

# PTC Taste Threshold Distributions and Age in Mennonite Populations.

By T. A. Koertvelyessy<sup>1</sup>, M. H. Crawford<sup>2</sup>, and J. Hutchinson<sup>2</sup>

## ABSTRACT

A number of studies report an impairment of the genetically inherited ability to taste PTC as a function of age, but ignore the cumulative effect of smoking on taste deterioration. This study examines the effect of aging on taste sensitivity in non-smoking Mennonite populations. The results obtained preclude a cause and effect relationship between age and PTC taste sensitivity. These results are congruent with the claims which ascribe the observed deterioration in PTC taste sensitivity to the cumulative effects of smoking, rather than to the effects of aging *per se*.

A number of papers have been published on the effect of aging on diverse aspects of sensory function, including sensitivity to tactile stimuli (Axelrod and Cohen, 1961), vibration (Goff et al. 1965), thermal stimuli (Krag and Kountz, 1950), pain (Procacci et al. 1970), and auditory stimuli (Glorig and Nixon, 1962). The taste (e.g., Byrd and Gertman, 1959; Cooper et al. 1959; Hughes, 1969) and smell modalities (e.g., Kimbrell and Furghott, 1963; Rovee et al. 1975) also attracted attention in view of the obvious role that they play in the orientation and the reaction of an organism to its physical environment (Engen, 1977).

The taste modality is generally investigated with reference to the primary taste qualities of sweet, sour, salty, and bitter. Several investigators (e.g., Harris and Kalmus, 1949; Basu and Ghash, 1968; Akeasu and Ozalp, 1977) specifically focused on the genetically inherited ability to detect the bitterness of the chemical substance phenylthiocarbamide or phenylthiourea (PTC).

Individual differences in detecting PTC were first noted by Fox (1931; 1932). It was subsequently suggested that PTC tasting is inherited as a simple Mendelian autosomal trait (Blakeslee and Salmon, 1931; Snyder, 1932), or at least it represents a trait on the borderline of a good Mendelian character (Bodmer and Cavalli-Sforza, 1976). PTC "tasters" are either homozygous for the dominant allele (T) or heterozygous (Tt) while "non-tasters" are homozygous for the recessive allele (t). Recent claims (Rychkov and Borodina, 1969; Ibraimov and Mirrakhaimov, 1979) argue

<sup>1</sup>Anthropology, Ohio University, Athens, Ohio 45701

<sup>2</sup>Laboratory of Biological Anthropology, University of Kansas, Lawrence, Kansas 66045

for the existence of two co-dominant alleles ( $T_1$  and  $T_2$ ), both dominant to the non-taster allele ( $t$ ), with  $T_2$  being responsible for hypersensitivity to PTC. The linkage relationships of the PTC locus with other loci have been of considerable interest (e.g., Gedde-Dahl and Monn, 1967; 1968; Chautard-Freire-Maia, 1974; Cjrandall and Spence, 1974). While Conneally et al. (1976) showed its linkage to the Kell locus, its assignment to a given chromosome is yet to be made.

Most population studies of PTC tasting show a bimodal distribution of taste threshold frequencies, but reports also exist of polymodal distributions in some populations (e.g., Lugg, 1966a; 1966b). A review of the relationships between PTC tasting and disease may be found in Mourant et al. (1978). Its association with thyroid disorders is particularly interesting. While PTC is not a naturally occurring substance, the thiocarbamide group ( $S = C-N-H$ ), responsible for the bitter taste of the compound is also found in a number of antithyroid food sources (e.g., cabbage, Brussels sprouts). It has been, therefore, hypothesized that PTC tasting functions as an oral mechanism for the detection and avoidance of bitter tasting natural goitrogens (Kitchin et al. 1959; Green, 1974). According to this argument, non-tasters and less sensitive tasters may be at a selective disadvantage during the first and second decades of life due to thyroid stress resulting from the ingestion of greater amounts of naturally occurring goitrogens, especially if this is coupled with already low iodine intake. It is noteworthy that Azevedo et al. (1965) found that adenomatous goiter occurs in a significantly higher frequency in non-tasters than in tasters, especially in males. At the same time, the homozygous taster genotype may be at a selective disadvantage during the third and fourth decades of life due to hyperthyroidism.

A number of studies reported an impairment of PTC taste sensitivity with increasing age (e.g., Harris and Kalmus, 1949; Kalmus and Trotter, 1962; Mohr, 1951; Akcasu and Ozalp, 1977). However, these studies ignored the cumulative effect of smoking on the reported deterioration of the ability to taste PTC (Fischer et al. 1963; Kaplan et al. 1964; Eriksson et al. 1970). The purpose of this paper is to report the distribution of PTC taste threshold frequencies in non-smoking Mennonite populations from Kansas and Nebraska, with special attention to the possible effect of aging on PTC taste sensitivity.

## MATERIALS AND METHODS

*Subjects.* During fieldwork in 1979 and 1980 among Mennonite communities of Kansas and Nebraska by members of a multidisciplinary

research team investigating aspects of the aging process, 1157 individuals were tested for PTC taste thresholds. Of this total, 552 were males and 605 were females, with 526 individuals (244 males and 282 females) being members of the Goessel, Kansas, community, 87 (39 males and 48 females) belonging to the Meridian Mennonite congregation, and the remaining 544 individuals (269 males and 275 females) being from the Henderson, Nebraska community. With a few exceptions, all subjects were adults within the 18 to 92 age range.

*Historical background.* Mennonites are a denomination of the broad Anabaptist movement. The origins of this movement may be traced to the turbulence of the sixteenth century and to geographical areas of present day Holland, Switzerland, Poland, and Germany. The historical details of the movement are discussed elsewhere (e.g., Dyck, 1967; Bender and Smith, 1964; Klassen, 1953; and Hostetler, 1959). Let it suffice to say that Mennonite history is complex, and involves the movement of ideas as well as that of people. The persecution experienced by Mennonites in Europe, eventually resulted in the immigration of many Mennonite families to the United States and Canada.

Dyck (1967, p. 145) identifies eight major waves of Mennonite immigrants to the American continent. In the first wave, approximately 100 Mennonites entered the United States between 1683 and 1705 from the Lower Rhine region, while in waves 2 to 5 about 8,000 Swiss Mennonites came between 1707 and 1895. These immigrants first settled in the eastern part of the United States, and then gradually spread westward. The Meridian sample in this study is based on the congregation of Meridian Church of God in Christ Mennonite Church, located near Hesston, Kansas, and organized in 1873. Since the membership of this church is largely Pennsylvania Dutch (Mennonite Encyclopedia, 1973), it seems to represent the descendants of those immigrating with waves 1-5.

The Mennonites settling in the Molotschna Colony of the Ukraine between the late 1780's and the mid 1830's were split by a schism into two factions, one of which became the Mennonite Brethren and the other the General Conference of Mennonite Church. Of these, some 18,000 individuals, largely of Dutch origin, left for the United States and Canada between 1873 and 1884 when it appeared that the Russians might renege on an earlier agreement concerning the permanent exemption of Mennonites from military service. The Goessel and the Henderson samples represent the descendants of these wave 6 immigrants.

Approximately 2,000 Mennonites reside in the Goessel, Kansas, area (Mennonite Encyclopedia, 1973). This region has been inhabited since 1874 by Mennonites, and is currently served by six churches. The Goes-

sel sample was obtained from the three General Conference churches, namely, Alexanderwohl Mennonite Church, Tabor Mennonite Church, and Goessel Mennonite Church. The Alexanderwohl church was organized in 1874 by 265 Mennonites immigrating en mass from Alexanderwohl village in Russia. Tabor and Goessel Mennonite Churches are both offshoots of the Alexanderwohl congregation. Tabor was organized in 1908 and Goessel in 1920, both in response to overcrowding in the Alexanderwohl congregation.

Henderson, Nebraska was first settled in 1874 by 207 Mennonite immigrants from the Molotschna settlement in the Ukraine (Mennonite Encyclopedia, 1973). There are now about 3,000 Mennonites in the Henderson area. The sample was obtained from the four churches now serving this community, namely, Henderson Mennonite Brethren Church, Evangelical Mennonite Brethren Church, Bethesda Mennonite Church, and Calvary Bible Church. Bethesda, a member of the General Conference, was organized in 1874, and Henderson in 1876. The Evangelical Mennonite Brethren Church began in 1882 and the Calvary Church in the 1950's as the result of schisms.

*Procedures.* All subjects were tested under field conditions with a modified version of the Harrison and Kalmus (1949) technique. First, serially numbered solutions of PTC were prepared according to  $1.3 \times 2^{(n-1)}$  grams/liter, where  $n$  is the solution serial number. Subjects were administered the PTC solutions as squirts from polyethylene wash bottles, interspersed with distilled water and the liberal use of tap water as mouth-rinse in order to avoid the build-up of the chemical stimulus. An individual's taste threshold was then scored as the serial number of the weakest PTC solution correctly distinguished from water.

## RESULTS

The PTC taste threshold distributions are given in Figures 1 and 2 for males and females respectively in the three Mennonite groups. The taster/non-taster distribution between the sexes was tested in all samples with  $2 \times 2$  contingency tables. Tasters were defined as those individuals able to taste PTC solutions 4-14. None of the obtained chi-square values were statistically significant. The cumulative distribution of taste thresholds between the sexes was tested with the Kohnogorov-Smirnov two sample test (Siegel, 1956, p. 127), described in Hull and Nie (1979, p. 58). This is more powerful than the  $\chi^2$  test, and is an appropriate measure in this case to test whether or not two independent samples come from

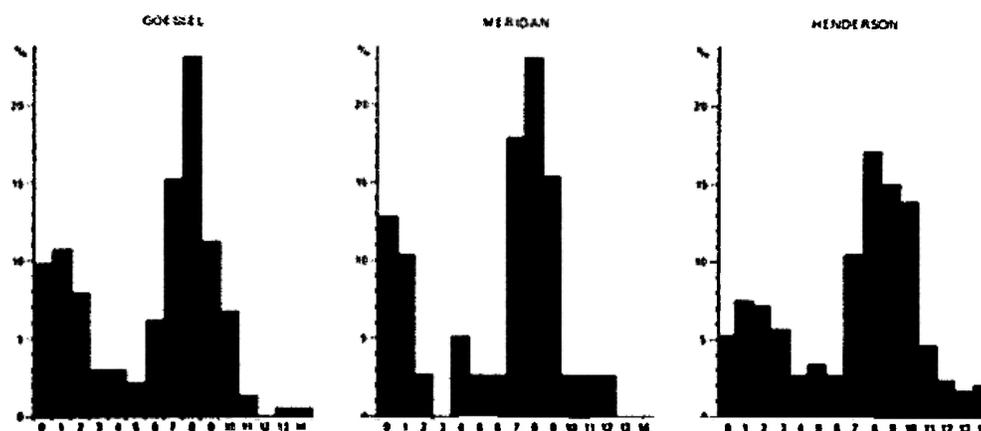


FIG. 1. PTC taste threshold distributions for Mennonite males.

the same population or from populations with the same distributions. This test is extremely sensitive to differences in the distributions from which the two samples were drawn. The results of the Kolmogorov-Smirnov test indicate differences in both the Goessel sample ( $Z = 1.603$ ; 2-tailed  $p = 0.01$ ) and the Henderson sample ( $Z = 1.848$ ; 2-tailed  $p < 0.01$ ). In the Meridan sample the results indicate homogeneity between the two sexes.

Similarly, contingency tables and the Kolmogorov-Smirnov test were used to examine the taster/non-taster distribution and the homogeneity of taste threshold values among the three Mennonite samples. The obtained results indicate genetic differences with regard to the PTC locus among the populations under consideration ( $\chi^2 = 7.88$ ;  $p < 0.02$ ). This difference derives from the uniqueness of the Goessel and Henderson samples, with an excess of non-tasters in both of the sexes in Goessel and an excess of

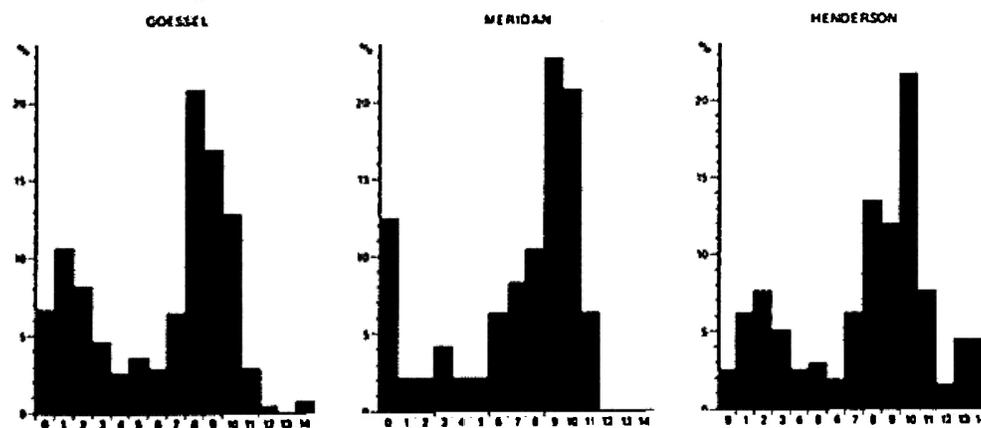


FIG. 2. PTC taste threshold distributions for Mennonite females.

tasters in both of the sexes in Henderson. However, only the differences present among the female subsamples are indicated to be statistically significant with  $\chi^2$  analysis ( $\chi^2 = 5.48$ ;  $p < 0.02$ ). The more sensitive Kolmogorov-Smirnov test, however, indicates statistically significant cumulative distributions for both males ( $Z = 2.148$ ; 2-tailed  $p < 0.01$ ) and females ( $Z = 2.710$ ; 2-tailed  $p < 0.01$ ) between the Goessel and Henderson populations. The Goessel-Meridian and Meridian-Henderson comparisons, on the other hand, yield homogeneous distribution in both of the sexes.

In view of these differences between the sexes and between groups, the effect of aging on PTC taste sensitivity was analysed separately in each subpopulation (i.e., sex, group) by the methods discussed in Sokal and Rohlf (1969, p. 404) for regression. The calculations were carried out with SPSS subprogram Scattergramm (Nie et al. 1970). The results obtained from regression analysis are summarized in Table 1.

An inspection of the obtained results for Pearson's  $r$  and  $r^2$  indicates a poor fit between the regression line and the data, and virtually no relationship between PTC taste thresholds and age, with most variation in PTC taste thresholds left unexplained by variation in age in all of the subsamples under consideration. Obviously, the obtained near zero values preclude a causal relationship between age and PTC taste thresholds in these Mennonite populations. The relationship between PTC taste sensitivity and age was also explored through the reanalysis of the data

Table 1

*Influence of Age on PTC Taste Sensitivity in Mennonite Males and Females*

Statistic Subgroup	Pearson's $r$ (Significance)	$r^2$	Standard Error of Estimate	Intercept a	Slope b
Goessel:					
Male:	-0.074 (0.125)	0.005	3.403	6.476	-0.013
Female:	-0.032 (0.291)	0.001	3.574	6.585	-0.006
Meridian:					
Male:	-0.024 (0.442)	0.000	3.610	6.114	-0.004
Female:	-0.024 (0.433)	0.000	3.580	7.247	-0.005
Henderson:					
Male:	0.013 (0.411)	0.000	3.619	6.673	0.002
Female:	0.035 (0.277)	0.001	3.716	7.199	0.008

separately within tasters and within non-tasters. The results obtained from the Goessel and the Henderson samples support the lack of association between age and PTC taste sensitivity. Small sample sizes in the Meridian sample, unfortunately, precluded meaningful statistical reanalysis of the data separately for tasters and for non-tasters in this group.

#### DISCUSSION

The results of this investigation show that (1) different samples of the same religious isolate differ with regard to the PTC locus, (2) differences at this locus also exist between the two sexes within the same sample, and (3) there is no cause and effect relationship between age and PTC taste thresholds.

If the variation observable in PTC tasting depends only on the alleles present at this locus, then population differences are only a function of gene frequency differences between the populations. Such differences in the present sample could have resulted either from local microdifferentiation (i.e., genetic drift, natural selection) or from sampling accidents in the initial immigrants (i.e., founder effect). However, change over time in an individual's PTC tasting threshold and/or taster status may be induced by the cumulative effect of smoking (Kaplan et al. 1964), and possibly it may also relate to certain types of diseases (Mourant et al. 1978; Balogh and Lelkes, 1961). Between-individual and within-individual variation in the taste receptors introduces an additional problem. It is generally thought that the bitterness of PTC is detected by "taster" genotypes on the dorsal surface and in the back of the tongue. Consequently, the taste buds of the circumvallate, and perhaps the fungiform papillae, are involved in PTC detection. However, observations made by one of us (M.H.C.) indicate that some individuals can detect PTC at the tip of the tongue also. It is noteworthy that taste impulses from the anterior and the posterior part of the tongue are carried by different nerves (Ham and Cormack, 1979, p. 649). In addition, the activity of gustatory papillae changes over time (Allara, 1939; El-Baradi and Bourne, 1951; Harris, 1952). Full development of the gustatory papillae occurs at puberty, and Forrai and Bankovi (1968) did observe a high proportion of tasters at this age. A quantitative decline in taste buds is observed during normal aging, with as much as two-thirds of the gustatory papillae becoming atrophic in old age. Thus, the variation observed in this study between populations and between sexes within a population could have also resulted from

differences between populations or between the sexes in any one or any combination of these variables.

The most interesting aspect of this study is the lack of a cause and effect relationship between age and PTC tasting. An aging effect on the sensitivity of PTC taste thresholds was first suggested by Harris and Kalmus (1949). Subsequently, this age-dependent deterioration was also noted by Mohr (1951), Kalmus and Trotter (1962), Glanville et al. (1964), and Akcasu and Ozalp (1977). The impairment of PTC tasting as a possible function of the age-dependent decrease in the quantity of gustatory papillae was explored by Glanville et al. (1964). However, in view of Pfaffman's (1952) experiment on rats, it was concluded that change in taste sensitivity was not likely to be directly related to the number of taste buds.

Investigations claiming an age-dependent deterioration in PTC taste sensitivity generally ignore the smoking habits of their subjects. Several studies (e.g., Krut et al. 1961; Fischer et al. 1963; Kaplan et al. 1965; and Eriksson et al. 1970), however, report an association between cigarette smoking and the sensitivity to taste bitter substances. The results of this investigation, based on ostensibly non-smoking Mennonite samples, preclude a causal relationship between age and PTC taste sensitivity. Our results, thus, complement those of Kaplan et al. (1964; 1965) which ascribe the observed deterioration in PTC taste sensitivity to the cumulative effects of smoking, rather than to the effect of aging *per se*.

Kaplan et al. (1965) and Fischer et al. (1963) also suggest that the previously reported sex differences in tasting sensitivity, based on data analysed without regard to smoking habits, might be ascribed to the occurrence of different proportions of smokers in the sexes. The female subsamples in this study are more sensitive also in their ability to detect PTC than are the males. However, it is difficult to ascribe this observation to differential smoking habits between the sexes in these ostensibly non-smoking populations. Otherwise, factors as yet unidentified are implicated in the observable sexual difference in the distribution of PTC taste thresholds.

Presumably the observed lack of association between age and PTC tasting is a specific expression of the absence of a cause and effect relationship between aging and the ability to detect bitter tasting substances in general. The relationship between the ability to detect bitter tasting substances on the one hand and sweet, salty, and sour substances on the other is as yet unclear. Byrd and Gertman (1959), and Cooper et al. (1959) report a decline in all four primary taste qualities, Hincheliffe (1962) reports decline in the ability to taste salt and sugar, and Grzegorzczak et al.

(1979) report an increase in salt taste detection thresholds as a function of age. However, Grzegorzczuk et al. (1979) stated that the previous reports of salt taste acuity loss (e.g., Murphy, 1978) have been exaggerated. In addition, these results might have been influenced by uncontrolled factors, for example the smoking habits of the subjects and the specifics of the testing-technique itself.

#### ACKNOWLEDGMENTS

This research was supported in part by NIA grant AG01646-02. MHC was on a PHS Research Career Development Award #5K04DE00028-05, and TAK was on an Ohio University Faculty Fellowship. We thank Gunther Schlager, Laurine Rogers and Genie Trapp for their technical assistance in the analysis of these data. Marcia Early and Laura Poracsky assisted in the preparation of this manuscript. A word of thanks goes to all of the members of the research team who aided in the organization and implementation of this field project. We are grateful to the people of the Alexanderwohl, Goessel and Meridian congregations; without their support and participation this study would not have been possible.

*Received: 27 July 1981.*

*Revision received: 26 January 1982.*

#### LITERATURE CITED

- AKCASU, A., AND E. OZALP 1977 Distribution of taste thresholds for phenylthiocarbamide among different age groups in Turkey. *Pahlavi Med. J.*, 8: 294-304.
- ALLAIA, E. 1939 Ricerche nell'organo del gusto dell'uomo. I. La struttura delle papille gustative nelle eta della vita. *Archivio Italiano di Anatomia e di Embriologia*, 42: 596-561.
- AXELROD, S., AND L. D. COHEN 1961 Senescence and embedded-figure performance in vision and touch. *Percept. and Psychophys.* 12: 283-288.
- AZEVEDO, E., H. KRIEGER, M. P. MI, AND N. E. MORTON 1965 PTC taste sensitivity and endemic goiter in Brazil. *Amer. J. Hum. Genet.* 17: 87-90.
- BALOGH, K. AND K. LELKES 1961 The tongue in old age. *Gerontologia Clinica*, 3: 38-54.
- BASU, A. AND A. K. GHOSH 1965 A note on the distribution of PTC taste sensitivity genes in India. *Acta Genet.* 18: 145-146.
- BENDER, HAROLD S. AND C. HENRY SMITH 1964 *Mennonites and their heritage*. Herald Press, Scottsdale.
- BLAKESLEE, A. F. AND M. R. SALMON 1931 Odour and taste blindness. *Eugen. News*, 16: 105-108.
- BODMER, W. F. AND L. L. CAVALLI-SFORZA 1976 *Genetics, evolution, and man*. W. H. Freeman, San Francisco.

- BYRD, E. AND S. GERTMAN 1959 Taste sensitivity in aging persons. *Geriatrics*, 14: 381-384.
- CAHTWRIGHT, R. A. AND E. SUNDERLAND 1967 Phenylthiocarbamide (P.T.C.) tasting ability in populations in the North of England; with a note on endemic goitre. *Acta Genet.* 17: 211.
- CHAUTARD-FREIRE-MAIA, E. A. 1974 Linkage relationships between 22 autosomal markers. *Ann. Hum. Genet.* 38: 191-198.
- CONNELLY, P. M., M. DUMONT-DRISCOLL, R. S. HUNTZINGER, W. E. NANCE, AND C. E. JACKSON 1976 Linkage relationships of the loci for Kell and phenylthiocarbamide taste sensitivity. *Hum. Heredity*, 26: 267-271.
- COOPER, R. M., I. BILASII, AND J. ZUBEK 1959 The effect of age on taste sensitivity. *J. Gerontology*, 14: 56-58.
- CRANDALL, B. F. AND M. A. SPENSE 1974 Linkage relations of the phenylthiocarbamide locus (*rrc*). *Human Heredity*, 24: 247-252.
- DYCK, CORNELIUS J. 1967 An introduction to Mennonite history. Herald Press, Scottsdale.
- EL-BARADI, A. F. AND G. H. BOURNE 1951 Theory of tastes and odors. *Science*, 113: 660-661.
- ENGEN, TRYGG 1977 Taste and smell. In: *Handbook of the psychology of aging*. J. E. Birren and K. W. Schaie (eds.), Van Nostrand Reinhold, New York, pp. 554-461.
- ERIKSSON, A. W., J. FELLMAN, H. FORSIUS, AND W. LEHMANN 1970 Phenylthiocarbamide tasting ability among Lapps and Finns. *Human Heredity*, 20: 623-630.
- FISCHER, R., F. GRIFFIN AND A. R. KAPLAN 1963 Taste thresholds, cigarette smoking, and food dislikes. *Medicina Experimentalis*, 9: 151-167.
- FORRAI, G., AND G. BANKOVI 1965 Taste sensitivity to P.T.C. in Hungarian school children. *Acta Genet.* 18: 137-144.
- FOX, A. L. 1931 Taste blindness. *Science*, 73: 14.
- FOX, A. L. 1932 The relationship between chemical constitution and taste. *Proc. Nat. Acad. Sci.* 18: 115-120.
- GEDDE-DAHL, T. AND E. MONS 1968 A note on the PGM<sub>1</sub>-PTC linkage relation. *Acta Genet.* 18: 420.
- GLANVILLE, E. V., A. R. KAPLAN AND R. FISCHER 1964 Age, sex, and taste sensitivity. *J. Gerontology*, 19: 474-478.
- GLORIG, A. AND J. NIXON 1962 Hearing loss as a function of age. *Laryngoscope*, 72: 1596-1610.
- GOFF, G. B., B. S. ROSNER, T. DETRE, AND D. KENNARD 1965 Vibration perception in normal man and medical patients. *J. Neurol. Neurosurg. Psychiat.* 28: 503.
- GREEN, LAWRENCE S. 1974 Physical growth and development, neurological maturation, and behavioral functioning in two Ecuadorian Andean communities in which goiter is endemic: PTC taste sensitivity and neurological maturation. *Am. J. Phys. Anthropol.* 39: 139-151.
- GURZEGORCZYK, P. B., S. W. JONES, AND C. M. MISTRETTA 1979 Age-related differences in salt taste acuity. *J. Gerontol.* 34: 834-840.
- HAM, A. W. AND D. H. CORMACK 1979 *Histology*. J. B. Lippincott, Philadelphia.
- HARRIS, H. AND H. KALMUS 1949 The measurement of taste sensitivity to phenylthiourea (P.T.C.). *Ann. Eugen.* 15: 24-31.

- HARRIS, W. 1952 Fifth and seventh cranial nerves in relation to the nervous mechanism of taste sensation: A new approach. *Br. Med. J.* 1: 831-836.
- HINCHCLIFFE, R. 1962 Aging and sensory thresholds. *J. Gerontol.* 17: 45-50.
- HOSTETLER, JOHN A. 1959 *Mennonite life*. Herald Press, Scottsdale.
- HUGHES, G. 1969 Changes in taste sensitivity with advancing age. *Gerontol. Clin.* 11: 224-230.
- HULL, C. H. AND N. H. NIE 1979 *SPSS update*. McGraw-Hill, New York.
- IBRAIMOV, A. AND M. M. MIHRAKHIMOV 1979 PTC-tasting ability in populations living in Kirghizia with special reference to hypersensitivity: Its relation to sex and age. *Hum. Genet.* 46: 97-105.
- KALMUS, H. AND W. R. TROTTER 1962 Direct assessment of the effect of age on P.T.C. sensitivity. *Ann. Human Genet.* 26: 145-149.
- KAPLAN, A. R., E. D. GLANVILLE AND R. FISCHER 1964 Taste threshold for bitterness and cigarette smoking. *Nature*, 202: 1366.
- KAPLAN, A. R., E. V. GLANVILLE AND R. FISCHER 1964 Cumulative effect of age and smoking on taste sensitivity in males and females. *J. Gerontol.* 20: 334-337.
- KIMBELL, G. AND E. FURCHGOTT 1963 The effect of aging on olfactory threshold. *J. Gerontol.* 20: 334-337.
- KITCHIN, F. D., W. HOWEL-EVANS, C. A. CLARKE, R. B. MCCONNELL AND P. M. SHEPPARD 1959 P.T.C. taste response and thyroid disease. *Brit. Med. J.* 1: 1069-1074.
- KLASSEN, WALTER 1973 *Anabaptism: Neither Catholic nor Protestant*. Waterloo: Conrad Press.
- KRAG, C. L. AND W. B. KOUNTZ 1950 Stability of body functions in the aged. I. Effect of exposure of the body to cold. *J. Gerontol.* 5: 227-235.
- KURT, L. H., M. J. PEIRUN AND B. BRONTE-STEWART 1961 Taste perception in smokers and non-smokers. *Brit. Med. J.* 1: 354-357.
- LUGG, J. W. H. 1966a Extremely high acuities of taste for phenylthiocarbamide in human population groups. *Nature*, 212: 841.
- LUGG, J. W. H. 1966b Taste thresholds for phenylthiocarbamide of some population groups. III. The thresholds of some groups living in Japan. *Ann. Hum. Genet.* 29: 217-230.
- The Mennonite Encyclopedia 1973 Cornelius Krahn (ed.) Volumes I-IV. Mennonite Publishing House, Scottsdale.
- MOHR, J. 1951 Taste sensitivity to phenylthiourea in Denmark. *Ann. Eugen.* 16: 282-286.
- MOURANT, A. E., ADA C. KOPEC, AND K. DOMANIEWSKA-SOBCZAL 1978 Blood groups and diseases: A study of associations of diseases with blood groups and other polymorphisms. Oxford University Press, Oxford.
- MURPHY, C. 1979 The effects of age on taste sensitivity. *In: Special senses in aging: A current biological assessment*. Proceedings of the Symposium on Biology of the special senses at the University of Michigan October 10 and 11, 1977. Han, S. and D. M. Coons (eds.) Institute of Gerontology at the Univ. Michigan, Ann Arbor.
- NIE, N. H., C. H. HULL, J. G. JENKINS, K. STEINBRENNER AND D. H. BENT 1970 *Statistical package for the social sciences*. McGraw-Hill, New York.
- PPAFFMANN, C. 1952 Taste preference and aversion following lingual denervation. *J. Comp. and Physiol. Psychol.* 45: 393-400.

- PROCACCI, B. B., G. BOZZA, G. BUZZELLI, AND M. D. CORTE 1970 The cutaneous pricking pain threshold in old age. *Gerontol. Clin.* **12**: 213-218.
- ROVEE, C. K., R. Y. COHEN, AND W. SHLAPACK 1975 Life span stability in olfactory sensitivity. *Developmental Psychology*, **11**: 311-318.
- RYCHKOV, JU. G., AND S. R. BORODINA 1969 Hypersensitivity to phenylthiourea (PTC) in one of isolated populations of Eastern Siberia. A possible hypothesis of inheritance. *Genetika*, **5**: 116-123.
- SIEGEL, SIDNEY 1956 *Nonparametric statistics*. McGraw-Hill, New York.
- SNYDER, L. H. 1932 The inheritance of taste deficiency in man. *Ohio J. Sci.* **32**: 436-440.
- SOKAL, R. R., AND J. ROHLF 1969 *Biometry*. W. M. Freeman, San Francisco.