individuals, and by Hamilton (16), who studied over a thousand subjects. Their average measurements,

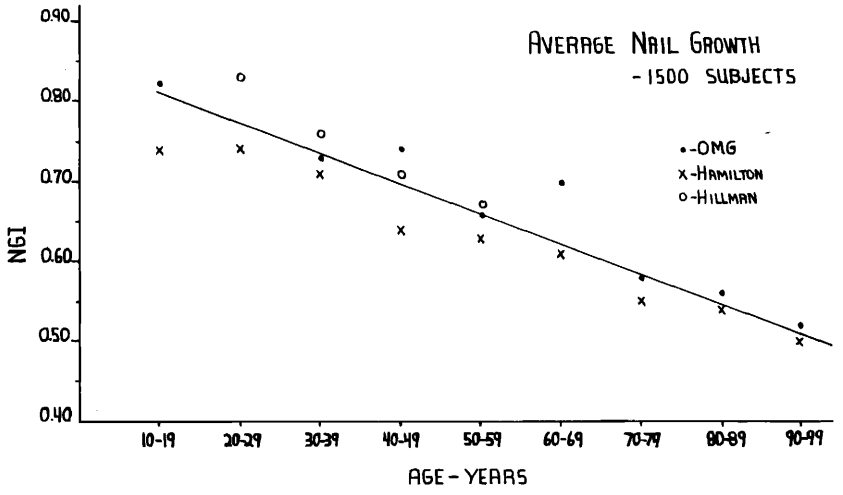

Figure 10. Average decline in nail growth with age, 1500 subjects

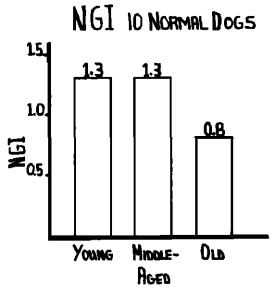

Figure 11. Nail growth in ten dogs

by decade, were converted into milliliter growth per week and, superimposed onto the slope of the graph from this study, revealed similar values at all ages to those reported in this paper. The average slope of these figures from all three experiment, as shown in Fig. 10, represents over 1500 subjects whose nail growth rates decrease on the average of 4.5 μ/week for every year of age, from age 20 to age 100. These figures represent a 40% diminution over a 70-year period and concur with the average changes which Shock found in his aging parameters.

The decrease in rate of nail growth with aging was linear for the cross-sectional studies. However, the individual longitudinal study performed for 20 years by Bean showed that the rate of growth declined at varying rates. Many more such studies over longer periods of time

are needed to determine if the average individual growth declines in a linear, stepwise, or other fashion.

Preliminary studies performed on dogs (Fig. 11) show that young and middle aged dogs' claws grow about 1.3 mm a week, whereas old dogs average 0.8 mm a week (18). Techniques described by Godwin (15) for measuring nail growth in the rat may permit controlled aging studies on this animal.

Further experiments on factors which affect nail growth, the relationship of linear growth to nail volume, and the linearity of longitudinal measurements over extended periods of time will reveal more information as to the true meaning of this measurement. To date, the use of linear nail growth measurements as a parameter of physiologic age appears both valid and significant.

(Received November 14, 1966)

REFERENCES

(1) du Nouy, P. leComte, *Biological Time*, The Macmillan Co., New York, 1937, pp. 51–101.
(2) Strehler, B. S., *Time, Cells, and Aging*, Academic Press, New York, 1962, p. 96.
(3) Epstein, W. L., and Maibach, H. I., Cell renewal in human epidermis, *Arch. Dermatol.*, **92,** 462 (1965).
(4) Katzberg, A. A., Influence of age on rate of desquamation of the human epidermis, *Anat. Record,* **112,** 418 (1952).
(5) Thuringer, J. M., and Katzberg, A. A., The effect of age on mitosis in the human epidermis, *J. Invest. Dermatol.*, **33,** 35 (1959).
(6) Van Scott, E. J., Ekel, J. M., and Auerbach, R., Determinants of rate and kinetics of cell division in scalp hair, *Ibid.*, **41,** 269 (1963).
(7) Weinstein, G. D., and Van Scott, E. J., Autoradiographic analysis of turnover times of normal and psoriatic epidermis, *Ibid.*, **45,** 257 (1965).
(8) Barman, J. M., Pecoraro, V., and Astore, I., Method, technic and computations in the study of the trophic state of the human scalp hair, *Ibid.*, **42,** 421 (1964).
(9) Barman, J. M., Astore, I., and Pecoraro, V., The normal trichogram of the adult, *Ibid.*, **44,** 233 (1965).
(10) Rook, A., Normal and abnormal hair growth in old age, *Gerontol. Clin.*, **7,** 8 (1965).
(11) Babcock, M. J., Methods for measuring fingernail growth rates in nutritional studies, *J. Nutrition*, **55,** 323 (1955).
(12) Bean, W. B., Nail growth, *Arch. Internal Med.*, **11,** 476 (1963).
(13) Bean, W. B., A discourse on nail growth and unusual fingernails, *Am. Clin. and Climat. Assoc.*, **74,** 152 (1963).
(14) Geoghegan, B., Roberts, D. F., and Sampford, M. R., A possible climatic effect on nail growth, *Appl. Physiol.*, **13,** 135 (1958).
(15) Godwin, K. O., Experimental study of nail growth, *J. Nutrition*, **69,** 121 (1959).
(16) Hamilton, J. B., Terada, H., and Mestler, G. E., Studies of growth throughout the life-span in japanese: growth and size of nails and their relationship to age, sex, heredity, and other factors, *J. Gerontol.*, **10,** 401 (1955).
(17) Hillman, R. W., Fingernail growth in the human subject, *Human Biol.*, **27,** 274 (1955).
(18) Orentreich, N., and Ettinger, S., Unpublished data.