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**A NEW THEORY RELATING CONSTITUTION TO TASTE.**

[PRELIMINARY PAPER.]

**SIMPLE RELATIONS BETWEEN THE CONSTITUTION OF ALIPHATIC COM-  
POUNDS AND THEIR SWEET TASTE.**

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**Introduction.**

The relation between the constitution of substances and their taste has always been of interest to the chemist and the physiologist. It has been well known for a long time that most of the acids taste sour. Previous to the advent of the dissociation theory this fact was hardly associated with the presence of any one element or group. It is now pretty certain that the hydrogen ions are the essential constituent. At least they alone are common to all the acids possessing this quality. The ionic theory may account for the "salty taste" of sodium chloride, sodium sulfate and other sodium salts in a similar way. The peculiar taste of typically basic substances such as potassium hydroxide and sodium carbonate, is associated with the presence of the common hydroxyl ion. In view of these facts and inferences it was logical to extend the analysis to organic compounds and to try to discover the particular atoms or groups common to substances having a sweet or bitter taste.

It has been pointed out by Nef that most of the compounds corresponding to the formula  $(\text{CH}_2\text{O})_n$  are sweet. Through the work of Emil Fischer<sup>1</sup> we became acquainted with the fact that many of the  $\alpha$ -amino acids have a sweet taste. L. Henry<sup>2</sup> sought to connect the taste of certain bitter compounds with the group  $-\text{CNO}_2\text{CH}_2\text{OH}$ . Finally G. Cohn<sup>3</sup> in his remarkable study of organic tastestuffs compiled an enormous amount of evidence, which proved that there is a close relation between constitution and taste. His work confirmed Henry's theory which he amplified by showing that taste in general is dependent on the presence of certain groups, such as the hydroxyl and amino groups. He calls them sapophoric groups. He points out that those sapophoric groups occur frequently in pairs. Finally, he cites a great number of instances showing that the lower members of certain homologous series have a sweet taste, while the higher members of the same series may be tasteless or bitter. He fails, however, to supply us with a simple theory which could include these facts and which would permit chemists to classify tastestuffs. And we still lack simple rules by which it would be possible to predict the taste of a given compound by a simple inspection of its formula.

#### Mode of Procedure.

We decided to start our investigation with the sweet aliphatic compounds. They are, of all the tastestuffs, undoubtedly the most important both from a chemical and physiological point of view. A great number of facts are known in connection with this subject. The relations within each class (sugars, amino-acids, halogen compounds) are pretty well known, while the lack of a theory embracing all the more important among them has been felt most keenly.

In approaching this problem we took advantage of the experience of other chemists who had attempted and finally succeeded in finding a relation between constitution and the dyeing properties of organic compounds. This relationship, as is well known, has been satisfactorily explained by O. N. Witt<sup>4</sup> and others by attributing these properties to two different kinds of groups, the so-called chromophoric groups, that are characterized by a double bond, and the auxochromic groups. A substance containing a chromophoric group is called a chromogene. A chromogene is a colored substance, a potential dyestuff, so to speak, yet it is only by the introduction of one or several auxochromic groups that those compounds are transformed into real dyestuffs. We shall see that something similar holds true for the constitution of tastestuffs.

<sup>1</sup> "Untersuchungen über Aminosäuren," etc. 1906.

<sup>2</sup> *Compt. rend.*, 121, 213 (1895).

<sup>3</sup> "Die Organischen Geschmackstoffe," 1914.

<sup>4</sup> *Ber.*, 9, 522 (1876).

### The Glucophores of Aliphatic Compounds.

As has been pointed out repeatedly by Cohn<sup>1</sup> the sweet taste of organic compounds is frequently bound to one or two sapophoric groups, which very often occur in pairs. This observation we considered to be a good starting point, but it had to be extended.

Instead of attributing the sweet taste of a given compound to one factor, the glucogene (Cohn) or glucophor, as we prefer to call it, we maintain that it is due to two distinct factors, a gluco phore and an auxo-gluc.

*Any glucophore will form a sweet compound with any auxogluc. It is the purpose of the present study to determine just what aliphatic groups may act as glucophores, and which as auxoglucs.*

**Definition.**—We define the glucophore as a group of atoms which has the power to form sweet compounds by uniting with a number of otherwise tasteless atoms or radicals.

A preliminary examination of the literature revealed the existence of the following glucophores:

1.  $\text{CH}_2\text{OH}\cdot\text{CHOH}$ —. Glycol,  $\text{CH}_2\text{OH}\cdot\text{CH}_2\text{OH}$ , which is the most simple substance in which this glucophore occurs, may be considered as a combination of the group  $\text{CH}_2\text{OH}\cdot\text{CHOH}$ — and hydrogen. Glycol is sweet, as A. Wurtz pointed out many years ago.

If the same glucophore,  $\text{CH}_2\text{OH}\cdot\text{CHOH}$ —, is linked to the methyl radical or ethyl radical, we obtain 1,2-propanediol  $\text{CH}_3\cdot\text{CHOH}\cdot\text{CH}_2\text{OH}$ , and 1,2-butanediol  $\text{CH}_3\text{CH}_2\cdot\text{CHOH}\cdot\text{CH}_2\text{OH}$ , respectively, two other sweet compounds.

If we combine this glucophore with the methylol-radical,  $\text{CH}_2\text{OH}$ —, then we get glycerin, which is notoriously sweet.

The group  $\text{CH}_2\text{OH}\cdot\text{CHOH}$ — falls clearly within our definition.

2.  $-\text{CO}\cdot\text{CHOH}$ —(H). This second glucophore yields with two hydrogen atoms glycolaldehyde, the simplest sugar.

With the methylol radical  $\text{CH}_2\text{OH}$ —, the glucophor  $-\text{CO}\cdot\text{CHOH}$ —(H), yields two different compounds. If the radical  $-\text{CH}_2\text{OH}$  is linked to the carbinol of the glucophore, and the hydrogen atom H is bound to the carbonyl group of the glucophore, we obtain the glyceric aldehyde  $\text{CH}_2\text{OH}\cdot\text{CHOH}\cdot\text{CHO}$ .

If furthermore the methylol radical is linked to the carbonyl of the glucophore, while the hydrogen (H) is linked to the carbinol, then dihydroxy-acetone,  $\text{CH}_2\text{OH}\cdot\text{CHOH}\cdot\text{CH}_2\text{OH}$ , results.

All the 3 compounds named are known to be sweet. The group  $-\text{CO}\cdot\text{CHOH}$ —(H) is then a glucophore. The hydrogen (H) simply indicates that the group must be united with one atom of hydrogen at least, in order to become a glucophore.

<sup>1</sup> *Loc. cit.*, p. 118.

3.  $\text{CO}_2\text{H}.\text{CHNH}_2$ —. From the third glucophore most of the sweet amino acids may be derived in a similar way. We know aminoacetic acid,  $\text{CH}_2\text{NH}_2.\text{CO}_2\text{H}$ , and  $\alpha$ -alanine,  $\text{CH}_3.\text{CHNH}_2.\text{CO}_2\text{H}$ , to be sweet. Even higher  $\alpha$ -amino acids, such as *dl*-leucin are sweetish. The group  $\text{CO}_2\text{H}.\text{CHNH}_2$ — is therefore a glucophore.

4.  $\text{CH}_2\text{ONO}_2$ —. This is the first example of a glucophore containing but one carbon atom. It has been pointed out by Cohn<sup>1</sup> that many compounds are known which evidently owe their taste to this group. Ethyl nitrate,  $\text{CH}_3\text{CH}_2\text{ONO}_2$ , and isobutyl nitrate,  $(\text{CH}_3)_2\text{CH}.\text{CH}_2\text{ONO}_2$ , are representatives of this class.

5.  $\text{C}_{\text{Hl}_x}^{\text{H}_r-x}$ —. This glucophore is present in sweet compounds containing halogen bound to one carbon atom. The abbreviation Hl is general for chlorine, bromine and iodine. Fluorine derivatives may be included possibly. The small index  $x$  refers to the number of halogen atoms in the glucophore. It may vary from one to three, the number of hydrogen atoms in the glucophore meanwhile decreasing from two to zero. An application of these principles is shown in the following two examples:

Methyl iodide has the glucophore  $\text{CH}_2\text{I}$ — which agrees exactly with the general formula given. In this case, the I limits the abbreviation Hl to a single atom of halogen. The index  $x$  equals one. In respect to the hydrogen, the index  $3 - x$  becomes equal to two. Obviously, this represents the number of atoms of this element in the glucophore.

Chloroform has a glucophore,  $-\text{CCl}_3$ , which agrees exactly, as before, with the general formula. In this particular case Hl stands for Cl, the index becoming 3 for the chlorine. The H term in the formula completely disappears, a condition following logically from the simple assumptions made.

6.  $\text{C}_{\text{Hl}_x}^{\text{H}_r-x} - \text{C}_{\text{Hl}_y}^{\text{H}_r-y}$ —. This glucophore is also present in sweet compounds containing halogen. In strict agreement with the former paragraph, the Hl is general for chlorine, bromine, iodine, and with doubt, fluorine. In respect to the indices,  $x$  may vary from one to three, and  $y$  from one to two. In consequence, the number of hydrogen atoms change at the same rate, but inversely. The following two examples will serve to make these relations clear:

Ethylene bromide has the glucophore  $\text{CH}_2\text{Br}.\text{CHBr}$ —, which satisfies the formula, since Hl is equivalent to Br and  $x$  and  $y$  are each equal to unity.

Pentachloroethane has the glucophore  $\text{CCl}_3-\text{CCl}_2$ —. Here Hl is represented by Cl, while  $x$  becomes equal to 3,  $y$  to two. Since the H term disappears, this glucophore contains no hydrogen.

7. While the 6 glucophores mentioned are undoubtedly the most important it is probable that this list may be expanded considerably. There

<sup>1</sup> *Loc. cit.*, p. 411.

are strong indications that the following groups, for instance, may be included in the list:

(a)  $\text{CO}_2\text{H}.\text{CHNHCH}_3-$ , (H). Example: sarcosine,  $\text{CH}_3\text{NH}.\text{CH}_2.\text{CO}_2\text{H}$ , which, according to Volhard<sup>1</sup> has a sweetish taste.

(b)  $\text{CH}_2\text{OHCH}_2.\text{CHOH}-$ , (H). Example: 1,3-propanediol,  $\text{CH}_2\text{OHCH}_2.-\text{CH}_2\text{OH}$ , described as sweet by F. Gerenmont.<sup>2</sup>

(c)  $\text{CHONO}-$ , (H). Example: ethyl nitrite—"sweet spirits of nitre." In view of the limited data at hand, we prefer to postpone a decision on this point.

### Auxogluc.

**Definition.**—We define an auxogluc as an atom or radical which combined with any of the glucophores yields a sweet compound. We have so far been able to identify nine of these.

1. **Hydrogen.**—Some combinations of this atom with different glucophores have been discussed already in the preceding paragraphs.

2.  $\text{CH}_3-$ .—Several instances are cited already showing that this radical forms sweet compounds with glucophores, but we wish to point out that the halogen derivatives, especially, yield numerous examples of such combinations. Thus ethyl bromide and iodide are sweet, although the taste of the former is said by Fehling<sup>3</sup> to be "burning" while the taste of the latter is not stated at all.

3.  $\text{CH}_3\text{CH}_2-$ .—Examples supporting this auxogluc are found in the literature, except in the case of glucophores containing halogens. We have been able to satisfy ourselves that it applies to those as well by tasting propyl bromide and propyl iodide. Both are sweetish as we expected.

4.  $\text{CH}_3.\text{CH}_2.\text{CH}_2-$ .—At present but few compounds containing this auxogluc are known to be sweet. We include it in our list with due reservation.

5.  $(\text{CH}_3)_2\text{CH}-$ .—Examples of combinations of this uxogluc with 5 of the 6 glucophoric groups are mentioned in the literature. The resulting substances are sweet with one notable exception. 3-Methylbutane-1,2-diol is said by F. Flawitzki<sup>4</sup> to be "burning bitter." An investigation of this compound is under way.

6.  $\text{CH}_2\text{OH}-$ .—This auxogluc yields with the different glucophores some of the most important sweetstuffs. Substances containing it will be cited from each class.

7 and 8.  $\text{CH}_3\text{CHOH}-$  and  $\text{CH}_2\text{OH}.\text{CH}_2-$ .—We have several instances to cite, especially in conjunction with the glucophores  $-\text{CHNH}_2\text{CO}_2\text{H}$

<sup>1</sup> *Ann.*, 123, 262 (1862).

<sup>2</sup> *Ibid.*, 158, 371 (1891).

<sup>3</sup> Cohn, *Loc. cit.*, p. 128.

<sup>4</sup> *Ann.*, 179, 351<sub>4</sub> (1875).

and  $\text{CH}_2\text{OH}\cdot\text{CHOH}\cdot$ , which indicate strongly that these two radicals are really auxoglucs. The *dl*- $\alpha$ -amino- $\gamma$ -oxybutyric acid of Fischer and Blumenthal<sup>1</sup> as well as the  $\alpha$ -amino- $\beta$ -oxybutyric acid of W. Sternberg<sup>2</sup> are sweet. 1,2,3-Butanetriol and 1,2,4-butanetriol are other examples. The list, however, is far from being complete in this instance and much work has yet to be done in order to prove that these two radicals may actually be included in the list.

9. Finally the radicals  $\text{C}_n\text{H}_{2n+1}\text{O}_n$  of normal polyhydric alcohols seem to act as auxoglucs without exception. The fact that sugars and polyhydric alcohols are sweet need hardly to be mentioned. The *d*-glucosaminic acid of Fischer and Tiemann<sup>3</sup> is a good example,<sup>4</sup> proving that this holds true for the glucophore  $\text{CO}_2\text{H}\cdot\text{CHNH}_2\cdot$  also.

#### Classification of the Auxoglucs.

As will be seen from the foregoing, the auxoglucs determined may be classified conveniently under 4 heads:

1. Hydrogen.
2. The radicals  $\text{C}_n\text{H}_{2n+1}$  of saturated hydrocarbons, in which  $n = 1-3$  (or 5).
3. The radicals  $\text{C}_n\text{H}_{2n+10}$  of monohydric alcohols in which  $n = 1-2$ .
4. The radical  $\text{C}_n\text{H}_{2n+10n}$  of normal polyhydric alcohols, in which  $n = 2-5$ .

It is very probable that this list may be enlarged considerably. The ether radical  $\text{CH}_2\text{CH}\cdot$ , for instance, may probably be included. But

it is not permissible to do this until more experimental data can be obtained. Hasty generalizations easily lead to wrong conclusions, especially in this field. Faulty or conflicting observations on the subject are pretty numerous and due largely to individual differences in the sense of taste. Besides we do not yet know all the factors which tend to make compounds containing a glucophore taste bitter, and the source of notable exceptions.

#### The Influence of Acid Radicals.

We have just seen that all the saturated alkyl groups containing from one to 3 carbon atoms may act as auxoglucs. All of the higher paraffins do by no means act in the same way. Normal octyl iodide, for instance, is not sweet. Nor do all derivatives of the first members of the paraffin series act as auxoglucs. Glyceric acid, for instance, contains the glucophore  $\text{CH}_2\text{OH}\cdot\text{CHOH}\cdot$ , yet the presence of the acid radical  $\text{—CO}_2\text{H}$  not belonging itself to a glucophore, causes the resulting compound to

<sup>1</sup> *Ber.*, 40, 110 (1907).

<sup>2</sup> *Arch. f. Anat. Physiol.*, 1915, p. 226.

<sup>3</sup> *Ber.*, 27, 142 (1894).

<sup>4</sup> C. Neuberg, *Ber.*, 35, 4013 (1903).

taste sour. The radicals of the lower fatty acids as well as the radicals of oxyacids yields, with a glucophore, acid compounds.

### The Influence of the Phenyl Group

As has been pointed out repeatedly by Cohn<sup>1</sup> the entrance of a phenyl radical tends to make an otherwise sweet compound bitter. Glycol is sweet, styrol is slightly bitter. There seem to exist quite a number of radicals which yield with a glucophore bitter compounds, but in view of the limited data on hand, we have to postpone the discussion of the rules governing this change of taste.

### The Influence of Stereoisomerism.

Some seeming exceptions to our rule are due to stereoisomerism.

Thus, *l*-valin  $(\text{CH}_3)_2\text{CH}.\text{CHNH}_2.\text{CO}_2\text{H}$ , is made up of the glucophore  $-\text{CHNH}_2.\text{CO}_2\text{H}$  and the auxogluc  $(\text{CH}_3)_2\text{CH}-$  and might be expected to be sweet. According to E. Fischer<sup>2</sup> it is insipid and weakly bitter. However, the *d*-valin, and consequently the *dl*-valin too are sweet.

It follows therefore that the racemic  $\alpha$ -amino acids, but not all the optically active  $\alpha$ -amino acids fall within the scope of our theory.

### Determination of the Taste of an Organic Compound.

If then we wish to predict whether a given compound is sweet or not, we first will determine if it contains a glucophore. If not, we may conclude immediately that the substance is not sweet.

But even if we find the substance under consideration to contain a glucophoric group, we have to determine further whether an auxogluc is present too, or if the substance contains perchance an acid radical. In the former case the substance will be sweet, in the latter sour.

A few examples will make this clear.

Serin,  $\text{CH}_3\text{OH}_2\text{CHNH}_2.\text{CO}_2\text{H}$ , may be divided in two parts,  $\text{CO}_2\text{H}.\text{CHNH}_2-$  and  $\text{CH}_2\text{OH}-$ . The former we have seen to be a glucophore, the latter is an auxogluc. The compound made up of two such parts should be sweet, a conclusion which agrees with the facts.

Isoserin,  $\text{CH}_2\text{NH}_2.\text{CHOH}.\text{CO}_2\text{H}$ , although made up of the same atoms and "sapophores" (Cohn), does not contain the same glucophore from the standpoint of our theory, and consequently it should not be sweet. In the literature it is described as "insipid."<sup>3</sup>

$\alpha$ -Amino-butyric acid,  $\text{CH}_3\text{CH}_2\text{CHNH}_2.\text{CO}_2\text{H}$  is made up of the glucophore,  $\text{CO}_2\text{H}.\text{CHNH}_2-$  and the auxogluc,  $\text{CH}_3\text{CH}_2-$ , and consequently it is sweet. On the contrary aspartic acid,  $\text{CO}_2\text{H}.\text{CH}_2.\text{CHNH}_2.\text{CO}_2\text{H}$ , while containing the same glucophore, is linked to an acid radical and it tastes sour.

<sup>1</sup> *Loc. cit.*

<sup>2</sup> *Ber.*, 39, 2328 (1906).

<sup>3</sup> E. Fischer and W. E. Jacobs, *Ibid.*, 40, 1057, 1064 (1907).

Acetylene tetrabromide is made up of the glucophoric group  $\text{CHBr}_2\text{-CBr}_2\text{-}$  and hydrogen as auxogluc. In accordance with our theory it should be sweet. A careful test convinced us that in alcoholic solution it tastes disagreeably sweetish.

1,2-Propanediol is sweetish. It contains the glucophore  $\text{CH}_2\text{QH-CHOH-}$  and the auxogluc  $\text{CH}_3\text{-}$

The monomethyl ether of glycol,  $\text{CH}_2\text{OH.CH}_2\text{OCH}_3$ , on the contrary does not contain a glucophore, and it is described in the literature as tasteless.<sup>1</sup>

Finally we select a member of the sugar group. Glucose is made up of the glucophore  $\text{CH}_2\text{OH.CO-}$  and the auxogluc  $\text{CH}_2\text{OH}(\text{CHOH})_5\text{-}$ , the latter corresponding to the general formula  $\text{C}_n\text{H}_{2+10n}$ .

The tables following, not only will include the necessary literary references to the above examples, but to a great number of other substances of this kind in addition. It is true that some of the derivatives included in our list are said to be bitter or tasteless. We question, however, some of these statements and we have already found them in several instances to be based on inaccurate observation.

#### Limitations and Possibilities of Our Theory.

It was pointed out at the beginning of this article that we confined the application of our theory at first to the more important sweet aliphatic compounds. The numerous cases in which the theory was verified seem to justify its publication, although we are well aware that there exist apparently some notable exceptions to our rule.

We hope to extend the scope of our theory soon. The combination of two glucophores for example seem to be sweet in most cases, *i. e.*, a glucophore may act probably as an auxogluc also.

We further intend to apply our theory, with certain modifications not only to sweet aromatic compounds, such as the saccharine of Remsen, but also to bitter substances in general. This study will require considerable time and work.

We finally have the pleasure to thank Professor Dr. R. E. Swain for interest and encouragement kindly given us in connection with this study.

#### Taste Trials.

*Methyl iodide*,  $\text{CH}_3\text{I}$ .—Prepared after Dumas and Peligot<sup>2</sup> by treating methyl alcohol with red phosphorus and iodine. B. p. 43°. Taste: sweetish.

*Ethyl bromide*,  $\text{CH}_3\text{CH}_2\text{Br}$ .—Prepared according to de Vries<sup>3</sup> by distilling ethyl alcohol with sulfuric acid and sodium bromide. B. p. 38–39°. Taste: sweet.

*Ethyl iodide*,  $\text{CH}_3\text{CH}_2\text{I}$ .—Prepared according to Serullas<sup>4</sup> by treating ethyl alcohol with phosphorus and iodine. B. p. 72–73°. Taste: sweet.

<sup>1</sup> M. H. Palonua, *Ber.*, **35**, 3300 (1902).

<sup>2</sup> *Ann.*, **15**, 30 (1835).

<sup>3</sup> *Jahrb. Chem.*, **1857**, 441.

<sup>4</sup> *Ann. chim. phys.*, [2] **42**, 119 (1829).



*1-Chloropropane*,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$ .—Prepared according to I. Pierre and E. Puchot,<sup>1</sup> by treating primary propyl alcohol with phosphorus trichloride. B. p. 46–47°. Taste: sweetish.

*1-Bromopropane*,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ .—Prepared according to E. Linnemann<sup>2</sup> by distilling primary propyl alcohol with sulfuric acid and sodium bromide. B. p. 71°. Taste: sweet.

*1-Iodopropane*,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{I}$ .—Prepared according to M. Chancel<sup>3</sup> from primary propyl alcohol, red phosphorus and iodine. B. p. 102°. Taste: sweetish. Taste develops tardily.

*1,1-, 2,2-, Tetrabromoethane*,  $\text{CHBr}_2\text{CHBr}_2$ .—Prepared according to W. Muthmann,<sup>4</sup> by treating acetylene (made from calcium carbide) with bromine. The raw product was successively washed with water, sodium carbonate, sodium thiosulfate and with water again. It was then extracted with ether, dried with calcium chloride, and the ether distilled off. Finally the acetylene tetrabromide was rectified by distilling *in vacuo*. B. p. 134° at 33 mm. Taste: sweetish and disagreeable when first placed on tip of tongue; to many people it tastes only disagreeably. Taste of a solution in alcohol, 60%; disagreeably sweetish.

### Classification of Aliphatic Sweetstuffs According to Glucophores and Auxoglucs.

In our new classification of aliphatic sweetstuffs, the substances are first subdivided in different classes, according to their glucophores. Thus all substances that owe their sweet taste to the glucophore  $\text{CH}_2\text{OH}$ .- $\text{CHOH}$ — are to be found in Table I. Within each table the sweetstuffs are arranged according to their auxoglucs.

TABLE I.—Glucophore $\text{CH}_2\text{OH}$ — $\text{CHOH}$ —.			
Auxogluc.	Name.	Taste.	Literature.
H—	Glycol	Sweet	A. Wurtz, <i>Ann. chim. phys.</i> , [3] 55, 410 (1857).
$\text{CH}_3$ —	1,2-Propanediol	Sweetish	A. Wurtz, <i>Ibid.</i> , [3] 55, 439 (1857).
$\text{CH}_3\text{CH}_2$ —	1,2-Butanediol	Sweetish	N. Grabowski and A. Saytzeff, <i>Ann.</i> , 179, 333 (1875).
$(\text{CH}_3)_2\text{CH}$ —	3-Methylbutane-1,2-diol	Burning bitter	E. Flawitzki, <i>Ibid.</i> , 179, 353 (1875).
$\text{CH}_2\text{OH}$ —	Glycerol	Sweet	Scheele, <i>Crell's, Ibid.</i> , 1, 99 (1784).
$\text{CH}_3\text{CHOH}$ —	1,2,3-Butanetriol	Sweet	Beilstein, <i>Org. Chem.</i> , 1, 277.
$\text{CH}_2\text{OHCH}_2$ —	1,2,4-Butanetriol	Sweet	G. Wagner, <i>Ber.</i> , 27, 2437 (1894).
$\text{CH}_3\text{CH}_2\text{CHOH}$ —	1,2,3-Pentanetriol	Sweet	G. Wagner, <i>Ibid.</i> , 21, 3349 (1888).
$\text{C}_n\text{H}_{2n-1}$	Polyhydric alcohols	All sweet	Cohn, <i>Loc. cit.</i> , pp. 212, 219, 224.

<sup>1</sup> *Ann.*, 163, 266 (1872).

<sup>2</sup> *Ibid.*, 161, 40 (1872).

<sup>3</sup> *Bull. soc. chim.*, 39, 648 (1883).

<sup>4</sup> *Kryst. Min.*, 30, 73 (1899).

TABLE II.—Glucophore, —COC—HOH—(H).

Auxogluc. H---	Name.	Taste.	Literature.
	Glycollic aldehyde	Distinctly sweet	Abderhalden, <i>Bioch. Handb.</i> , 2, 266.
CH <sub>3</sub> —	Oxyacetone	Sweet	A. Kling, <i>Ann. chim. phys.</i> , [8] 5, 496 (1905).
	Oxypropionic aldehyde	Unknown	
	monomolecular	Slightly bitter	A. Wohl, <i>Ber.</i> , 41, 3609 (1908).
	bimolecular	bitter	
CH <sub>2</sub> OH—	Glyceric aldehyde	Sweet and bitter	A. Wohl, <i>Ibid.</i> , 31, 1801 (1898).
	monomolecular	bitter	
	bimolecular	Slightly sweet	A. Wohl, <i>Ibid.</i> , 31, 2394 (1898).
	Dioxyacetone	Sweet	O. Piloty, <i>Ibid.</i> , 30, 3165 (1897).
CH <sub>3</sub> CHOH—	Methyl-glyceric aldehyde CH <sub>3</sub> (CHOH) <sub>2</sub> CHO	Sweet and bitter	A. Wohl and F. Franz, <i>Ibid.</i> , 35, 1908 (1902).
	Methyl-dioxyacetone	Sweetish	O. Diehls and E. Stephan, <i>Ibid.</i> , 42, 1788 (1909).
C <sub>n</sub> H <sub>2n-1</sub> O <sub>n</sub>	Sugars, <i>e. g.</i> , hexoses	Sweet	Common knowledge

TABLE III.

Glucophore, CO<sub>2</sub>H—CHNH<sub>2</sub>.

Auxogluc. H---	Name.	Taste.	Literature.
	Amino-acetic acid	Sweet	E. Abderhalden, <i>Bioch. Handb.</i> , 4, 403.
CH <sub>3</sub> —	<i>dl</i> -α-Amino-propionic acid	Sweet	A. Strecker, <i>Ann.</i> , 75, 31 (1850).
CH <sub>3</sub> CH <sub>2</sub> —	<i>dl</i> -α-Amino-butyric acid	Sweet	C. Frideel and V. Nachhuch, <i>Ann. Suppl.</i> , 2, 71 (1861).
CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> —	<i>dl</i> -α-Amino- <i>n</i> -valeric acid	Sweet	A. Lipp, <i>Ann.</i> , 211, 360 (1882).
(CH <sub>3</sub> ) <sub>2</sub> CH—	α-Amino-isovaleric acid ( <i>dl</i> -valin)	Sweet	M. D. Slimmer, <i>Ber.</i> , 35, 400 (1902).
(CH <sub>3</sub> ) <sub>2</sub> CHCH <sub>2</sub> —	<i>dl</i> -leucine	Slightly sweet	Tierfelder, " <i>Handbuch</i> ," p. 235.
CH <sub>2</sub> OH—	<i>dl</i> -Serine, α-amino-β-hydroxy-propionic acid	Sweet	Schmidt, <i>Pharm. Chem.</i> , 1, 460.
CH <sub>3</sub> CHOH—	<i>dl</i> -α-Amino-β-hydroxy-butyric acid	Sweet	W. Sternberg, <i>Arch. Anat. Physiol.</i> , 228 (1905).
CH <sub>2</sub> OH.CH <sub>2</sub> —	<i>dl</i> -α-Amino-γ-hydroxy-butyric acid	Sweet	E. Fischer and Blumenthal, <i>Ber.</i> , 40, 110 (1907).
CH <sub>3</sub> CHOH.- CH <sub>2</sub> —	<i>dl</i> -α-Amino-γ-hydroxy-valeric acid	Very sweet	E. Fischer and Leuchs, <i>Ibid.</i> , 35, 3797 (1902).
C <sub>n</sub> H <sub>2n-1</sub> O <sub>n</sub> —	<i>d</i> -Glucosaminic acid	Agreeably sweet	E. Fischer and F. Tie- mann, <i>Ber.</i> , 27, 142 (1894). C. Neuberg, <i>Ibid.</i> , 35, 4013 (1903).

TABLE IV.  
 Glucophore  $\text{CH}_2\text{ONO}_2$ —.

Auxogluc.	Name.	Taste.	Literature.
$\text{CH}_3$ —	Ethyl nitrate	Sweet	Millon, <i>Ann.</i> , <b>47</b> , 374 (1843). G. Bertoni, <i>Gazz. chim. ital.</i> , <b>20</b> , 373 (1890).
$\text{CH}_3(\text{CH}_2)_{2n}$ —	Butyl nitrate	Sweet	G. Bertoni, <i>Ibid.</i> , <b>20</b> , 373 (1890). Cohn, <i>Loc. cit.</i> , <b>20</b> , 412 (1890).
$(\text{CH}_3)_2\text{CH}$ —	Isobutyl nitrate	Sweet	A. Wurtz, <i>Ann.</i> , <b>93</b> , 120 (1855).
$(\text{CH}_3)_2\text{CHCH}_2$ —	Isoamyl nitrate	Sweetish	W. Hofmann, <i>Ibid.</i> , <b>68</b> , 333 (1848).
$\text{CH}_2\text{OH}$ —	Glycol mononitrate	Sweet	Fehling, <i>Handwörterbuch der chemie</i> , <b>6</b> , 1273. L. Henry, <i>Ann. chim. phys.</i> , [4] <b>27</b> , 247 (1872).

 TABLE V.  
 Glucophore  $\text{C}_{\text{H}_x}^{\text{H}_2-x}$ .

Auxogluc.	Name.	Taste.	Literature
H—	Methyl chloride	Sweetish	Fehling, <i>Loc. cit.</i> , <b>4</b> , 401. Cohn, <i>Loc. cit.</i> , p. 123.
	Methylene chloride	Sweetish	W. H. Perkinsen., <i>J. Chem. Soc.</i> , [2] <b>7</b> , 260 (1869). A. Butlerow, <i>Jahresb.</i> , <b>1869</b> , p. 343.
	Chloroform	Sweet	W. Sternberg, <i>Z. Anat. Physiol.</i> , <b>1905</b> , p. 119.
	Methylene bromide	Sweet	L. Henry, <i>Ann. chim. phys.</i> , [5] <b>30</b> (1883).
	Bromoform	Sweetish	Kolbe, <b>1</b> , 601. Cohn, <i>Loc. cit.</i> , p. 130.
	Methyl iodide	Sweet	Oertly and Myers.
	Methylene iodide	Sweet	A. Butlerow, <i>Compt. rend.</i> , <b>46</b> , 595 (1858).
	Iodoform	Sweetish	Schmidt, <i>Pharm. Chem.</i> , <b>1</b> , 108.
	Chlorobromo-methane	Sweetish	L. Henry, <i>Compt. rend.</i> , <b>101</b> , 599 (1885).
	Chlorodibromo-methane	Sweetish	Cohn, <i>Loc. cit.</i> , p. 130.
	Dichloro-iodo-methane	Sweetish	A. Borodine, <i>Ann.</i> , <b>126</b> , 239 (1863).
	Bromo-iodo-methane	Sweetish	L. Henry, <i>Compt. rend.</i> , <b>101</b> , 599 (1885).
$\text{CH}_3$ —	Ethyl chloride	Sweetish	Fehling, p. 126. Cohn, <i>Loc. cit.</i> , p. 126.
	Ethylidene chloride	Sweetish	A. Geuther, <i>Ann.</i> , <b>105</b> , 324 (1888).

TABLE V (continued).

Auxogluc.	Name.	Taste.	Literature.
	Ethyl bromide	Burning	Fehling, <i>Loc. cit.</i> , p. 124. Cohn, <i>Ibid.</i> , p. 128.
	Ethyl iodide	Sweet	Oertly and Myers.
	1,1-Chloro-bromo-ethane	Sweet	Oertly and Myers.
	1,1-Chloro-iodo-ethane	Sweetish	W. Staedel and J. Denzel, <i>Ann.</i> , 195, 193 (1879).
CH <sub>3</sub> —	1,1-Chloro-iodo-ethane	Sweet	M. Simpson, <i>Pharm. Zentralh.</i> , 27, 424
	1,1-Bromo-iodo-methane	Sweet	M. Simpson, <i>Pharm. Zentralh.</i> , 27, 424
CH <sub>3</sub> CH <sub>2</sub> —	1-Chloropropane	Sweetish	Oertly and Myers.
	1-Bromopropane	Sweet	Oertly and Myers.
	1-Iodopropane	Sweetish	Oertly and Myers.
		taste develops tardily.	
CH <sub>3</sub> CH <sub>3</sub> —	Isobutyl chloride	Sweetish	Pierre and E. Puchot, <i>Ann.</i> , 163, 276 (1872).
CH <sub>2</sub> OH—	Ethylene chlorohydrine	Sweet	A. Butlerow, <i>Ibid.</i> , 144, 42 (1867).
	Ethylene bromohydrine	Bitter	L. Henry, <i>Ann. chim. phys.</i> , [4] 27, 252 (1872).
	Ethylene iodohydrine	Sweet	A. Butlerow and M. Ossekin, <i>Ann.</i> , 144, 44 (1867).
		Bitter	L. Henry, <i>Bull. Belg.</i> , [3] 183.
	2,2-Dibromo-ethane-1-ol	Sweet as sugar	E. Demole, <i>Ber.</i> , 9, 50 (1876).
CH <sub>3</sub> .CHOH	1-Chloropropane-2-ol	Sweetish	Oser, <i>Jahresb.</i> , 1860, p. 448

TABLE VI.

Glucophore  $\text{C}_{\text{H}_2}^{\text{H}_3-x} - \text{C}_{\text{H}_2}^{\text{H}_2-x}$  —

Auxogluc.	Name.	Taste.	Literature.
H—	Ethylene chloride	Sweetish	Fehling, <i>Loc. cit.</i> , 1, 154.
	Ethylene bromide	Sweetish	Fehling, <i>Ibid.</i> , 1, 1153.
	Ethylene chloro-iodide	Sweet	M. Simpson, <i>Ann.</i> , 125, 102 (1863).
	1,1-Dichloro-2-iodo-ethane	Sweet	L. Henry, <i>Compt. rend.</i> , 98, 518 (1884).
	1,1,2,2-Tetrachloro-ethane	Sweet	E. Paterno and G. Pisati, <i>Jahresb.</i> , 1871, p. 508.
	1,1,1-Trichloro-2-bromo-ethane	Burning	L. Henry, <i>Compt. rend.</i> , 98, 370 (1884).
	1,1,2,2-Tetra-bromo-ethane	Sweetish	L. Henry, <i>Compt. rend.</i> , 98, 370 (1884).
		Nearly tasteless	Cohn, <i>Loc. cit.</i> , p. 132.
	Pentachloro-ethane	Sweetish	Oertly and Myers.
		Sweet	J. Pierre, <i>Jahresb.</i> , 1847, pp. 48, 686.
CH <sub>3</sub> —	2-Chloro-1-iodopropane	Sweet	M. Simpson, <i>Ann.</i> , 127, 337 (1863).

TABLE VI (continued).

Auxogluc.	Name.	Taste.	Literature.
	2-Chloro-1,2-dibromo-propane	Sweet	C. Friedel, <i>Ann.</i> , <b>112</b> , 236 (1859).
CH <sub>2</sub> OH—	2,3-Dichloro-1-hydroxypropane	Burning spicy	B. Tollens, <i>Ibid.</i> , <b>156</b> , 165 (1870).
	2-Chloro-3-bromo-propane-1-ol	Sweet	L. Henry, <i>Bull. Belg.</i> , [2] 37, 370.

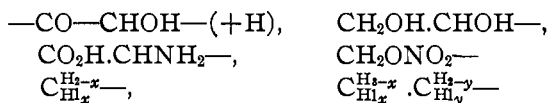
In order to locate a given sweet compound, determine first its glucophore and its auxogluc by the method previously described. Then examine lists for the corresponding glucophore and auxogluc, the latter to be found in the first column of each table.

If the substance be sweet and there is no space for it in the table, its taste is not yet known, as far as we can ascertain; or it does not fall within the present scope of our theory.

### Summary.

1. A theory has been worked out relating the sweet taste of organic compounds to their constitution. The taste was found to be dependent on two factors. The glucophores make a given compound a potential tastestuff. If a glucophore is bound to any of the auxoglucs, a sweet compound results.

2. The following radicals are found to be glucophores in the sense of our theory:



Some others may very likely be included later on.

3. The following atoms or radicals seem to act as auxoglucs, yielding with glucophores sweet compounds:

(a) H, hydrogen.

(b) The radicals, C<sub>n</sub>H<sub>2n+1</sub>O, of saturated hydrocarbons, containing from one to 3 carbon atoms. Example CH<sub>3</sub>CH<sub>2</sub>—.

(c) The radicals C<sub>n</sub>H<sub>2n+1</sub>O of monohydric alcohols, *n* being equal to one or two. Example CH<sub>2</sub>OH—.

(d) The radicals C<sub>n</sub>H<sub>2n-1</sub>O<sub>n</sub> of polyhydric alcohols. Example CH<sub>2</sub>OHCHOH—.

4. Numerous examples supporting this theory are cited, and a new classification of sweet aliphatic compounds is proposed.

5. An outline of plans for future work on our theory is given.