# A STUDY OF PHENYL-THIO-CARBAMIDE TASTE DEFICIENCY IN A NEGRO POPULATION AND IN FAMILY GROUPS

# A STUDY OF PHENYL-THIO-CARBAMIDE TASTE DEFICIENCY IN A NEGRO POPULATION AND IN FAMILY GROUPS

by

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# PREFACE

The writer wishes to acknowledge appreciation to Dr. Clarence P. Oliver, who directed this problem and whose advice and counsel were invaluable and often sought in the student's graduate career. To many other teachers and students, too numerous to mention here, the writer also acknowledges his indebtedness and deep appreciation for courtesies and kindness received.

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# INTRODUCTION

Laselle and Williams (1926) first recorded the discovery of a differential taste response that was observed in experiments with creatin, a substance found in lean meat, but the genetic implications of the discovery escaped them. It remained for A. L. Fox (1931) to discover the dimorphism in taste sensitivity and to infer its genetic implications. In preparing a solution of phenyl-thio-carbamide (PTC), Fox discovered that the substance was bitter to his co-worker but tasteless to himself. Subsequent studies have proven that the trait, the ability or the inability to taste PTC, is common to man, and to the anthropoid apes as well (Ford, Fisher and Huxley, 1939, 1944). This discovery supplied the geneticists with a new and easily applied tool in the study of inheritance and its use is now widespread.

Physiological basis of this difference in taste reaction is not yet clearly understood, but several experiments have shed light on the problem. Once it was believed that the pH content of the saliva was responsible for this differential taste reaction until Hartmann (1939) showed that the saliva from a taster did not affect the taste blindness of a non-taster and experiments of Blakeslee (1932) also disproved the theory. However, Blakeslee (1931), Fox (1932), Mee (1934), and Blakeslee and Salmon (1935) all suggest that the saliva and not the 'taste apparatus' is the determiner of the ability to taste. Fox suggests the presence of a protein or colloid in the non-taster's saliva that precipitates the PTC as an insoluable substance which cannot evoke a taste reaction.

Cohen and Ogden (1949a) conducted a taste-test, employing 35 college

students, in which PTC was dissolved in water, in saliva of non-tasters, and in saliva of tasters. Neither tasters nor non-tasters perceived any sensory sensation when PTC dissolved in water was placed on a dry tongue. Nor were tasters able to taste PTC when dissolved in the saliva of another taster and placed upon a dry tongue. There was no noticeable change in effect upon the non-tasters. To further check the influence of saliva upon taste perception, saturated aqueous solutions of salt and saccharin were tried on 27 individuals. All were able to taste the solutions when placed upon a wet tongue but sixteen individuals failed to taste the saccharin and nine failed to taste the salt when solutions were placed upon a tongue that had been dried previously. The results from these tests suggest that taste perception depends upon the 'taste apparatus' and the saliva. The 'taste apparatus' is extremely sensitive and highly specialized to the particular saliva that the individual possesses and this saliva-difference is genetic.

Colin (1949) suggests that these taste differences may well depend upon differences in the nervous system. The nervous system is certainly involved, but, in the light of the results of the experiments of Cohen and Ogden just cited, a satisfactory answer to the problem cannot be based entirely upon neurological differences.

Cardullo and Holt (1951) discovered that the ability or inability to taste PTC is present at birth. This trait, according to the accepted hypothesis, is due to the presence of a pair of alleles T, t; one dominant (T) and one recessive (t). The phenotype referred to as taster is composed of homozygous dominants (TT) and the heterozygotes (Tt) while the non-tasters are homozygous recessives (tt). Hence, the genetic basis for tasters is

the presence of at least one dominant gene (T) and the basis for non-tasters is the presence of two recessive genes (tt). However, evidence from the study of monozygotic twins (Rife 1938) indicates that cases of incomplete penetrance of the taster allele sometimes occur and genotypes have been observed that fail to express the phenotype characteristic of their genic composition.

The hypothesis of only two alleles at the locus for this trait is not accepted by Botsztejn (Quoted by Cohen and Ogden 1949b) who conducted an elaborate twin-study wherein he divided his population into three groups--tasters, tasters weak, and taste blind. Botsztejn proposed a theory based upon the action of multiple alleles to account for all the classes and for the results obtained. Boyd and Boyd (1937 ) also believed that the theory of two allelomorphs, one dominant and one recessive, is too simple to account for the frequencies observed by them.

Taste reactions to chemicals belonging to the group possessing at least one thio atom in the molecule and showing a $= \underset{\underset{S}{\|}}{N} - C -$ grouping correlate closely with the reactions evoked by PTC. There exist many other chemicals, not containing the sulphur atom nor showing this characteristic grouping, that show a distribution of threshold taste reactions. A study that investigated the possible correlation between reactions to these compounds might well show the existence of other allelomorphs that influence our taste perceptions.

The complexity of the reactions involved in smell and taste has been recognized by many. Blakeslee (1935) suggests that these sensory

reactions are greatly influenced by our physiological states and vary with each individual from day to day and even from hour to hour.

It was natural that Fox, being a chemist, should become interested in the compound itself after such a varied response was observed. Fox (1932) tested a large number of compounds closely related to PTC after other workers had demonstrated that tasters and non-tasters existed for many of these compounds, also. He found twenty related compounds that elicited differential responses and four closely related compounds that failed to do so. All twenty-four compounds were thio-carbamides and Fox concluded that the specific element responsible for this sensory reaction was the -C- group. He showed that the substitution of the thio atom by an
S
oxygen atom in any of these compounds robbed the compound of the ability to evoke this differential response.

Blakeslee and Salmon (1935) conducted an intensive test on forty-seven individuals, employing the threshold method for fourteen varied compounds, and observed only slight or no correlation between the thresholds for these substances and the thresholds for PTC. Snyder (1937) employed crystals of diphenylguanidine in a test on a large number of individuals and discovered that some could taste the substance and some could not. Those who could taste the substance found it bitter and were classed as tasters and those who could not were classed as non-tasters. The same individuals were classified for reaction to PTC in the same manner and the results indicated that the responses to the two substances were independent.

Barrows (Quoted by Harris and Kalmus 1949b) found no correlation between the inability to taste brucine (dimethoxystrychnine) and the inability to taste PTC. It is of interest to note that brucine is obtained from the seeds of nux vomica and from Ignatius beans. Hopkins extracted from the seeds of Conringa orintalis (hare's ear mustard) the substance dimethyl-thio-oxazaldine and found that the crystals are bitter to PTC tasters and tasteless to PTC non-tasters.

Harris and Kalmus (194b) conducted intensive tests determining the threshold for sixteen compounds. The correlation coefficients they obtained divided the compounds into two classes, high positive correlation and slight or zero correlation with the reactions to PTC. The group with the high positive correlations all possessed a thio atom, in the molecule, involved in a characteristic $=\underset{\underset{S}{\|}}{N}-C-$ linkage and were, for the most part, synthetic compounds. Thus we might conclude that the chemical specificity for this reaction is bound in the $=\underset{\underset{S}{\|}}{N}-C-$ linkage.

Blakeslee and Salmon (1931) showed that the inability to taste PTC is inherited as a simple Mendelian recessive. The same conclusion was reached independently by L. H. Snyder (1931). Further studies illustrated the bimodality of the threshold distribution curve, with females showing a lower threshold than males, resulting, when classed according to sex, in a shifting of the curve for females down the scale of thresholds (Snyder 1936; Falconer 1947; Setterfield, Schott, and Snyder 1936). This threshold difference in the sexes is not interpreted to indicate a real difference in the

distribution of genotypes among men and women but is taken as a sex difference in sensitivity. This difference in sensitivity between the sexes varies in different populations and in different races.

The frequency distribution of thresholds varies for races as well. This fact makes it extremely desirable that the selection of a critical solution, one that separates tasters from non-tasters, be based upon results of threshold tests and not chosen arbitrarily. The arbitrary choice of the critical solution could lead to gross error in the classification of the phenotypes.

The relationship of age to threshold for PTC has only recently been considered. Harris and Kalmus (1949a) in a test that involved 441 males ranging from 10 to 91 years of age, concluded, "A real deterioration with age (about one dilution step for each 20 years) in taste sensitivity occurred." This was true for both tasters and non-tasters. This change is probably due to physiological changes that occur in the process of aging, probably involving the decrease in number of taste buds in the foliate papillae.

According to the conclusions by most investigators, taste ability is inherited in accordance with Mendelian laws as govern the involvement of two allelomorphs, one dominant and one recessive, that is, if we are willing to accept the exceptions pointed out by Rife (1938) as cases of incomplete penetrance. As previously stated, in the discussion of genetic basis for the trait, tasters possess at least one dominant gene (T) and non-tasters possess two recessive genes (tt). Hence, in the mating of non-taster (tt) to non-taster (tt), only non-taster offspring (tt) are

expected. In the mating of taster to non-taster, there exist two probabilities; that the taster is homozygous (TT), or that the taster is heterozygous (Tt). The occurrence of the first probability would produce only heterozygous (Tt) taster offspring, while the occurrence of the second probability would produce both homozygous (tt) non-taster and heterozygous (Tt) taster offspring with equal frequencies. In the mating of taster to taster, there exist three probabilities; that the mating involves two homozygotes (TT), that the mating involves one homozygote (TT) and one heterozygote (Tt), or, that the mating involves two heterozygotes (Tt). In the occurrence of the first probability (TT x TT) only homozygous taster (TT) progeny would be expected, and in the second probability (Tt x TT) also, only taster progeny could be expected but with different genotypes, homozygous (TT) tasters and heterozygous (Tt) tasters occurring with equal frequency. In event of the occurrence of the third probability (Tt x Tt), both taster and non-taster progeny would be expected in the ideal ratio of three tasters to one non-taster. According to the genotypes expected, the ratio would be 1 (TT) : 2 (Tt) : 1 (tt). It might be stated here that there is at present no known method of distinguishing between homozygous and heterozygous tasters except in those cases where the observation of their progeny furnishes the answer; the genotypes of the parents can sometimes be determined by the phenotypes of their offspring. The results of this method have proven so reliable that they, along with the results of serological tests, could be used in the courts of law in cases of doubtful paternity.

Snyder (1932), in a test involving 3643 whites of both sexes recorded 70.2% tasters, a frequency of 0.454 for gene T and 0.546 for t. Levine and

Anderson (1932) found 94% tasters in a sample of pure American Indians, a frequency of 0.755 for T and 0.245 for t. The racial variationsrecorded range from 40.8% non-tasters or 0.361 for T in the eastern Eskimo to 6% non-tasters or 0.755 for T in New York Chinese (Barnicot 1950). Lee (1934) in a sample of 3156 American Negroes figured the frequencies to be: T .695 and t .305. A worker for Lee tested 805 Egyptian Sudan natives and reported the proportion of tasters to be 95.8%, a frequency of .2049 for t and .7951 for T.

Terry (1950), in a study of the Negro population of Jamaica reports 9.44% non-tasters in the general colored population, but observed only 3.26% non-tasters among the Maroons of Acompong, an endogamous group. It is now evident that the frequencies for the taster gene varies in different races (Parr 1934, Boyd and Boyd 1937) and in endogamous groups within races as well (Sanghvi and Khanolkar 1949).

The genetic significance of this trait, the ability or the inability to taste a synthetic compound that does not occur in nature, is not yet satisfactorily explained. The presence of the trait in the anthropoid apes suggests the appearance of the trait in some common ancestral stock before the separation of anthropoid and man (Ford, Fisher and Huxley 1944). The mere existence of such a gene poses many questions, and one of the most important is the question of function. What can the function of such a gene be?

Boyd (1950) suggests that the function of the gene may in some way be related to glandular function. Support for the suggestion lies in studies made possible by the discovery and isolation of a compound that oc-

curs in nature (Astwood, Greer and Ettlinger 1949), in members of the genus Brassica which includes cabbage, turnips, cauliflower, kholrabi, etc. This compound, 1-5-vinyl-2-thio-oxazolidone, and other related compounds, act as antithyroid drugs and evoke a differential taste reaction that has high positive correlations with the taste reactions to PTC. It thus seems probable that the gene that controls the ability to taste PTC also controls the ability to taste these compounds that occur in nature.

The homozygous non-taster might be unduly insensitive to these antithyroid compounds which occur in nature, a fact which would constitute a selective disadvantage in areas poor in iodine. Thus the heterozygote would possess the better endocrine balance (Boyd 1950). The heterozygote might enjoy some selective advantage over both homozygotes. Fisher, Ford and Huxley (1939) demonstrated the presence of the gene in the anthropoids, a fact that suggests the existence of the gene over a very long period of time. The persistence and established equilibrium of this gene, in the face of selection and/or genetic drift, lend credence to such a hypothesis (Darlington 1943). It is possible that this gene is of evolutionary importance, and at some earlier stage was more important to survival than seems to be true at this stage in evolution.

The taste reaction to PTC has proven a handy tool to the geneticists. The test is quite simple and easily given under field conditions and the reaction is easily measurable. The results from these tests, along with results from other tests, have been used in deciding cases of doubtful paternity, in the study of the probable origin of ethnological groups and races, and in the attempt to establish linkage groups in the study of human genetics.

The establishment of linkage groups in man would be of extreme importance and would aid in furnishing answers to many questions in human genetics now unanswerable. Man cannot be studied in the laboratory, as have been Drosophilia, Habrobracon, and other laboratory subjects, due to man's long life span and our inability to establish necessary controls. The only means available to establish chromosome maps and linkage groups are through statistical studies applied to vast amounts of data on as many traits as possible. The taste reaction fits the requirements for such studies.

The purpose of this study is to add to the data already assembled on taste reaction and to compare results obtained with the study of Lee and others on the American Negro.

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## MATERIALS AND METHODS

A pilot test was first run to allow the student to become familiar with the problems involved in mass testing. Paper strips impregnated with phenyl-thio-carbamide crystals were used in these tests. The paper method was chosen because of the ease with which the test could be administered under field conditions. It has been shown (Harris and Kalmus, 1950a) that the use of solutions is the most efficient method for testing with PTC, especially when thresholds are to be determined. This method is not adaptable to mass testing necessary in population studies and did not suit our purpose.

Two grams of PTC crystals were weighed and placed in a 1000 cc flask and the flask filled to the 1000 cc mark with acetone, thus making a 0.2% solution of PTC. Acetone was used as a solvent because the PTC crystals are readily soluble in the compound, and because acetone evaporates rapidly and completely leaving the crystals in the paper and no residue or after taste of its own. In the pilot test, only a single solution of 0.2% was used as no attempt to determine thresholds was made.

In hopes of eliminating elements of the sense of feel from the taste tests, the smoothest textured paper available was used. Large sheets of 250 mm x 250 mm filter paper were quartered into squares which were small enough to be immersed into a large petri dish containing the 0.2% solution of PTC. The petri dish was kept covered, as much as the operation allowed, to prevent excessive evaporation of the solvent, for rapid evaporation would increase the concentration of the remaining solution and it was desired to produce the test strips of as uniform strength as possible.

After the squares were thoroughly soaked they were removed from the solution and placed upon clean sheets of filter paper to dry. The dry squares were cut into the desired shapes with a paper knife. Controls, pieces of paper without the PTC, were also cut into desired shapes in the same manner. Two controls were used in the pilot test, one before the strip containing the PTC and one after. (Fig. 2). It was discovered that those who could taste the strip containing the PTC crystals were often confused by the taste remaining from the treated strip so that the last control was often recorded as bitter or sour, also. The second control was eliminated from the final test.

In the final test, the 0.2% solution was serially diluted; one part in two to produce a 0.1% solution, one part in four to make a 0.05% solution, one part in eight to make a 0.025% solution, and one part in sixteen to make a 0.0125% solution. Squares of filter paper were impregnated with each of these solutions and when dry were cut into desired shapes, a characteristic shape for each concentration (Fig. 4).

It has been shown (Hagy, 1948) that some tasters with extremely low thresholds could taste PTC on control paper that had been rubbed against strips containing the 0.2% solution of PTC, so care was exercised to keep the various strips separated at all times. These different-shaped strips of paper were passed out separately at the time of testing. Mimeographed forms of two pages were given all persons taking the tests. The first page contained information concerning the test, its harmless nature, general instructions, and the fact that no abnormality was involved in the differences observed in taste reactions. The second page contained directions for taking the test and a chart for recording reactions. In the pilot test, this sheet

also contained blanks to fill in information concerning the person taking the test, such as name, age, address, preference for cabbage and turnips, etc. (Fig. 2). It was noted that many of the tasters failed to fill in this information, probably due to their reactions to the bitter or sour taste experienced. This information blank was therefore moved to the first page in the final test (Fig. 3).

A report (Astwood, Greer and Ettlinger, 1949) of the discovery of a compound, found in the genus Brassica, which showed the NCS linkage and evoked a differential taste response caused the consideration of the possibility that some observable correlation exists between the preference for these vegetables and the ability to taste PTC. The pilot test only investigated the preference for cabbage and turnips. In the second test, it was attempted to determine the taste reaction to cabbage and turnips, and blanks were provided to fill in this information (Fig. 4).

These tests were administered to an entire class of students at the time. The students were always informed that there is no abnormality in the individual who can or can not taste the test-pads, and that taste patterns for PTC differ as much in individuals as do the color of the eyes, the texture and color of the hair or the shape of the nose.

Each class was supervised closely, being instructed when and how to use each test pad. The procedure was to first wet the pad on the tongue and if no taste was experienced to chew the pad slightly, and if then no taste was discovered, to discard the pad from the mouth. This procedure was followed with each test pad. The student recorded his reactions in the proper column under the shape of paper being tasted. Pep-O-Mint Life Savers were

passed out after the test to counteract the taste.

In the final test, the same procedure was followed except that the test pads were placed in separate compartments of a box and were passed separately to individuals taking the test. The Pep-O-Mint Life Savers were placed in separate coin envelopes which were used for disposing the discarded test pads. In consideration for the tasters, the students were instructed that an individual receiving an intense taste reaction from any test-strip need not try the following strip which would be of higher concentration. They could then use the Life Saver to remove the bitter taste. Those receiving no reaction were instructed to proceed with the test to the end. All the final tests were supervised personally.

The population used in the pilot test consisted of 141 students and teachers of Samuel Huston College. The population in the final test was composed of 327 students and 3 teachers of Anderson High School. This latter group represented the science classes from the ninth through the twelfth grades.

At the same time that the population tests were being conducted, tests were being run on available family groups. The family groups were not selected as carefully as the population in the pilot test with regards to meeting the requirements for statistical validity as representative of the Negro group as a whole. Any families who could be completed and who would cooperate were used in analysis. Only families where both parents were available for testing were used. The same materials and method of testing were employed in family studies as in the population tests other than that the tests were given to one individual at the time and were administered in

the homes whenever the persons could be contacted. Only eleven family groups could be completed and this group totaled sixty-two parents and offspring.

## RESULTS

### Pilot Study

The population in the pilot test consisted of 141 individuals mostly in the 15 to 25 year age-group. From this group 23 were omitted from the analysis because of insufficient information or because they tasted the first control strip. This represents 16.3% of the population. It is thought that failure to impress sufficiently upon the population being tested the fact that taste blindness is not an abnormality was partly responsible for this high percentage of tests being unusable.

As only one solution (0.2%) was used in this instance, it can be said only that the population was divided into two groups. One group had a threshold of 0.2% or less, and one group a threshold greater than 0.2%. The people having the threshold greater than 0.2% numbered 15 and represented 12.71% of population. The group with threshold of 0.2% or less included 103 individuals and was 87.29% of the total. Those with threshold greater than 0.2% can be listed as non-tasters, but the other group contains both tasters and non-tasters. The final and more complete test showed that the critical solution--one that divides tasters from non-tasters--is 0.1% (Fig. 5).

The population used in the pilot test was composed of 64 males and 54 females, of whom 52 males and 48 females were included in the group with thresholds of 0.2% or less--a percentage of 81.25 for the males and 88.89 for the females. Of the group with thresholds greater than 0.2%, 12 were males and 3 were females. 18.75% of the males and 11.11% of the females were in this group. As stated previously, the method of grouping used does

not provide us with material that can be tested for gene frequencies since one group contains both tasters and a small number of non-tasters.

Fifty of this population were smokers. The two-fold (2 x 2) contingency table was used to analyze for possible correlations between smoking and ability to taste PTC. The contingency table determines Chi square and a reference to a Chi square table will reveal a value that represents the probability of obtaining, due to chance, results as poor as or worse than results obtained. If this value is small, less than .05 which is observed as a fiducial point, the deviation between the observed data and the actual data is considered as significant and due to factors other than chance.

The two-fold contingency table is composed of four cells as follows:

| | T | NT | |
|---|---|---|---|
| S | a | b | (a + b) |
| NS | c | d | (c + d) |
| | (a + c) | (b + d) | Total |

where S = smokers, NS = non-smokers, T = tasters, NT = non-tasters.

The following is the formula for determining Chi square:

$$\frac{(\ (ad) - (cb)\ )^2\ (\text{Total})}{(a + c)(b + d)\ (a + b)\ (c + d)} = X^2$$

in which the difference, squared, between the products of the diagonals is multiplied by the grand total, this result divided by the product of the subtotals gives Chi square. Table 2 gives the analysis for these data.

The population was also divided on the basis of preference for cabbage and turnips to see if there existed a correlation between the preference for these vegetables and ability to taste PTC. Of the 103 tasters in the population, four gave no information concerning their preference.

Eighty-five tasters out of 99 liked cabbage and 13 non-tasters out of 15 liked cabbage, representing 86% of the tasters and 86.6% of the non-tasters. Fifty-four per cent of the tasters and 53.25% of the non-tasters liked turnips, while 51.5% of the tasters and 53.25% of the non-tasters liked both cabbage and turnips. Only 11.1% of tasters and 13.3% of non-tasters liked neither. Table 4 presents the analysis of these data.

No conclusions were drawn from the analysis of the data on food preference as it was recognized that too many factors affected taste preferences. Family food habits, economic and social status, and psychological conditions are a few such factors. Some persons liked turnips and cabbage because of what was to them a bitter taste and this fact, also, made it difficult to discover correlations on the basis of the questions asked. (Do you <u>like</u> cabbage? Do you <u>like</u> turnips?) It was decided to ask, in the next test, how raw cabbage and how raw turnips tasted to the person being tested and the blank in the second test listed suggestions as to their probable taste (Fig. 4).

## Threshold Tests

The population in the second test was composed of 327 high school students and 3 teachers, a total of 330 individuals. Of this population, 61 individuals were invalidated because they tasted the control or tasted one solution and recorded a stronger solution as having no taste. This group contained 28 males and 33 females and represented 18.49% of the population tested; 20% of the males and 17.37% of the females tested were thus omitted.

The sample was taken from Anderson High School, Austin, Texas. The

population of a high school was selected rather than a college group because it was believed that representatives from the lowest grade through the highest grade would represent more nearly a random sample of the Negro population. Compulsory education in public schools works against selection and makes this probability more likely.

In determining thresholds, the first concentration from low to high to which there was a recognizable taste reaction, whether bitter, sour or sweet, was recognized as the threshold. Salmon and Blakeslee (1935) testing with solutions discovered that individuals often possessed a "Twilight Zone"--a range of varying taste impressions, such as sweet, sour, salty, astringent or metallic, leading up to the threshold where the individual recognized a distinct, bitter taste. However, Hagy (1948) in his study of individual taste patterns, showed the existence of individuals who taste as sour, in increasing intensity, all concentrations from .05 to .2. Two individuals in our test recognized the taste of all solutions as "salty" and another recognized the taste as "like pepper." The basis for this difference is not yet understood. These individuals received a distinct taste from the PTC and were classed as tasters and assigned threshold values just as those that tasted PTC as bitter.

The frequency distribution of thresholds for both males and females is shown in Figure 5, for males in Figure 6, and for females in Figure 7. These data are given in Table 1. The solution that divides tasters from non-tasters, called the critical solution, should be determined by threshold tests. The solution with the lowest frequency distribution has been considered as the critical solution. The tables indicate 0.1% solution since

only one individual in the sample reacted to this concentration. All persons with thresholds lower than 0.1 are considered as tasters, and all persons with thresholds of 0.1 and higher are considered non-tasters.

This sample exhibits the characteristic bimodal threshold distribution curve as found by other workers (Snyder 1936; Falconer 1947; Setterfield, Schott, and Snyder 1936). The sample was considered too small to afford a valid comparison of threshold distributions of the two sexes, but 7.14% males were non-tasters and only 4.45% of the females. Indicating that a sex difference as found in other groups exists in the American Negro. However, the difference in proportions of non-tasters in the sexes is not statistically significant.

In testing the significance of the difference between the two sexes, the standard error was determined for the sample and for both males and females by employing the formula:

$$\text{S. E.} = \sqrt{\frac{T \times t}{N}}$$

where T equals the per cent of tasters and t equals the per cent of non-tasters, and N equals number in sample.

$$\text{S. E. for sample} = \sqrt{\frac{(.9442) \times (.0558)}{269}}$$

$$= .1399 \text{ males and females}$$

$$\text{S. E. for males} = \sqrt{\frac{(.9285) \times (.0715)}{112}}$$

$$= .02435$$

$$\text{S. E. for females} = \sqrt{\frac{(.9554) \times (.0446)}{157}}$$

$$= .01648$$

Using the S. E. for males and the S. E. for females, the standard error of the difference was determined by employing the formula:

$$\text{S. E.}_d = \sqrt{(\text{S. E.}\,♂)^2 + (\text{S. E.}\,♀)^2}$$

$$= \sqrt{(.02435)^2 + (.01648)^2}$$

$$= .0294$$

The deviation between the sexes determined for tasters,

$$= .9554 - .9285$$

$$= .0269$$

and this value compared with the S. E.$_d$,

$$\frac{.0269}{.0294} = .9149$$

The difference between the sexes is just .9149 times the standard error of the difference. This is less than one standard error and hence the deviation within the sample is not statistically significant and such a deviation could be expected to occur by chance in better than 65% of the samples drawn from the same population.

Grouping the sample on the basis of the critical solution, 0.1, into tasters and non-tasters gives 94.42% tasters and 5.58% non-tasters. From these values, the gene frequency in the sample can be determined by the application of the frequency method (Snyder 1932, 1934). In the study of

those traits where it is impossible to distinguish between heterozygotes and homozygous dominants, one can estimate the gene frequencies by the use of the frequency of the recessive type, on the assumption that matings have occurred at random in so far as the taste-trait is concerned.

The method makes use of the formula,

$$(p + q) = 1$$

where p equals the proportion of the dominant gene T, and q equals the recessive gene t, and 1 equals the sample. Each individual carries two genes for the trait, and $p^2 + 2pq$ represents the proportion of the tasters, which includes the homozygous dominants and the heterozygotes, while $q^2$ equals the non-tasters and includes only the homozygous recessives. Since this latter group includes only a single class, we can determine the frequency for the recessive gene t.

$$q^2 = .0558$$

$$q = \sqrt{.0558}$$

$$= .2362 \text{ or } 23.62\% \text{ the frequency of gene t.}$$

then $$p = 1 - q$$

$$= 1 - .2362$$

$$= .7638, \text{ or } 76.38\% \text{ the frequency of gene T}$$

Now $$p^2 = (.7638)^2$$

$$= .5834$$

and $$2pq = 1 - (p^2 + q^2)$$

$$= 1 - (.5834 + .0558)$$

$$= .3608$$

Translating decimal values into percentages, our population consists of 58.34% homozygous tasters, 36.08% heterozygous tasters, and 5.58% homozygous non-tasters.

The use of this method of computing the gene frequency in this sample is considered justifiable (Hogben 1946) in that the population from which the sample was drawn is a fairly homogeneous isolate, occupying the same restricted geographic locale and subject to a high degree of nonassortive mating, and in that the trait is a common one.

## Family Studies

The 11 families completed were composed of both parents and at least one offspring, with one family wherein there were 10 children available for the tests. Of the 11 matings observed, 6 were taster x taster, 3 were taster x non-taster, and one was non-taster x non-taster.

From the taster x taster matings only taster offspring were observed. From the non-taster x taster matings, 12 tasters and 3 non-tasters were observed. From the non-taster x non-taster mating, there were four offspring. Three were non-tasters and the fourth is probably a non-taster, also. The fourth, a girl six years of age, was tested last and claimed to have tasted the strip containing the .0125% solution but said that the following strips had no taste, but judging from the expression on the child's face at the time of testing, it is strongly believed that no taste was experienced on any of the strips. The child is therefore listed as a non-taster.

## DISCUSSION

Little can be done statistically with the data obtained in the pilot test, because grouping of the sample was done with a single, 0.2% solution and the later threshold tests indicate that 0.1% is the critical solution for the Negro population. As stated previously, it can be said only that the sample was divided into groups: one group with thresholds of 0.2 or less, and another group with thresholds greater than 0.2. Into the first group fell 87.3% of the subjects and into the latter group, 12.7%.

The analysis of the data for possible correlation of smoking and ability to taste a 0.2% concentration of PTC (Table 2) indicates that the observed association for males, and that the males and females combined closely approach the expected association on the assumption that the two events are independent. The probability for males, less than .90 and greater than .80, indicates that such a deviation of observed from expected could be due to chance in excess of 80 times in a 100 of such random samples. The probability for males and females combined, less than .20 and greater than .10 is much lower but still indicates that the deviation is statistically insignificant.

Probability for the females alone, less than .05 and greater than .02, is significant and indicates that factors other than chance are responsible for such a deviation. This sample was drawn from a religious school where smoking by females is prohibited and smoking in general is frowned upon. The girl students would hardly admit, in writing, an infraction of the rules of the institution. This is probably one of the factors contributing to the deviation.

The ancestors of the present Negro population were imported from widely different parts of Africa and brought with them a diverse array of genetic materials, with gene frequencies for identical traits probably varying significantly. It is now believed however that the present Negro population represents a single race with specific gene frequencies unlike any of its ancestors (Stern 1949). This is no doubt true, but since it is recognized that random or nonassortative mating actually occurs only within a single relatively small isolate (Hogben 1946) of a racial group, one could expect to find isolates within the Negro race where the frequencies for a specific gene would vary, and in some instances vary significantly.

Lee (1934) recognized the fact that the American Negro group is not the result of random mating within the group. He believed that there exists a continuous inflow of genes from sympatric populations. He also recognized the existence of a large degree of selective mating within the hybrid element.

It is regrettable that this study cannot be compared with Lee's. The data for the two studies were gathered by different methods. Lee did not test for thresholds. He employed crystals of PTC to determine tasters and non-tasters. This points out the need for the adoption of uniform techniques of testing for identical traits. The use of uniform techniques would make available vast amounts of data for statistical analysis and would make possible the comparison of races or isolates with other races or isolates where ever tested.

In the absence of available data, it was decided to compare the pilot test with the second test. The population of the pilot test was composed of college students and the population of the second test was composed of

high school students.

Deterioration of taste acuity due to age is considered to be one dilution step for each 20 years (Harris and Kalmus 1949a). However, any deviation observed between the college and high school populations can hardly be attributed to difference in age because only 15 individuals in the college group exceed 30 years of age and of these 15, only 2 possessed threshold greater than 0.2%.

Although thresholds were not determined in the pilot test, we can compare the two observations on the basis of ability to taste 0.2% concentrations. In the sample from the college group, 103 registered thresholds of 0.2 or less while 15 registered thresholds greater than 0.2%. In the high school group, 261 registered thresholds of 0.2 or less while 8 registered thresholds greater than 0.2. The following are the percentage values: for the college sample, 0.2 and less, 87.29%; greater than 0.2, 12.71%; for the high school sample: 0.2 and less, 97.03%; greater than 0.2, 2.97%.

The application of the Chi square method (Stern, 1949) of comparison of two sets of data where there is no a priori expectation allows the determination of the probability of these two sets of data being drawn from the same general population. For convenience, the college sample is designated as A and the high school sample as B. The observed results are:

| | Taste 0.2 | Not Taste 0.2 | Total |
|---|---|---|---|
| Sample A | 103 | 15 | 118 |
| Sample B | 261 | 8 | 269 |
| Total | 364 | 23 | 387 |

The expected value for each class is derived by determining the proportion of each sample to the total for both samples and taking that proportion of the total for that particular class. Thus there were 387 individuals included in both samples and the 118 individuals in Sample A is .3049 times the total. Hence the class taste 0.2 in Sample A would be expected to contain .3049 times 364, the total for class taste 0.2 in both samples. Expected values for the other class are arrived at in the same manner. Then Chi square and probability are determined as in the previous problems.

| | Taste | Not Taste | |
|---|---|---|---|
| | 0.2 | 0.2 | Total |
| Expected A | 111 | 7.013 | 118 |
| Expected B | 253 | 15.987 | 269 |
| Total | 364 | 23 | 387 |

$$X^2 = \frac{(103 - 111)^2}{111} + \frac{(261 - 253)^2}{253} + \frac{(15 - 7.013)^2}{7.013} + \frac{(8 - 15.987)^2}{15.987}$$

$$= 13.9156$$

$$N = 1$$

$$P = \text{less than } .001$$

The $X^2$ value indicates that the deviations observed between these two samples are not the obvious result of chance and that some other factor or factors may be responsible.

Hagy (1948) sampled 62 Negro college students and found 10.29% non-tasters employing the same paper method and the same critical solution as employed in this study. This value is in close agreement with the per cent of non-tasters in our college group and fits the opinion that there may

exist a true difference between the college and high school populations.

The sample of family groups obtained is too small to afford data adequate for analysis. But it can be said that the results observed are close to the expected. In the taster x taster matings in the actual population, there would occur some non-taster offspring because this combination of parents would include some matings between heterozygotes. Since the frequency of the heterozygotes (2pq or .3608) is lower than that of homozygous tasters (.5834) in the Negro population, it may be assumed, without too much risk, that each of the six matings observed included at least one homozygous taster thus accounting for the fact that the twenty-five offspring observed from these matings included no non-tasters.

In the matings of taster x non-taster, fifteen offspring were observed, twelve tasters and three non-tasters. As stated previously, there are two probabilities in such matings: the taster mate may be heterozygous (Tt), or may be homozygous (TT). The expected ratio of taster to non-taster offspring in the first probability will be 1:1, while in the second probability the ratio would be 1 taster to 0 non-tasters. There were three matings of this type observed and only one had produced no non-taster offspring. It may be concluded that in at least two of these matings, the taster parent was heterozygous or that chance was responsible for the lack of a non-taster child.

Only one mating of non-taster x non-taster was observed and considering the low frequency for the recessive gene in the population under study, it was unusual luck that such a small sample should contain one such mating. From this mating there were four offspring. Three were non-tasters with

thresholds of 0.1, 0.2, and greater than 0.2. The fourth, a girl of six years, is in all probability a non-taster, also. She claimed to have tasted the strip .0125 as very bitter, but declared the strips with higher concentration (.05, etc.) as having no taste. Her facial expression during testing indicated that she probably did not taste any of the strips during the test. It was also noticed that she did not rush to get the Life Saver into her mouth as did those children of her age who did experience a very bitter taste. She was classified as having a threshold greater than 0.2 and hence a non-taster. This, according to Mendelian laws as govern a single gene substitution, meets the expected--only non-taster offspring from non-taster parents.

A pair of identical male twins were found in one family tested. Fortunately, they were tested at different times and different places on the same afternoon. One was at home and the other at his father's garage. It is interesting to note that their taste patterns and thresholds were identical.

| | Control | .0125 | .025 | 0.5 |
|---|---|---|---|---|
| Twin A | NT | NT | Bs | Bv |
| Twin B | NT | NT | Bs | Bv |

NT indicates no taste; Bs, slightly bitter; Bv, very bitter. This is in accord with the expected findings. However, Rife (1933, 1938) and Ardashnikov (1936) report identical twins with variations in their taste thresholds for PTC.

Among the forty-four offspring of the eleven pairs of parents, seven were non-tasters. This is a much higher incidence (.16) of non-tasters than observed in the general population. The small size of the sample and the

presence in the sample of the non-taster mating can be assumed to account for this high percentage of non-tasters.

Thresholds of the offspring, except in one instance, were never higher than the thresholds of both parents. In the one exception, the thresholds of the parents were .025 and .05, but one child recognized a slight bitter taste on .0125 although he did not recognize a very bitter taste until .05 was used.

## SUMMARY

1. In the American Negro population the dominant allele (T) for taster occurs with a high frequency, probably higher than that determined in previous studies. This study indicates the frequency for T to be .7638. On the basis of Lee's data (1934) the frequency of T would be .695, and on Hagy's (1948) the value for T is .6808. It must be noted that Lee employed the crystal method for the determination of tasters and non-tasters while Hagy employed the paper method and used 0.1 for a critical solution.

2. The critical solution for the sample of the American Negro population was 0.1% as employed by Hagy. Only one individual, in the 269 tested by us for thresholds reacted to 0.1, while 19 reacted to .05.

3. The American Negro population possesses a low taste threshold for PTC. Of the population tested, 75% tasted the .0125% solution, the weakest used.

4. A sex difference in the percentage of non-tasters exists also. Of the male population 7.14% were non-tasters while only 4.457% of the female population were non-tasters. Although the differences are not significant statistically, the sample is similar to others which have been reported in that a higher proportion of males than females are taste blind.

5. There probably exists a real difference between the college and high school population. This suggests the existence of isolates within the race in a restricted geographical area. It is proposed to study further this problem in other areas of Texas where Negro colleges and high schools

occupy the same areas. As yet interpretations as to the probable causes would be mere speculation.

6. From taster x taster matings only taster offspring were observed. The low frequency for the heterozygotes and the smallness of the sample probably accounts for the failure to observe the expected non-taster offspring from such matings.

7. A much higher incidence of non-tasters (.16) was observed in the family groups than found in the general population (.0558). The explanation is obvious. The sample was small and included one family having only non-tasters.

8. Thresholds in offspring observed are seldom higher than thresholds of parents. Only in one instance was such a threshold observed.

## CONCLUSION

The American Negro population has a high percentage of tasters, 94.42%, indicating a much higher frequency for the dominant taster allele than shown in previous studies.

The very significant variation derived from the comparative analysis of the high school and college populations suggests:

1. The need for further studies of the Negro population
2. The possible existence of isolates, with varying frequencies for the taster gene, within the confines of restricted geographical areas
3. The taster gene in the Negro population is not at equilibrium
4. The difficulty of determining a frequency for the taster gene that can be considered representative of the Negro race as a whole.

The attempts to compare the findings in this study with the findings of other workers reveal the need for standardization of methods of testing identical traits so that data will find universal use.

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What Taste World Do You Live In?

This is a scientific test in which a harmless chemical, phenyl-thio-carbamide (commonly called P T C), has been soaked into some paper. Everyone is not able to taste P T C. Others who can taste it may find that P T C tastes differently to them than to someone else. The difference in the reaction is inherited. Neither the taster nor the non-taster can be said to be abnormal, but P T C is a good example that each of us lives in his own taste world. In order for the test to have scientific value please follow the instructions carefully.

In the enclosed envelope there are three different shapes of paper to be tasted. Two things are very important to record: First, how each piece of paper tastes; second, when you taste it. Several suggestions have been listed on the next page about how each piece may taste to you, but if the paper does not seem to be sweet, sour, or bitter, write in how it does seem to taste.

Figure 1

P. T. C. Taste Test

Directions:

Place one piece of paper in your mouth. Discard from mouth as soon as tasted, or if taste is not evident, chew thoroughly for one minute before discarding. Proceed in a like manner for all three pieces of paper.

Record your answers by checking in the appropriate column.

| How does each piece taste to you? | |  |  |  |
|---|---|---|---|---|
| 1. No taste | | | | |
| 2. Sweet | Slight | | | |
| 3. | very | | | |
| 4. Sour | slight | | | |
| 5. | very | | | |
| 6. Bitter | slight | | | |
| 7. | very | | | |
| 8. Other (write in) | | | | |

| When do you taste it (if you do)? | | | |
|---|---|---|---|
| 1. As soon as it touches tongue? | | | |
| 2. As soon as you begin to chew it? | | | |
| 3. Only after chewed for a while? | | | |
| 4. Only after it is removed from mouth? | | | |
| 5. Other | | | |

Please fill in the following information?

Name_____ Nationality_____

Address_____ _____

_____ Male _____ Female_____

Do you smoke? Yes ___ No.____ Do you like cabbage ____?

Do you like turnips? _____

Check your age group: 1-5___, 6-10___, 11-15___, 16-20__, 21-25__, 26-30__, 31-35__, 36-40__, 41-45__, 46-50__, 51-55__, 56-60__, 61-65__, 66-70__, 71-75___, 76-80__, 81-85__, 86-90__, 90 or over__.

Figure 2

What Taste World Do You Live In?

This is a scientific test in which a harmless chemical, phenylthiocarbamide (commonly called P T C), has been soaked into some paper. Everyone is not able to taste P T C. Others who can taste it may find that P T C tastes differently to them than to someone else. The difference in the reaction is inherited. Neither the taster nor the non-taster can be said to be abnormal, but P T C is a good example that each of us lives in his own taste world. In order for the test to have scientific value please follow the instructions carefully.

In the enclosed envelope there are six different shapes of paper to be tasted. Two things are very important to record: First, how each piece of paper tastes; second, when you taste it. Several suggestions have been listed on the next page about how each piece may taste to you, but if the paper does not seem to be sweet, sour, or bitter, write in how it does seem to taste.

Please fill in the following information?

Name_____ Nationality_____

Address_____

Male _____ Female_____

Do you smoke? Yes___ No___ Do you like cabbage_____?

Do you like turnips?_____

Check your age group: 1-5___, 6-10___, 11-15___, 16-20___, 21-25___, 26-30___, 31-35___, 36-40___, 41-45___, 46-50___, 51-55___, 56-60___, 61-65___, 66-70___, 71-75___, 76-80___, 81-85___, 86-90___, 90 or over___.

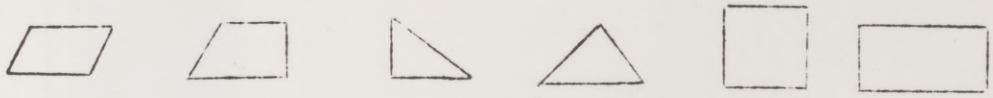
TxU

Figure 3

P. T. C. Taste Test

Directions:

Place one piece of paper in your mouth. Discard from mouth as soon as tasted, or if taste is not evident, chew thoroughly for one minute before discarding. Proceed in a like manner for all six pieces of paper. Taste the papers in the following order:



Record your answers by checking in the appropriate column

| How does each piece taste to you? | |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
| 1. No taste | | | | | | | |
| 2. Sweet: | slight | | | | | | |
| 3. | very | | | | | | |
| 4. Sour | slight | | | | | | |
| 5. | very | | | | | | |
| 6. Bitter | slight | | | | | | |
| 7. | very | | | | | | |
| 8. Other (write in) | | | | | | | |

| When do you taste it? (If you do.) | | | | | | |
|---|---|---|---|---|---|---|
| 1. As soon as it touches the tongue? | | | | | | |
| 2. As soon as you begin to chew it? | | | | | | |
| 3. Only after chewed for a while? | | | | | | |
| 4. Only after it is removed from mouth? | | | | | | |
| 5. Other | | | | | | |

How do turnips taste to you? (raw)

Sour ___

Sweet ___

Bitter ___

Other ___

How does cabbage taste to you? (raw)

Sour ___

Sweet ___

Bitter ___

Other ___

Figure 4

Figure 5

Graph of Threshold Distribution for PTC

in a Negro Population

FIGURE 5

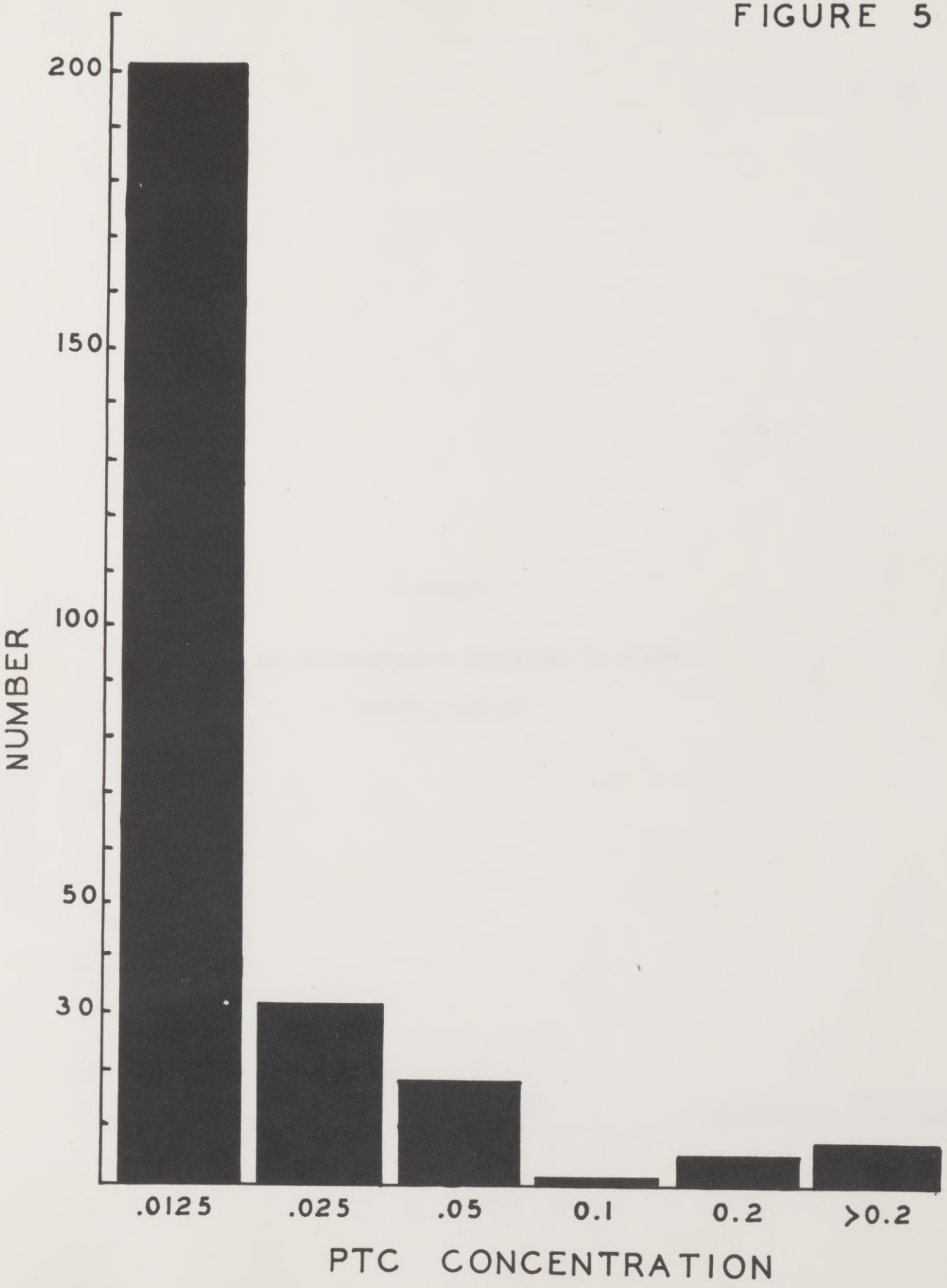

200
150
100
50
30
NUMBER
.0125
.025
.05
0.1
0.2
>0.2
PTC CONCENTRATION

Figure 6

Graph of Threshold Distributions for PTC

in Negro Males

FIGURE 6

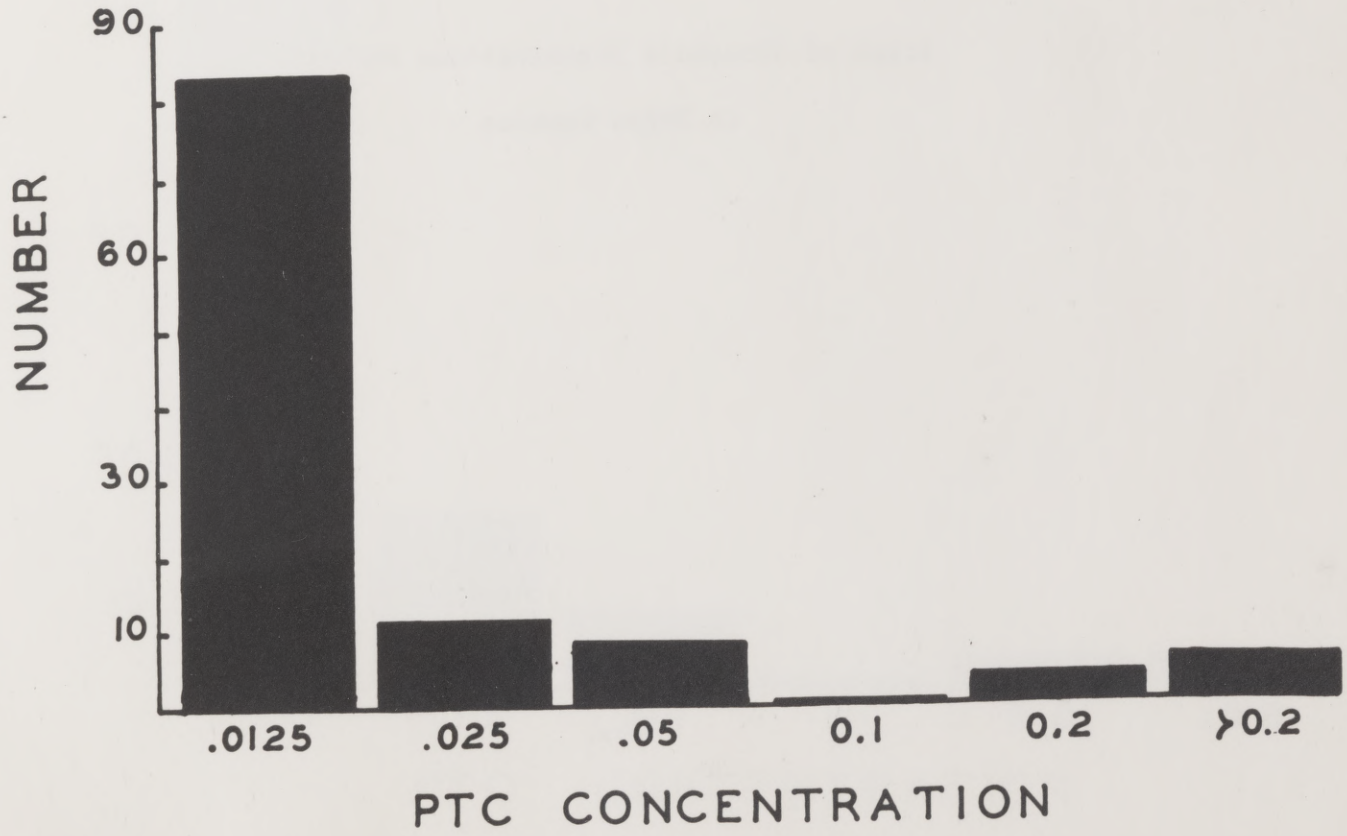
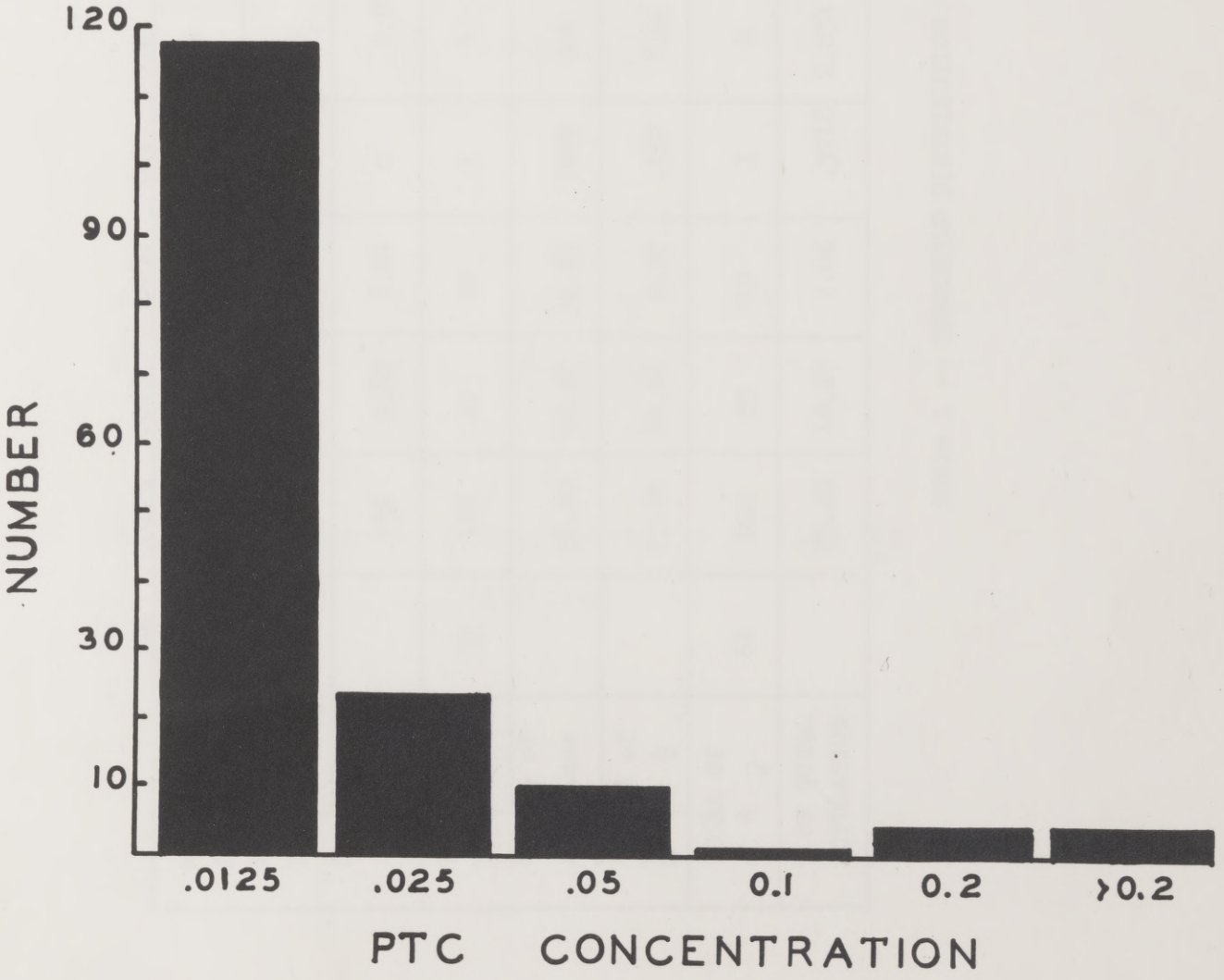


Figure 7

Graph of Threshold Distributions for PTC

in Negro Females

FIGURE 7



| | | TC | .0125 | .025 | .050 | 0.1 | 0.2 | >0.2 | Total Tested | Total Used |
|---|---|---|---|---|---|---|---|---|---|---|
| MALES | No. | 28 | 84 | 11 | 9 | 0 | 3 | 5 | 140 | 112 |
| | % of Class | | 41.58 | 33.33 | 47.37 | 0 | 50 | 62.5 | | 41.64 |
| | % of ♂ | | 75% | 9.82 | 8.04 | 0 | 2.68 | 4.46 | | 100 |
| FEMALES | No. | 33 | 118 | 22 | 10 | 1 | 3 | 3 | 190 | 157 |
| | % of Class | | 58.42 | 66.67 | 52.63 | 100% | 50% | 37.5 | | 58.36 |
| | % of ♀ | | 75.16 | 14.01 | 6.37 | .637 | 1.91 | 1.91 | | 100 |
| TOTAL OF ♂ & ♀ | | 61 | 202 | 33 | 19 | 1 | 6 | 8 | 330 | 269 |
| % OF TOTAL POPULATION | | | 75.09 | 12.27 | 7.06 | .3718 | 2.231 | 2.98 | | 100% |

Table 1 -- THRESHOLD DISTRIBUTION

| | | T | NT | | Chi Square | Probability |
|---|---|---|---|---|---|---|
| MALES | S | 32 | 7 | 39 | .05178 | .90-.80 |
| | NS | 20 | 5 | 25 | N = 1 | |
| | | 52 | 12 | 64 | | |
| FEMALES | S | 8 | 2 | 10 | 4.633 | .05-.02 |
| | NS | 43 | 1 | 44 | N = 1 | |
| | | 51 | 3 | 54 | | |
| MALES AND FEMALES | S | 40 | 9 | 49 | 2.4 | .20-.10 |
| | NS | 63 | 6 | 69 | N = 1 | |
| | | 103 | 15 | 118 | | |

Table 2--Relation for Smoking and Ability to Taste PTC

Pilot Test

| | | .0125 | .025 | .050 | 0.1 | 0.2 | >0.2 | Total |
|---|---|---|---|---|---|---|---|---|
| MALES | S | 10 | 1 | 3 | 0 | 0 | 0 | 14 |
| | NS | 74 | 10 | 6 | 0 | 3 | 5 | 98 |
| | % OF S | 11.90 | 9.09 | 33.33 | 0 | 0 | 0 | 12.50 |
| | TOTAL ♂ | 84 | 11 | 9 | 0 | 3 | 5 | 112 |
| FEMALES | S | 4 | 0 | 0 | 0 | 0 | 0 | 4 |
| | NS | 114 | 22 | 10 | 1 | 3 | 3 | 153 |
| | % OF S | 3.40 | 0 | 0 | 0 | 0 | 0 | 2.53 |
| | TOTAL ♀ | 118 | 22 | 10 | 1 | 3 | 3 | 157 |
| TOTAL ♂ & ♀ | | 202 | 33 | 19 | 1 | 6 | 8 | 269 |

Table 3--Distribution of Smokers and Non-Smokers According to Thresholds

PREFERENCE FOR CABBAGE AND TURNIPS

Pilot Test

Tasters

| | Cabbage + | % | Turnips + | % | Both | % | Neither | % |
|---|---|---|---|---|---|---|---|---|
| Male | 35 | 73 | 24 | 50 | 23 | 46 | 8 | 16.7 |
| Female | 50 | 98 | 29 | 56 | 28 | 54.9 | 3 | 5.9 |
| Total | 85 | 86 | 53 | 54 | 51 | 51.5 | 11 | 11.1 |

Non-Tasters

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Male | 10 | 83.3 | 6 | 50 | 6 | 50 | 2 | 16.7 |
| Female | 3 | 100 | 2 | 66.7 | 2 | 66.7 | 0 | 0 |
| Total | 13 | 86.6 | 8 | 53.25 | 8 | 53.25 | 2 | 13.3 |

Table 4

The vita has been removed from the digitized version of this document.