Comments and Communications

Theory of Tastes and Odors

WE WERE interested in the article on "A Theory of Odors" by G. B. Kistiakowsky (*Science,* **112**, 154 [1950]) because we have been independently approaching the same problem from an experimental direction. Our results are not sufficiently advanced to enable us to draw final conclusions regarding the mechanisms of taste and smell, but the results we have so far obtained suggest that the primary mechanism of both these senses might be that of interference with one or more enzymes by the substances possessing the properties of odor or taste.

It has been shown by one of us (Bourne, *Nature,* **161**, 445 [1948]) that, by Gomori's histochemical method, alkaline phosphatase was present in a relatively high concentration in, or in the epithelium overlying, the taste buds in various mammals. In addition, the olfactory mucosa was also found to contain an appreciable concentration of this enzyme.

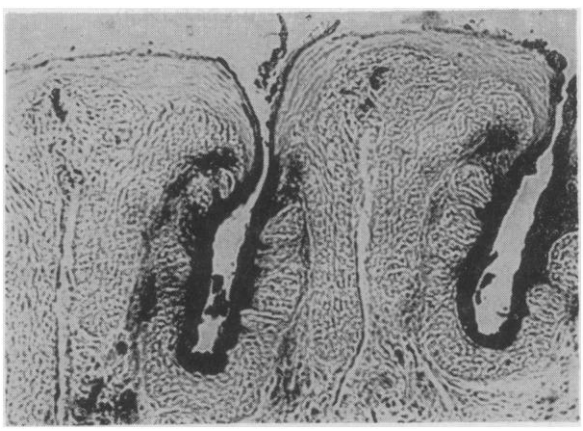

FIG. 1. Alkaline phosphatase reaction in the papilla foliata of the rabbit. The epithelium overlying the taste buds and at the bases of the papillae is seen to be heavily impregnated, indicating a high concentration of the enzyme in this region. Elsewhere there appears to be little phosphatase. (× 120.)

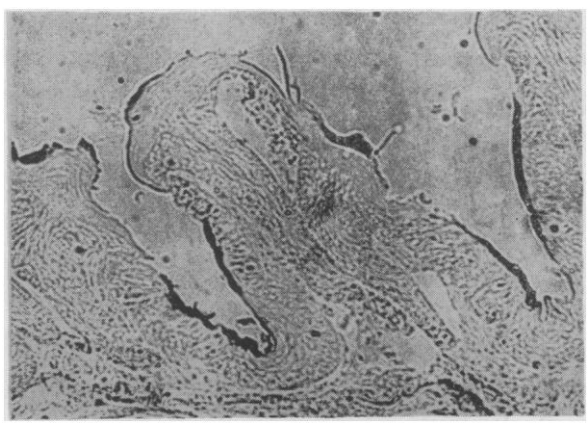

FIG. 2. Alkaline phosphatase reaction in the papilla foliata of the rabbit after adding 0.05% of vanillin to the substrate. Some reaction is still present in the epithelium, but it is greatly reduced. (× 120.)

Working on the assumption that part of the mechanism of tasting may be associated with the inhibition of this enzyme by various substances with taste properties, studies had been made on the effects of such substances on the Gomori phosphatase reaction in the papilla foliata of the rabbit's tongue. We have found that vanillin strongly inhibited the gustatory phosphatase reaction (Fig. 1). In the rabbit this reaction is in the epithelium overlying the taste buds, and it was found that a concentration of 0.05% of vanillin in the substrate produced quite a strong inhibition of the reaction, and at a concentration of 0.5% the reaction was completely abolished (Fig. 2). Histochemical demonstration of alkaline phosphatase was also inhibited to varying degrees in kidney, gut, and bone, and in nasal mucosa by vanillin.

The substrate used for demonstrating this gustatory phosphatase (or phosphatases) was sodium β-glycerophosphate, but the following substrates have also given positive results: hexose diphosphate, muscle adenylic acid, yeast adenylic acid, and adenosine triphosphate.

The inhibiting effects of vanillin and other substances on the ability of the gustatory phosphatase(s) to split these other substrates have not yet been investigated.

Obvious inhibition of gustatory phosphatase has also been found with infusions of tea and with capsicum, but sugar, sodium chloride, and quinine have no effect. Infusions of coffee, oil of aniseed, and oil of peppermint have a slight effect.

In addition to the phosphatase(s), we have also shown histochemically that a simple esterase is present in fairly high concentration in the taste buds and to a much smaller extent in the epithelium of this region of the tongue. There was a fairly high concentration of this esterase also in the neighboring accessory salivary tissue. The enzyme was demonstrated by Gomori's modification of the Nachlas-Seligman method (*J. Natl. Cancer Inst.,* 9, 415 [1949]), which is as yet unpublished.

The histochemical reaction for this esterase is inhibited strongly by quinine but not by sugar or sodium chloride. We have not as yet established whether these inhibitions are true interference with enzyme activity or whether they represent some interference with the histochemical reaction. However, the points we should like to emphasize are:

1) We have found in the papilla foliata of the rabbit 2 enzymes (or groups of enzymes) of the 4 groups postulated by Kistiakowsky as being required to explain the mechanism of smell (and presumably also of taste).

2) We have found so far that the histochemical reactions of these enzymes (or groups of enzymes) are inhibited by some substances that have a well-defined taste and are not inhibited by others.

We had not intended to publish this work until we had accumulated many more data, but the remarkable coincidence between the experimental results we are obtaining and the theory propounded by Kistiakowsky influenced us to make this preliminary report.

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Cartesian Diver Balance

RECENTLY Smith and Post (*1*) published a paper entitled "Improved Technique for Weighing Tissues with the Cartesian Diver." The authors employed the formula of Zeuthen (*2, 3*)

$$RW_x = RW_{st} \frac{1 - \frac{b}{B - p_x}}{1 - \frac{b}{B - p_{st}}}, \qquad (1)$$

in such a way that they inserted in it the directly read equilibrium pressures (p_x and p_{st}) of the diver when loaded with an unknown weight and a known standard. However, in (*3*) it is stated: "By this procedure the pressure at which the balance neither sinks nor rises in water (the equilibrium pressure, or e.p) may be measured. The change in equilibrium pressure (p_x) resulting from the loading of the balance with some biological object (RW_x) is compared with the change in e.p. (p_{st}) resulting from the loading of the balance with a known RW (RW_{st})." It seems impossible that "change" could mean anything but the difference in equilibrium pressure between an empty and a loaded balance. Because of this misunderstanding Smith and Post find that the formula (1) gives meaningless results under certain conditions. If the formula is used correctly, the calculations lead to values in good agreement with those obtained by Smith and Post (*cf.* Table 1). We cannot, of course, explain the relatively large deviations between actual RW and RW measured on their diver balance. For better results (in the µg-range), see (*4*).

Smith and Post introduce two new formulas concerning which we wish to make a few comments. First, a simple calculation shows that they are identical. In spite of this, Smith and Post arrive at different results when using them. Second, they are not new. Løvtrup (*4*) has published the same formula in a different form. It reads:

$$RW_x = Z \frac{-\Delta p_x}{p + \Delta p_x} = Z \frac{-\Delta p_x}{B + p_D + \Delta p_x} \qquad (2)$$

The e.p. of the empty diver is p_D, so that $p_D + p_x$ is equal to the manometer reading when RW_x is weighed. In Smith and Post's terminology formula (2) reads:

$$RW_x = V_c \frac{p_e - p_x}{B + p_x}, \qquad (3)$$

which is identical with their formula (6). The diver constant (Z) is equal to the reduced weight of the diver balance proper and therefore equal to the gas

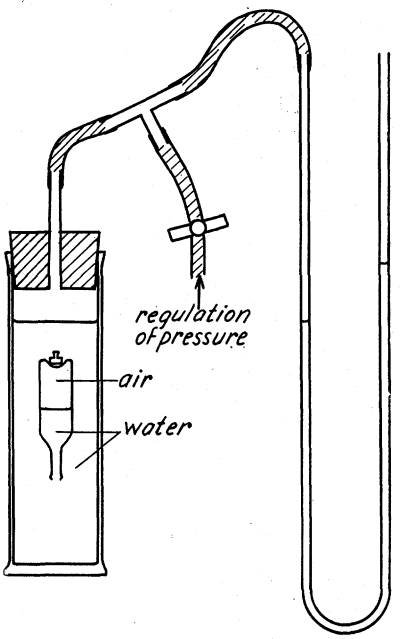

FIG. 1.

volume of the empty diver when the density of the flotation medium is 1. Thus (Z) is identical with V_c in Smith and Post's paper.

At the time of publication of (*2, 3*) it was still doubtful whether the reduced weight of the diver proper remained absolutely constant. In all cases the empty diver was found to change its e.p. gradually. This could—with a constant RW of the empty submerged diver—be due to loss of gas by diffusion out of the diver. It could also, however, be due to change in RW of the submerged diver proper, caused by unknown factors. Later experimental work (*4*) has supplied evidence that Z is in fact a constant, thus making the former possibility the more likely one. This forms the basis for the routine use of the convenient diver constant.

When the modified formula was introduced, it was expressly stated that formula (1) does not lead to wrong results, but the new formula (2) makes it possible to simplify both the weighing procedure and the calculations. The constant Z is found by loading the diver with a known standard, and standardization is carried out only occasionally; previously this was done between each short series of measurements of the biological samples.

Concerning the conditions of the experiments, Smith and Post violate a number of rules that we consider imperative, and that are published in (*3*). For example, air bubbles on the outside of the diver should never be tolerated. They can easily be avoided if the basic physical principles for the solubility of gases in water are considered. The diver should never be used at pressures very different from 1 atm to avoid air bubbles on the outside of the diver, especially at very low pressures. Neither standards nor