[1]References have been given in detail by Metz and Gay in these PROCEEDINGS, **20**, 617–621 (1934). See also Bridges, *Amer. Nat.*, **69**, Jan.-Feb. (1935); Painter, *Ibid*, Jan.-Feb. (1935); Metz and Gay, *Science*, **80**, 595–596 (1934).

[2]See Metz and Gay, these PROCEEDINGS, loc. cit., for discussion.

GENETICS OF SENSORY THRESHOLDS: VARIATIONS WITHIN SINGLE INDIVIDUALS IN TASTE SENSITIVITY FOR PTC[1]

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Not only is the taste world of one individual different from that of another[2] but it now appears that the taste world of any one individual is not a stable one. Because of its threshold range among individuals, PTC (Phenyl Thio Carbamide) has become a convenient reagent for testing taste reactions. Evidence has already been published[3] which shows that the ability of some and inability of others to taste the crystals of PTC, as well as taste acuteness for solutions of different concentration, are due to innate hereditary differences in the individuals tested. The present paper gives results from a study of the methods used in determining individual taste thresholds for PTC in preparation for investigation of taste thresholds for a number of unrelated substances.

The persons tested were all adults, members of the secretarial and technical staff of the Department of Genetics. The same number or letter has been retained for each individual throughout. Concentrations of PTC were used from 1:5120M up to 1:312.5 using a factor of two, such that each solution used in a test was twice as concentrated as that previously administered. In each test approximately 0.6 cc. was given by means of the straw method.[4]

Figure 1 shows the distribution of thresholds for 94 persons. In this graph each person is represented by a single record taken during the past summer. The curve is at least skewed toward the right and shows a second mode at 1:625. The curve is irregular, as would be expected from such small numbers. How pronounced the bimodality would appear if a larger population were tested is uncertain. A similar bimodality is indicated by earlier records[3] by one of us in which a factor of 4 instead of 2 was used in making up the test solutions and in which those who could not taste the crystals were classified as negative without threshold determinations with concentrated solutions, which may be tasted by those to whom the crystals are tasteless. These earlier records totaled 433 individuals, only a very few of whom are included in figure 1.

To determine whether the correct quantity was being used to insure the perception of a threshold solution by the subject, twelve individuals whose thresholds had been determined previously with 0.6 cc. were tested with increasing amounts of the dilution just below the threshold dilution (i.e., half as strong). Table 1 shows the results. In no case could a half threshold concentration be tasted even when the quantity was increased to a dosage of as much as 10 cc. Some individuals can taste as little as 0.2 cc. of a threshold solution (i.e., the concentration tasted in 0.6 cc.). Five persons kept 5 cc. of a half threshold solution in the mouth exactly one minute without taste, but immediately afterward all reported a taste within a few seconds when given 0.6 cc. of a threshold solution. It would appear, therefore, that 0.6 cc. in a straw is an adequate quantity to use in tests, since the threshold was not lowered by giving larger amounts.

PTC has the widest range of thresholds of any substance so far studied. For this reason perhaps it is more likely to show a "Twilight Zone" of

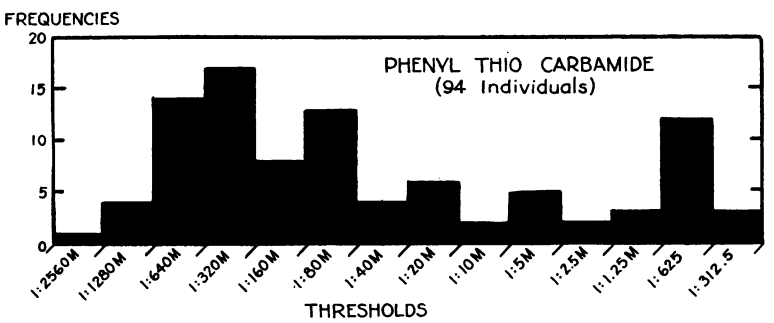


FIGURE 1

several dilutions before a distinct threshold is reached. Taste impressions in this twilight zone are uncertain and include sweet, metallic, salt, sour, astringent and sensations which the subjects recognize as different from water, but which they cannot name or describe.

Changes in temperature of solutions appeared to have no material influence on thresholds. Using solutions of half threshold, threshold and twice threshold at about 8°C., room temperature and about 55°C., no lowering of threshold was observed. Reaction to cold solutions was delayed in some cases. Apparently the solution had to be raised toward mouth temperature before it was tasted.

In a test of the possible influence of the saliva, the tongue was dried with blotting paper and rinsed with water. In no case was a subject able to detect on a blotted or rinsed tongue a solution which under ordinary circumstances was slightly below his threshold. Of 6 subjects who were showing relatively constant thresholds, 2 did not appear to lose their sensitivity to their threshold concentrations, but 4 were rendered less

TABLE 1

SUBJECT NUMBER		CONC.	HALF THRESHOLD CONCENTRATION 0.2 cc.	0.4 cc.	0.6 cc.	0.8 cc.	1 cc.	2 cc.	5 cc.	10 cc.	CONC.	THRESHOLD CONCENTRATION 0.2 cc.	0.4 cc.	0.6 cc.
4	♀	1:1250	−	−	−	−	−	−	−	−	1:625	−	+	
41	♀	1:1280*M*	−	−	−	−	−	−	−	−	1:640*M*	−	−	++
12	♀	1:10*M*	−	−	−	−	−	−	−	±	1:5*M*	−	±	+ Met.
23	♀	1:160*M*	−	−	−	−	−	−	−	±	1:80*M*	+	++	
3	♀	1:2500	−	−	−	−	−	−	−	−	1:1250	−	+	
13	♀	1:5*M*	−	−	−	−	−	−	−	−	1:2500	−	+	+
31	♀	1:650*M*	−	−	−	−	−	±	−	−	1:320*M*	±	±	+
5	♀	1:1250	−	−	−	−	−	−	−	−	1:625	±	±	+
10	♀	1:1250	−	−	−	−	−	−	−	−	1:625	±	++	
45	♀	1:1280*M*	−	−	±	−	−	−	−	−	1:640*M*	±	++	
W	♀	1:640*M*	−	−	−	−	±	−	−	−	1:320*M*	+	++	
32	♀	1:640*M*	−	−	−	−	−	−	−	±	1:320*M*	+	++	

Key: − no taste; ± different from water, cannot describe as a taste; + slight bitter; ++ medium bitter; Met. metallic.

sensitive after the treatment, the extent to which the thresholds were raised varying considerably among the 4 subjects. The time of recovery varied from about a half hour to several hours.

Some individuals perceive the bitter in PTC at once when the threshold concentration is reached, others require several seconds before the taste is noticed. In some the taste is fleeting, in others it persists for the rest of the day.

The various subjects have reported all parts of the tongue as responding to bitter stimuli. Some taste it chiefly in the front; others in the middle, sides or back; some in the throat, of whom some include the uvula. At concentrations above threshold, subjects have difficulty in reporting any particular area as most sensitive.

There was at least no strong correlation between the use of tobacco and sensitivity to PTC.

Various experiments indicated that some persons could not be relied on to keep the same threshold from one test to another. This past summer ten people were tested four times a day over a period of from four to nine days: in the morning upon arriving at work, before lunch, after lunch and late afternoon. Figure 2 shows the threshold variations of members of the group within the periods indicated. Subject No. 3, with a factor of 2 between the lowest and highest thresholds,

was the most nearly uniform, although subjects Nos. 13, 46 and 42, who varied by a factor of 4 between extreme records, were relatively constant; subjects Nos. 18, 28, 41 and 33 varied by a factor of 8; subject No. 12 varied by a factor of 16. Subject *T* was the most variable person yet discovered in taste thresholds, with a factor of 256 between extremes. On three occasions she could detect bitter in dilutions of 1:2560*M*, but once was not able to taste the solution until it was 256 times as strong, or 1:10*M*.

Figure 3 shows the taste curves during one day for 7 individuals. Tests were made every fifteen minutes after meals, and at least every hour during the remainder of the day. The subjects were asked not to eat between

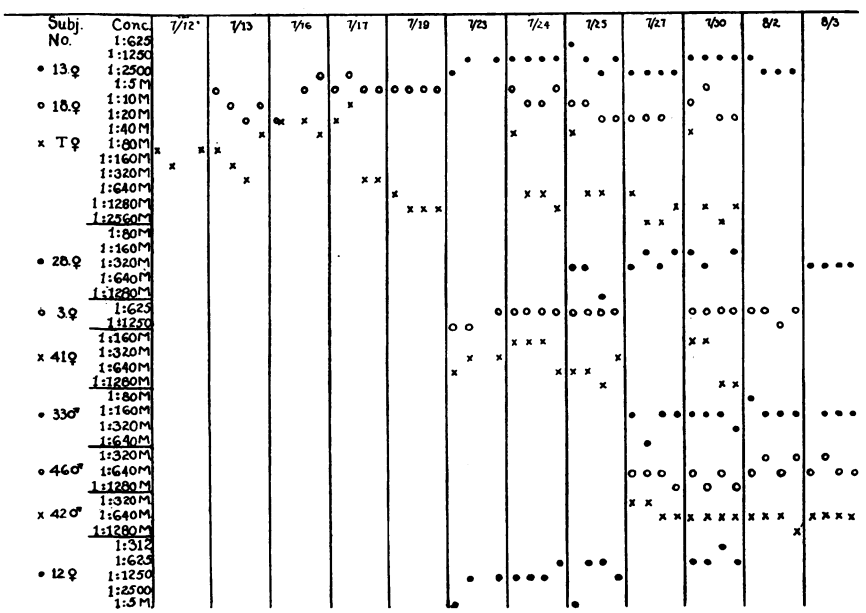


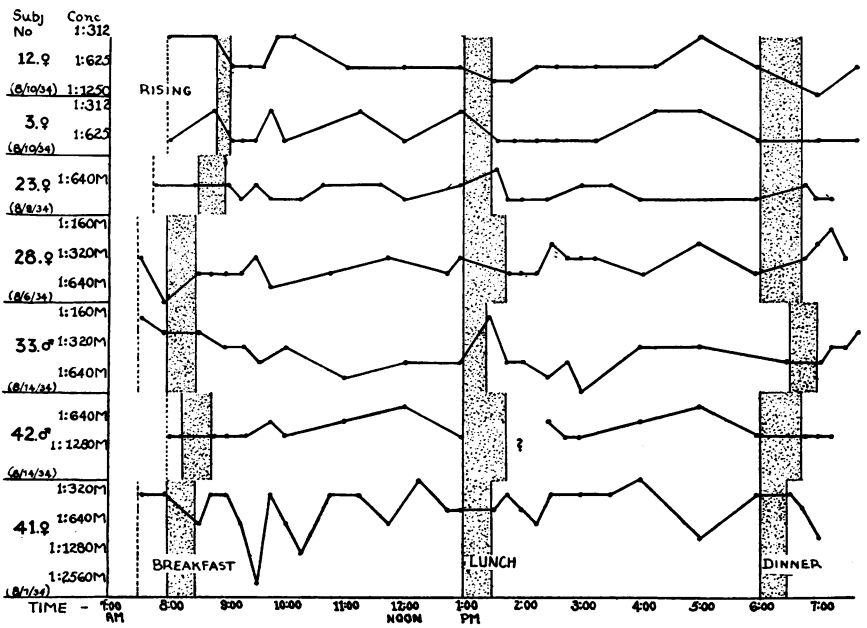
FIGURE 2

meals during the day's test. In addition to the regular dilutions made up on the basis of a factor of two, extra solutions half-way between these were inserted with the purpose of detecting any possible rhythm more easily. Differences were observed after so short an interval as fifteen minutes. Thus, subject No. 41 at 9:30 A. M. could detect PTC in a dilution of 1:2560*M*, but fifteen minutes later needed a 1:320*M* solution, which is eight times as strong. Even when the intervals have been made as short as five minutes, there has been no regularity noted in direction of changes after short intervals, which might suggest taste fatigue or an increased reaction from continued or prolonged stimulation. Fatigue is marked in the case of odors, but in our experience with taste this factor

apparently may be neglected as at most of relatively minor importance.

Henderson and Millet[5] have shown from a study of twelve subjects that the pH of saliva follows a regular daily rhythm, rising during meals and falling again shortly thereafter. The pH of the saliva has earlier been shown by one of us[3] to have no close connection with taste acuity. The lines of taste variation in no way suggest any connection with the rhythmic change in pH of the saliva observed by the authors cited, but the pH of the subjects of figure 3 were not tested.

The number of individuals tested and the limited period of time during



PTC TESTS DURING SINGLE DAYS

FIGURE 3

which the tests were continued were not sufficient to give an adequate sample of the range of variability which people are capable of showing at different times. Schrijver[6] reported that for one person who was tested ten times on successive days, the threshold concentration for quinine hydrochloride varied between 0.005 and 0.015 gram per liter and for saccharine, between 0.010 and 0.0175 gram per liter. These thresholds have the factors between extremes of 3 and $1^3/_4$, respectively, and indicate that the subject was relatively uniform in reactions to the two substances used in comparison with our subjects who were tested with PTC. Such great differences as we have found (from factor of 2 to factor of 256) in single individuals appear not to have been reported before in the literature.

Other tests than those shown in the graphs confirm our belief in the reality of variability of the same subject in respect to threshold reactions taken at different times. One person, for example, who could not taste crystals in the summer of 1933 was found to be able to taste crystals in the summer of 1934 and to detect a definite bitter in a 1:20*M* solution.

Subject No. 23 held a threshold of 1:80*M* consistently for two weeks in July, while numerous tests were made. After an interval of two weeks another series of tests showed a consistent threshold of 1:320*M*. In the same subject, after a second interval of two weeks, the threshold was found to be 1:160*M*. Other subjects, e.g., Nos. 3 and 42, showed very little variation in the threshold from time to time, a quite consistent, slightly varying range being held all summer. As to the fact of variability in thresholds of a single subject there can be no longer any doubt and, as Schrijver[6] has pointed out from fewer data, this variability renders unnecessary the extreme refinement in method recommended by some individuals for determining taste thresholds.

The reason for the variations is not clear. An inspection of the graphs as well as inquiry of the subjects would seem to eliminate the possibility of a regular rhythmic change in taste sensitivity associated with routine daily habits or with regular periodic changes in their physiology. It is our belief, however, that the changes observed in taste thresholds are in some way connected with differences in physiological states. If this should prove to be the case it might be possible to use taste thresholds as an index of unrecognized internal conditions. Such an index might prove to be of clinical value.

[1] Paper presented before Section I (Psychology) at the Pittsburgh Meeting of the A.A.A.S., Dec. 27, 1934.

[2] Blakeslee, A. F., and Fox, A. L., *J. Hered.*, **23**, 97–107 (1932).

[3] Blakeslee, A. F., these PROCEEDINGS, **18**, 120–130 (1932); Snyder, L. H., *Science, N. S.*, **74**, 151–152 (1931); and *Ohio Jour. Sci.*, **32**, 436–440 (1932).

[4] Blakeslee, A. F., and Salmon, M. R., *Eugenical News*, **16**, 105–108 (1931).

[5] Henderson, M., and Millet, J. A. P., *J. Biol. Chem.*, **75**, 559–566 (1927).

[6] Schrijver, F., *Zeitschr. f. Psych.*, **130**, 385–392 (1933).