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THE SYNTHETIC FOOD OF THE FUTURE.[1]

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THE problem of human nutrition is the great groundwork of sociology. I use the word nutrition in its broadest sense, including clothing and fuel, which, while not as essential as food to life, are quite as important factors in civilization. Until within a few years the study of nutrition and the means of providing it have been deemed the exclusive function of agriculture. In the development of this idea, we have seen springing into existence in all parts of the civilized world, within the past twenty-five years, colleges of agriculture and agronomic experiment stations in large numbers. Especially in this country have we seen the greatest activity in this line. In all the states and territories, fostered by the federal government, schools have been established in which instruction in agriculture has been made a fundamental branch of the college curriculum. There are fifty-seven agricultural experiment stations in the United States. Each state and territory has at least one. Louisiana has three, Alabama, Connecticut, Massachusetts, New Jersey, and New York each two, and the Department of Agriculture two, one in Florida and one in California. For the support of the state and territorial stations, Congress has made an appropriation for the fiscal year ending June 30th, 1895, of $745,000 and for the Department stations $10,000, in all $755,000. The agricultural colleges in the states and territories have also been endowed by

[1] Retiring Address of Harvey W. Wiley as President of the Society, Boylston Hall, Harvard University. Dec. 28, 1894.

grants of public land proportionate in extent to the numbers of senators and representatives in congress. The annual money value of these grants varies with their extent and the wisdom with which they have been invested, but the total sum is approximately a million and a half dollars. In addition to this a sum of money is granted annually to each agricultural college directly from the treasury, and this sum is to be increased at the rate of $1000 per annum until it amounts for each institution to $25,000 a year. This amount will be reached in five years. At present the total sum so granted is nearly a million dollars, and it will soon be a million and a quarter. The total amount of the financial aid thus granted directly from the treasury to the agricultural colleges and experiment stations is at the present time approximately three million and a quarter dollars annually. To this must be added the amount given directly by the states and arising from private endowments—a sum of no inconsiderable importance. In all it may be said that about four million dollars in this country are annually devoted to the promotion of agricultural and allied education and research, a sum more liberal than that devoted by any other country to similar objects.

The natural result from such investigations is an increase in soil productiveness, the reclamation of lands supposed heretofore to be unfit for tillage and a greater economy of food production. The supply of human food, therefore, appears to more than keep step with the increase in population and food consumption. In so far as economic reasons extend, there is no occasion to look outside of scientific agriculture for the supply of human food.

But another view is presented of the subject of a more strictly scientific aspect, based on the remarkable progress which has been made in the past few years in the domain of synthetic chemistry. The year 1828 marks a new era in the history of chemistry. It was in this year that Wöhler succeeded in making synthetic urea by the union of cyanic acid and ammonia. Urea is not of a high order of organic bodies; in fact, it is a result of retrograde action in the living organism and the consequent result of the breaking down of higher organic bodies; yet its artificial formation was a brilliant victory of chemical methods, a bold and successful charge on the breastworks of organic compounds. To change the figure, it was the crossing of the dead line which had been drawn previously between the living cell and the inanimate crucible. The line once having been crossed, the old distinctions between the organic and the inorganic world have been completely obliterated. With them have gone also the divisions which were supposed to separate the animal from the plant. It is now known that animals do not get their entire nourishment from so-called organic nor plants from inorganic compounds. Many plants, especially those free of chlorophyl, live alone on organic compounds. Especially noteworthy among these, from the character of the chemical activity which they manifest, are the vegetations of a bacterial nature, living largely on organic products. Even the green plants first fabricate the inorganic elements into organic compounds before taking them into their tissues. The green cells are the tiny kitchens in which the meals of the plant molecules are prepared.

Without dwelling on further details of this subject, it is sufficient for the present purpose to state that the progress of modern science has entirely changed our ideas respecting the sharp lines of division which were formerly thought to exist between the animal and vegetable, and between the nature of artificial chemical compounds and those produced by biochemical action in the living organism. We stand, therefore, face to face with the fact that it is possible to produce, by artificial means in the laboratory, compounds which have heretofore been the results of exclusive biochemical functional activity of living organisms.

One remarkable fact in connection with Wöhler's synthesis of an organic compound is of interest here. While all the chemical world wondered at Wöhler's achievement, nearly fifty years elapsed before this rich field of chemical progress was further cultivated to any extent, with the single exception of the synthesis of acetic acid by Kolbe, in 1845. But since that time remarkable progress has been made. It is not my purpose here to recite in detail the synthetic accomplishments of Berthelot, Kekulé, Kolbe, Maumené, Baeyer, Hoffmann, Frankland, Ladenberg, Fischer, and many other celebrated workers in this field.[1]

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[1] See Rise and Development of Organic Chemistry, by C. Schorlemmer, revised edition, 1894.

For the purpose of the present paper, only two points in organic chemical synthesis need be considered; *viz.*, first, the economy of the process, and second, the probability of the production of food compounds suited to the nourishment of man.

In respect of the first point, we find many illustrative examples of synthetic products which are furnished at so small an expense as to practically exclude from the market the corresponding natural articles. Among these may be mentioned salicylic acid made artificially by Kolbe's[1] process. Salicylic acid occurs as a natural product in the flowers of *Spirea ulmaria* and as a methyl ether in the oil of wintergreen (*Gaultheria procumbens*). It can be formed by synthesis in various ways, as, for instance, by fusion of salicylaldehyde with potassium hydroxide. Salicine, coumarine, indigo, cresol, or toluenesulphonic acid may be substituted for the salicylaldehyde. When phenyl carbonate is heated with a caustic alkali, salicylic acid is also produced. It may also be obtained when an alkaline solution of phenol is boiled with carbon tetrachloride. But none of these processes, although of great interest chemically, have any value commercially save that of Kolbe, or more properly, Kolbe and Lautemann, which consists of passing carbon dioxide into sodium phenylate.

But it will be observed that the phenol which is the base of the process, is itself an organic compound, or the result of the destructive distillation of an organic compound produced by nature. It is not impossible to produce phenol by artificial synthesis. It is said that by surrounding the points of an electric arc light with hydrogen that carbon and hydrogen combine to form acetylene, C_2H_2. According to Berthelot,[2] fuming sulfuric acid absorbs acetylene and the product so formed fused with caustic soda forms phenol or sodium phenate. But it needs no further illustration to show that a phenol formed in this manner could never, on account of its great cost, be used for the commercial manufacture of salicylic acid.

A distinction should be made in this matter between the formation of possible food products by synthesis from existing organic natural bodies, and the synthesis which begins with the inorganic elements themselves. The transformation of one organic

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[1] *J. prakt. Chem.*, 2, 10, 93.

[2] *Compt. rend.*, 68, 539.

body into another of greater value to human industry is quite a different matter from the building up of organic bodies without the help of a living organism. Berthelot himself, who is now the apostle of synthetic foods, summarizes the steps which will probably be traversed on the way which is to end in the substitution of the chemist for the farmer:

1. Hydrocarbons, obtained by the union of hydrogen and carbon.
2. Alcohols formed from the hydrocarbons in various ways.
3. Aldehydes and acids obtained from alcohol by oxidation.
4. Amides produced by the action of ammonia on the alcohols.
5. Alkaloids formed by the action of ammonia on the alcohols and aldehydes.

But even granting the fullest development of such a scheme, the impartial observer will be compelled to admit that there is still an immense gulf between the best of the products formed and human food.

In the case of medicines and drugs, perhaps the case is more hopeful. In so far as mere transformation of one organic substance into another of greater therapeutic value is concerned, much progress has already been made. But in nearly all of these cases the products are obtained by the splitting up of more complex into less complex molecules. In other words, it is a retrograde synthesis and not a constructive one. A mere list of remedies in common use, which have been formed in this way, would form an extensive index of pharmacy.

Both Liebig and Wöhler, as early as 1837, foresaw this advance in synthetic chemistry and predicted the synthesis of alkaloids and antiseptics and even of sugar.

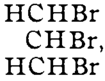
Founded on the classical researches of Williamson on etherification has been built the art of forming by synthesis a great variety of flavoring matters for food and drink. In the strict sense of the term, these condiments are not foods inasmuch as they are not subject to digestion and do not take any part in the nourishment of the tissues. They have a nearer relationship, however, to the purpose of this address than the bodies already mentioned.

The slow natural oxidation of the alcohols in fermented and distilled drinks, giving rise to ethers of delicate odor and flavor, is an expensive process, and synthetic chemistry has boldly come to the aid of nature. The essences of fruits and flowers are now elaborated in great numbers in our laboratories and supply to a certain extent the natural products. With the aid of ethyl alcohol, burnt sugar, and a collection of artificial essences, the skillful manipulator will mix, in short order, drinks which resemble bourbon and old rye, madeira and sherry. The pure fruit flavors of many soda-water fountains could easily prove an alibi in respect of orchards. In the great majority of cases these essences are also the products of retrograde synthesis, or have for the base of manufacture an alcohol derived from the fermentation of a natural sugar. While it is true that they can be manufactured at a lower cost than attends their natural production, and while they are used as condiments in foods and drinks, yet in no sense can they be regarded as a step toward the preparation of foods from inorganic elements by purely chemical means. The principal artificial flavoring extracts are the derivatives of the fatty acids, especially the ethers and aldehydes. The ethereal salts of acetic, valerianic, benzoic, salicylic, and butyric acids, are the most common of these bodies. Methyl, ethyl, and amyl are the bases most usually found in the above compounds. Vanillin has also been made synthetically. Analysis showed that this natural product of the vanilla fruit was methylprotocatechuic aldehyde. This knowledge led to its artificial production. From turpentine is derived a perfume turpineol which is known as "lily of the valley." The artificial production of musk and of the perfume of the violet have also been accomplished.

Whether or not these bodies are injurious to health is a question whose discussion can not be entered into here. In the case of one of the best known of these condiments, and one which is not of ethereal origin, it may be said that its use in foods is prohibited in some countries, whether it be used as a sweetener or as an antiseptic. In justice to saccharin, however, it should be stated that repressive legislation against it has been quite as much due to a feeling of jealousy on the part of beet-sugar producers as to a suspicion of unwholesomeness on the part of the medical fraternity. Certain it is, however, that, even as a sweetener, it will never take the place of sugar and because of its antiseptic properties it must necessarily interfere to some degree with the action of the digestive ferments.

It is not necessary to take up in detail other synthetic compounds which have attained a commercial success. The artificial dye stuffs are types of these bodies and illustrate, in a most brilliant manner, the progress of chemical synthesis based on the knowledge of the internal constitution of organic compounds derived from analytical investigations. But even the most enthusiastic believer in the future triumphs of chemical science will fail to find anything more than an inspiration in these achievements in respect of the production of foods. In all cases of coloring matters, original organic compounds derived from living cells, or the products of their destruction, have served as the bases of the processes. Without an elaborate review of this field therefore, and which, moreover, has already been made,[1] we pass at once to consider these achievements in synthesis which relate directly to the matter under consideration.

Along two lines of especial interest to food production, synthetic chemistry has made its greatest advances; *viz.*, the production of glycerides and of sugars. Wurtz[2] has described a method of synthesizing glycerol, which, in logic, would be called arguing in a circle.

Tribromhydrine,  $\begin{matrix}\mathrm{HCHBr}\\ \mathrm{CHBr}\\ \mathrm{HCHBr}\end{matrix}$, is decomposed with silver acetate forming triacetine. This is saponified by baryta yielding glycerol. The tribromhydrine, however, is first prepared from glycerol or rather from allyl iodide made from glycerol. At the end of this long synthesis, therefore, the chemist is exactly on the spot whence he started. Friedel and Silva[3], however, made glycerol in a different way. Trichlorhydrine is prepared from propylene chloride and saponified by heating with water. The propylene used is made from acetone. Wagner[4] produced glycerol by oxidizing allyl alcohol with potassium permanganate.

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[1] *Ber d. chem. Ges.*, *1891*, **24**, 1007.

[2] *Ann. Chem.* (Liebig), **102**, 339.

[3] *Bull. Soc. Chim.*, **20**, 98.

[4] *Ber d. chem. Ges.*, **21**, 3351.

Glycerol has also been formed synthetically by other investigators, but the principles involved are not greatly different from those set forth.

The first notice I have seen of the artificial formation of a fat is in a paper by Pelouze and Gelis[1] published in 1844. It is said that by gently heating a mixture of glycerol, butyric acid, and strong sulphuric acid, and afterwards diluting with water a yellowish oil separates. This fat is not soluble, or only slightly so, in water. It is soluble in all proportions in strong alcohol and in ether. Caustic potash breaks it up into butyric acid and glycerol. It may be formed at ordinary temperatures by passing a current of hydrochloric acid into a mixture of butyric acid and glycerol and afterwards diluting. The authors thought this body to be the butyrine discovered in butter by Chevreul. Its great solubility in alcohol would lead us in this day to suppose that the body was not a true butyrine.

Our present knowledge of the natural fats is based almost solely on the classic researches of Chevreul. While the work of Chevreul was purely analytic in its character, the knowledge of the constitution of fats which it disseminated has been the foundation on which all subsequent structures have been built. While at the present day chemists do not recognize the existence of margaric acid and margarine, all the other fatty bodies described by Chevreul have been found to have substantially the constitution which he assigned them.

Berthelot's first important contribution to the synthesis of fats was presented to the French Academy of Sciences on the 5th of September, 1853. It was entitled "Memoire sur les combinaisons de la glycerine avec les acides et sur la synthese des principes immediats des graisses des animaux."[2] From Berthelot's paper we learn that glycerol was discovered in 1779 by Scheele[3] in making lead plaster.

Fourcroy was the first to theorize on the nature of fats[4].

Berthelot regarded the formation of soap as due to the affinity of oils for alkali.[5]

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[1] *Ann. chim. phys.*, *1844*, [3], 10, 434.

[2] *Ann. chim. phys.*, *1854*, [3], 41, 216.

[3] *Opuscula*, 2, 175.

[4] *Systeme des connaissances chimiques*, 7, 142, 323, 329, and 334.

[5] Chevreul, *Ann. chim. phys.*, 88, 226.

Fourcroy in his work on the fat of cadavers, substituted another idea for this rational one, thinking the formation of soap due to the oxidation of the oil under the influence of alkali and air. He classed the vegetable oils, waxes, cadaveric fats, fats liberated from soaps by acid, cholesterine, etc., together under the name "adipocere."[1]

In 1815, simultaneously with the discoveries of Chevreul, Braconnot rejected the ideas of Fourcroy, saying:

"When tallow is agitated with acid or alkali, the three constituents, hydrogen, oxygen, and carbon, which had been in a state of equilibrium, separate and rearrange themselves in another order, giving rise to adipocere and to a very fusible fat, soluble in alcohol.[2]

Pelouze produced sulphoglyceric acids and phosphoglyceric acids and together with Gelis[3] he made butyrine, the first artificially prepared fat.

Berthelot has generalized this work by combining glycerol with both organic and inorganic acids. The bodies produced are, as a rule, neutral and incapable of directly uniting with alkali. Some reproduce the natural fats.

Stearins.—Stearic acid, melting at 70° and prepared according to the method of Chevreul,[4] forms with glycerol three neutral bodies, mono-, di-, and tristearin. The last is identical with natural stearin. To make monostearin; Berthelot heats equal parts of glycerol and stearic acid to 200° for thirty-six hours in a sealed tube. The body formed is insoluble in glycerol and readily separates from the excess of this body. It may be purified by heating to 100° with ether and quicklime to deprive it of excess of stearic acid.

To make distearin: This body may be formed by heating equal parts of glycerol and stearic acid to 100° for 114 hours, or to 275° for seven hours. It may also be formed by heating natural stearin to 200° for twenty-hours in the presence of glycerol. Another method is to heat monostearin to 260° for three

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[1] *Ann. chim. phys.*, 3, 129; Ibid, 5, 154; Ibid, 8, 17, 23, 31, and 67.

[2] *Ann. chim. phys.*, 93, 271.

[3] Sur la acide sulfoglycerique, *Compt. rend.*, 21, 718; Sur la butyrine, Nouvelles, *Ann chim phys.*, 10, 455.

[4] Recherches sur les corps gras, page 206.

hours in the presence of three parts of stearic acid. However formed, it is to be purified by the treatment with ether and lime.

To make tristearin: This body is obtained by heating monostearin to 270° for three hours with fifteen or twenty times its weight of stearic acid. Water is eliminated. The product is to be purified with ether and lime. The properties of natural and artificial stearin coincide as nearly as can be expected, considering the fact that natural stearin is never obtained pure. The nearest approach in properties by natural stearin to those of the artificial, was that shown by a preparation made by P. Duffy[1] who purified it by thirty-two crystallizations. The acid prepared by saponification, etc., from the synthetic stearin had the same melting-point as that originally employed.

Margarines.—Margaric acid from human fat[2] forms two neutral combinations with glycerol, monomargarine, and trimargarine.

To make monomargarine: Monomargarine may be prepared by heating a mixture of glycerol and margaric acid to 200° for twenty-one hours or to 100° for 106 hours. The reaction takes place with great readiness, in fact the synthesis is easier than that of any other fat. The same body or a similar one, is formed by simple contact of the constituents at ordinary temperatures for three months, though in very small quantity. A margarine is also formed by heating a mixture of margaric acid and glycerol saturated with hydrochloric acid, to 100° for some hours, but it is always contaminated with chlorhydrine.

Trimargarine is formed by heating monomargarine to 270° for seven hours in the presence of excess of margaric acid. The fat acid separated from it by saponification, etc., had the same melting-point as that originally employed.

Palmitins.—Three palmitins were formed in the way employed for the preceding fats.

Oleins.—Three were formed. The oleic acid employed was purified by the method suggested by Gottliebe.[3] The commercial acid was twice chilled and filtered and then converted into a potash soap. The soap was dissolved in twice its weight of alco-

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[1] *Quart. Jour. Chem. Soc.*, Jan., *1853*, pages 303, 309, 310.

[2] Chevreul, Recherches, sur les corps gras, page 59.

[3] *Ann. der Chem. u. Pharm.*, 57, 93.

hol, filtered cold, and precipitated with barium chloride. The barium soap was recrystallized from boiling alcohol (one liter of strong alcohol dissolves five grams), and then decomposed by tartaric acid in an atmosphere of hydrogen.

Valerines, butyrines and acetines were formed in the same general manner.

All these fats could also be produced, and more easily, by heating the components to 100° in the presence of an auxiliary acid, such as sulphuric, hydrochloric, tartaric, phosphoric, etc. Triacetine has also been formed by Böttenger[1] by the action of acetic anhydride on glycerol in the presence of acid potassium sulphate.

In this direction the work of molecule building has been carried a step further in securing the construction of a higher glyceride containing phosphorus. Hundeshagen[2] has succeeded in preparing a substance similar to lecithin, which is one of the essential constituents of cell plasma. In this work he followed first in the steps of Berthelot in securing distearin (distearylglycerol) by heating stearic acid with an equal volume of anhydrous glycerol for thirty hours in closed tubes at 200°. The purified distearin, heated to 110° with metaphosphoric acid or phosphoric anhydride, gave the desired phosphorus compound. Numbers of the salts and derivatives of the distearylglycerol phosphoric acid have also been prepared and studied.

In the matter of sugars greater progress has been made. The elder Thenard, more than fifty years ago, proposed a scheme for the direct production of sucrose by the condensation of carbon dioxide, water, and ethylene. Kiliani, Tollens, and many others have made important contributions to this work, but by far the most important advances in the synthesis of sugars have been made by Fischer. His work has been most thoroughly reviewed in this country by Keiser[3] and Stone.[4] Fischer[5] has also published a résumé of his work. Starting with formaldehyde and passing through glycerol and acrolein, Fischer, by a series of beautifully conceived researches, has succeeded in forming,

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[1] *Ann. Chem.*, 263, 359.

[2] *J. prakt. Chem.*, neue Folge, 28, 219.

[3] *Am. Chem. J.*, 11, 277, and 12, 357.

[4] *Ag. Science*, 6, 166.

[5] *Ber d. chem. Ges.*, 23, 2114, and 27, 3189.

by synthesis, a large number of sugars, some of which have not been discovered in nature. For the details of this work, the reviews mentioned can be consulted.

Lately in the same direction, another step has been taken. Fischer and Bunsch[1] have shown that the sugars under the influence of hydrochloric acid in the presence of alcohols and oxyacids are condensed to polysaccharides resembling glucosides.[2] Of these bodies methyl glucoside, $C_6H_6O_{11}CH_3$, methyl arabinoside, $C_5H_9O_5CH_3$, ethylarabinoside, $C_5H_9O_5C_2H_5$, ethylglucoside, $C_6H_{11}O_6C_2H_5$, methylgalactoside, $C_6H_{11}O_6CH_3$, ethylgalactoside, $C_6H_{11}O_6C_2H_5$ and benzylarabinoside, $C_5H_9O_5$, CH_2, C_6H_5 have already been formed.

Previous to the appearance of the above papers, Michael[3] had described a method for the synthesis of a glucoside. This method depends on the interaction taking place between so-called acetochlorhydrose and the alkaline carbolates. The method yields only a moderate product and is somewhat troublesome.

The process employed by Fischer in converting sugars into glucosidal bodies is well illustrated by the following example:

Grape sugar is dissolved in methyl alcohol and in the cold the solution is saturated with gaseous hydrochloric acid. The solution soon loses its power to reduce alkaline copper under this treatment and a crystalline product is formed. The reaction which takes place is represented by the following formula:

$$C_6H_{12}O_6 + CH_3OH = C_6H_{11}O_6CH_3 + H_2O.$$

To this substance the name methyl glucoside is given. The other bodies named above are formed by similar reactions.

Fischer, however, freely admits that although synthesis has done so much in the way of producing compounds which heretofore have been deemed the exclusive product of living vegetable cells, yet in the case of sugars an essential difference still exists.[4] In the laboratory there is produced at first only an inactive sugar which afterwards, by means of special operations, is split up into the active modifications, while the assimilation

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[1] *Ber d. chem. Ges.*, **27**, 2478.

[2] *Ber d. chem. Ges.*, **26**, 2400.

[3] *Compt. rend.*, 89, 355.

[4] Oration before the Institute for Military Surgeons, August 2, 1894. Neue Zeitschrift für Rübenzucker-Industrie, **23**, 185.

process of plants gives directly the active sugars of the same geometrical series. The stereochemistry of the carbohydrates, however, furnishes for this fact a full explanation.

If, in the case of an active sugar, by means of hydrocyanic acid, an additional carbon atom is added, the artificial process takes place in an asymmetric way. Since now in plant assimilation the optically active constituents of the chlorophyl granule take part in the production of carbohydrates, it is easy to understand how from the beginning, the formation of sugars with six carbon atoms takes place in an asymmetric manner.

In so far as I have been able to determine, no experiments have been made to determine the digestive coefficient of these synthetic foods. In the case of the artificial sugars many of them are unaffected by alcoholic ferments and it is safe to assume that the digestive ferments would be equally powerless to disintegrate them. The direct products of sugar synthesis are, as a rule, neutral to polarized light. This does not imply that morphologically they are so different from the natural products, but rather that the carbon asymmetry is inversely twinned and the product is composed of equal quantities of right and left-handed sugars.

Of the natural sugars, levulose is the only left-handed one of any economic or digestive importance. The specific rotatory power of this body varies with the temperature, and at 88° the disjointed carbon atoms are so much reduced in position as to show a rotatory power equal to that of dextrose.

So far, it does not appear that the left-handed sugars made by synthesis have all the properties of levulose. They seem to be somewhat different in their stereometric relations from the natural product. In fact, the theory does not require that the left-handed sugars be levulose, but that they be simply the twin asymmetric duplicates of the right-handed varieties. Left-handed dextrose, therefore, is an entirely different substance from levulose. For the old name dextrose, Fischer uses glucose, and for levulose, fructose. The prefixes l., d., and i., signify left and right polarizing and inactive respectively. In one case, however, he has discovered a. d. fructose as well as a. l. glucose

We have seen how by slow and painful steps and by roundabout ways the synthesis of sugar has gradually progressed until products containing nine molecules of carbon have been obtained. The ordinary sugar of commerce, saccharose, contains a molecule with twelve atoms of carbon. This sugar, however, can not be strictly considered as a dodekose, for it appears to be the product of the condensation of two hexoses. Whatever may be the true theory of its composition, whether wholly of the aldehyde type or a hybrid aldehyde ketone, yet its structure is of a higher order than the simple hexoses and it has not been formed artificially by any of the usual processes of synthesis.

It has remained for an inventor to take a short cut across the synthetic field and make saccharose *per saltum.*

Jean Ercole Pelligrini, a citizen of Italy, residing in France, has taken out a patent in this country for making sugar in a thoroughly direct manner. Ethylene gas, carbon dioxide, and steam are admitted in proper porportions to a channeled cube of pumice stone, impregnated with platinum sponge. The carbon dioxide and ethylene are used in practically equal volumes and the steam *ad libitum.* The pressure is so regulated that each gas will gradually diffuse through the whole porous platinized space. The operation is continued for about half an hour and "at the end of this period" to quote the language of the letters patent, "a sirup containing from twenty to twenty-five per cent. of sugar is withdrawn."

A sample of the sirup submitted with the application for the patent was examined in the laboratory of the Division of Chemistry at Washington and found to be sucrose. That it was made in the manner described, however, is a matter which, to my mind, requires further demonstration. The examiners of the Patent Office were, nevertheless, assured of the genuineness of the sample, by what proof I know not. For my part, I do not believe that a single molecule of sucrose can be made by that process. Some simple organic acid might be produced in this way, possibly some inactive sugar, but where shall we look for the stereochemical asymmetry which is so predominant a feature in that complex molecule which we call saccharose?

But for the sake of argument, grant the actual production of this substance. The price of a pound of carbon dioxide is far greater than that of a pound of sugar, and ethylene is still far more expensive. If the process of Pelligrini really works as well as the United States has certified, the sugar would cost nearly a dollar a pound. The whole process, in my opinion, may be classed with the electrical refining methods so successfully employed a few years ago in scientific buncoing. A full exposition of the fallacies of the method is given by Maumené.[1]

In the foregoing pages I have attempted to give a synopsis of some of the forms of organic synthesis which would enable us to come to a definite opinion regarding the possible production of artificial food. The prospect, it must be admitted, is not a flattering one.

First of all, it is seen that all cases of successful synthesis from an economic sense, belong either to the class already mentioned, *viz.*, retrograde synthesis, or to a process depending on the use of already existing organic compounds.

In this direction chemistry has a wealth of future achievements to offer commerce. The changes and modifications which can be made in natural products will continue hereafter, as in the past, to present to chemical science problems of the most promising success. As in the case of the polysaccharide starch, from which a simple hexose sugar is produced of the widest use in the arts, so with other organic products of the field, many victories in retrograde synthesis may be won. Chemistry will show how to make many foods more useful, and in the way of cooking more nutritious and palatable. In respect of the direct or indirect union of the elements into successful food products, there is not a single instance in all that have been cited to give any hope whatever.

In the way of economy the simple synthesis of hydrogen and nitrogen to form ammonia has never seen any chance of economic success. Here in one way, at least, synthesis might help to increase the stores of food. Nitrogen in ammonia salts is now worth eighteen cents a pound to the farmer. A simple synthesis would materially reduce its price. It might be well for the ambitious chemist to begin with ammonia before attempting albumen. While the scientific difficulties are less formidable

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[1] *Jour. de Fab. de Sucre*, 35, No. 4.

than the economic ones, yet they are apparently unsurmountable. A single pound of synthetic sugar must be worth many dollars, and we do not know that it will submit itself to digestion. The complex molecules of albuminoids and starches seem to me to be beyond the reach of chemical handicraft. There is no possibility of making many of the nutritive constituents of porterhouse steak, much less the mixing of them into an attractive and tempting form. In the field of scientific research, however, and the light which will be thrown on molecular structure, there are no limits to the triumphs of synthetic chemistry.

As the periodic law among the elements, so the theories of stereostructure, isomerism, asymmetry, and condensation have led and will lead to the greatest discoveries. When the investigator is once convinced of the possibility of any compound he will never cease to look for it until its discovery crowns his efforts. As the disturbance caused by an unknown body in space leads the astronomer to train his glass on the unexplored depths of the heavens, so do the missing links in molecular structures incite the chemist to renewed exertions. This fact is beautifully illustrated in the case of the carbohydrates. In the last few years there have been added to the number of sugars known to be produced by nature, more than twenty built by synthesis. But large numbers of possible sugars are still missing.

According to Fischer,[1] every asymmetric carbon atom in a carbohydrate molecule makes two forms possible. There can, therefore, be at least eight hexoses, and each of these is optically paired, making sixteen in all. Ten years ago only two of like structure of this number were known. Now ten have been discovered, and six yet remain unknown. Of the pentoses there are eight possible forms, of which four have been discovered. Of the thirty-two possible heptoses, only six are known, and of the 128 nonoses, only two. Since the possible number of compounds increases in a geometrical ratio with the addition of carbon atoms, it is seen that the field for discovery is not soon likely to be exhausted. But the molecule builder, it seems certain, must take his stones from Nature's quarries. He may fashion and change them, adapt them to new uses and endow them with more

[1] Neue Zeitschrift für Rübenzucker-Industrie, 23, 169.

valuable properties, but he can not make them of the raw original materials.

Schorlemmer in the revised edition of his Development of Organic Chemistry, while taking a very sanguine view of the future progress of synthetic chemistry, does not expect it to interfere with the farmer. He expects, at most, morphia and quinia to come from the laboratory instead of from the poppy and cinchona.

Roscoe says: "But now the question may be put, is any limit set to this synthetic power of the chemist? Although the danger of dogmatism, as to the progress of science, has already been shown in too many instances, yet one can not help feeling that the barrier which exists between the organized and unorganized world is one which the chemist at present sees no chance of breaking down.

It is true that there are those who profess to foresee the day when the chemist by a succession of constructive efforts, may pass beyond albumen and gather the elements of lifeless matter into a living structure. Whatever may be said regarding this from other standpoints the chemist can only say that at present no such problem lies within his province. Protoplasm with which the simplest manifestations of life are associated is not a compound but a structure built up of compounds. The chemist may successfully synthesize any of its component molecules, but he has no more reason to expect the synthetic production of the structure than to imagine that the synthesis of gallic acid leads to the artificial production of nutgalls."[1]

It seems strange, therefore, that one of the most eminent of living chemists should have so unequivocally committed himself to the doctrine of future synthetic foods.

In an address before the Society of Chemical and Mechanical Industries in Paris, on the 5th of April, 1894, Berthelot publicly proclaimed his theory of the coming suppression of agriculture and the substitution of synthetic foods for its products. This theory he has more fully elaborated in McClure's Magazine for September 1894. The accomplishments in synthetic chemistry on which he bases his predictions are essentially those which

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[1] Presidential Address, British Association, *Chem. News*, Sept. 2, *1887*, p. 100.

have been set forth already in this address. With proverbial European provincialism, however, he fails to mention one of the strongest of the arguments he might have used; *viz.*, Fischer's sugar synthesis. The wildcat process lately patented in this country, however, as well as in France, for making sugar by the condensation of ethylene receives favorable mention and no doubt is entertained of the speedy manufacture of sugar on the largest scale synthetically and that the culture of the sugar-beet and sugar-cane will be abandoned because they will have ceased to pay. The struggling sugar planters of our own country who during the present season have been making sugar at a cost of four cents a pound and selling it for three, will bear witness to the fact that this happy period has already arrived.

The synthesis of the dyestuffs, especially of alizarin and indigo, he cites as examples of the destruction of an agricultural industry by chemical achievements. He dwells and very properly, on his own work in the synthesis of fats as evidence of what may be accomplished in that line. The beefsteak of the future may not be identical with that of to-day, but it will be a tablet of any color or shape desired and will entirely satisfy the epicurean senses of the year 2000. Chemistry has developed the whole science of cookery and flavoring and provided all the utensils of the kitchen. It remains now only for it to complete its work and furnish the food itself. Even at the present time, according to Berthelot, tea and coffee could be made artificially if the necessity should arise. The caffeine of the chemist has the following genealogy:

Carbon and oxygen beget carbon dioxide.
Carbon dioxide and chlorine beget carbonyl chloride.
Carbonyl chloride and ammonia beget urea.
From urea comes uric acid.
From uric acid is derived xanthin.
Xanthin yields theobromine.
Theobromine yields theine or caffeine.

From this pedigree it is concluded that tea plants, and cocoa and coffee trees will soon follow the madder and indigo plants into economic eclipse. No attempt is made to compute the cost of the caffeine necessary for a single cup of Java; and the fact that caffeine is only one of its constituents is naively ignored.

Tobacco also is soon to follow because something resembling nicotine has already been made synthetically. While nicotine has not yet been made synthetically, its near relationship to conine, the active principle of hemlock, which has been so formed, leaves little doubt of the speedy accomplishment of this desirable end.

In regard to the synthesis of food products directly from the elements attention is called to the following points:

By means of the electric spark acting on hydrogen and carbon at a white heat, acetylene is produced.

Acetylene will combine with another atom of nascent hydrogen forming ethylene and marsh-gas.

Ethylene can be made to combine with the elements of water forming common alcohol, while marsh-gas in similar circumstances, yields methyl alcohol.

Acetylene with nascent oxygen forms oxalic acid.

Acetylene in contact with nitrogen subjected to the electric spark forms hydrocyanic acid.

Acetylene and oxygen in the presence of water and an alkali form an acetate, whence acetic acid.

" I also found," says Berthelot, "that ethylene under certain conditions could be transformed directly into benzene. Here then we have seven familiar compounds of wide utility; acetylene, marsh-gas, alcohol, oxalic acid, acetic acid, cyanhydric acid, and benzene, to say nothing of many others which I might mention obtained from these elements direct. Now imagine for a moment the enormous number of organic compounds into the constitution of which, according to regularly acting laws, these seven different compounds enter. There are six different families of alcohols alone and each one of these families embraces a greater or less number of special alcohols. Over the whole field of organic chemistry the mystery of possibilities extends. Its combinations and intercombinations are so limitless that we can only work on regularly to ends that it is impossible to foresee."

According to Berthelot, the fields which are now defaced by agriculture will be beautified by regaining their natural covering and the earth will be one vast park of pleasure and the chemist the great conservator of the human race.

A synthetic climate will replace the capricious one furnished by nature. Winds and waterfalls will provide power and light, and the bowels of the earth, tapped by frequent wells to a great depth, will supply the superheated steam to turn the winter into spring and to bring together the pole and the equator. When these predictions are read we first think that Bellamy has turned chemist, and by reincarnation in the shape of the great Parisian Savant has thrust upon the scientific world a new edition of "Looking Backwards."

In all the instances brought forth there is not the slightest approach to anything to justify the prophecy of a period of artificial food. The few cases of synthesis in which the products approach the composition of anything digestible present such insurmountable difficulties in expense and supervision as to render any expectation of reaching economic results utterly futile. In the great majority of cases, as has been seen, the process of synthesis is conducted on materials already organized by living cells. The enormous cost of building up any kind of a commercial, synthetic organic body directly from the elements is such as to render it, in my opinion, utterly improbable of successful achievement.

Even if food products can be formed in the crucible there is no reason whatever for supposing that they can ever play any rôle in an economic sense. The untold billions of laboratories which nature builds are infinitely cheaper in construction and operation than those filled with platinum and porcelain. The sun ignites the crucibles of nature at an expense far less than attends the use of the city gas works. The director of Nature's laboratory depends on no endowment nor legislation for his salary and his bills for supplies are not disallowed by any board of auditors on the score of economy. Night and day his patient faithful assistants work without thirst for fame, without hope of reward. They fight not for priority of discovery and their anonymous papers are printed in rich profusion in the great Berichte of the universe. The chemistry of the chlorophyl cell is far more wonderful than any of the achievements of Lavoisier, Berzelius, or Fischer.

It would doubtless be a solace to the weary toiler in the sun to look forward to a time when he might lie in the shade while proteids were pricking up their ears in the condenser and fats frying in the scientific pan. But in the days of the far future, while Berthelot will still be honored and Fischer praised, the farmer will be found following in the furrow, fields of waving grain will brighten the landscape, and herds of kine graze upon the hills.

Members of the Society:

According to the provisions of our Constitution, the time has arrived when I am to take my leave of you as President of the Society. I thank you most heartily for the honor twice conferred upon me of presiding over this great organization. It is only fitting at this moment that I should give a brief account of my stewardship.

One of the most gratifying features in connection with the history of the Society during the past two years, is the increase in membership. In two years, according to the data furnished by the Secretary, the Society has more than doubled its membership. Our membership now is well up to the thousand mark. I should have been better pleased at this time to take leave of a membership of fully 1,000, but I feel sure that this number will soon be reached.

The JOURNAL of the Society has fully kept pace with the increase of membership. The volume for 1893 contains 720 pages, devoted almost exclusively to original articles, of which 98 appeared. The volume for 1894 contains 891 pages, exclusive of proceedings, and 158 original articles. In addition to the copies furnished the members of the Society, there is a large number of subscribers to the journal in this and foreign countries, so that the total circulation at the present time is over 1,000. It is recognized as a leading chemical journal by the editors of foreign periodicals. More than thirty of its articles, during the past year, have been reprinted wholly or in part in the *Chemical News*, and a large number of abstracts has appeared in the *Journal of the English Society*, the *Berichte*, and the *Central-Blatt*, in which, during the past twelve months, over 100 abstracts of articles from the JOURNAL OF THE AMERICAN CHEMICAL SOCIETY have appeared. These are figures which are very gratifying to us all.

The prosperity of the Society has been due to united action among all its members, and a determination to make it a success.

Local Sections have been established during the past two years in Washington, the Lehigh Valley, and in New Orleans. The chemists of the Pacific Slope have also expressed a desire to unite with the Society at an early date and establish a Local Section. There are many other places where the membership of the Society would justify the establishment of Local Sections, and especially is this true of Baltimore, Philadelphia, Boston, Cleveland, and Chicago, and it is hoped that speedy action may be taken to secure these desirable results.

To the editor and the Committee on Publications the Society is indebted for energetic and systematic work in increasing the efficiency of the JOURNAL, but the efforts which these gentlemen have made would have had but little success had not the members of the Society throughout all parts of the country come forward with contributions of papers. There are often good reasons why a paper on any particular subject should be published in a particular journal in this or other countries, but as a rule it seems to me that American authors should first offer their papers to American journals, and if this rule is followed it is certain that the journal of our own Society will receive a fair share of the contributions. We would not desire to exclude from the field any other journal, but we are justified in asking that due consideration be given our own journal by our members in the distribution of their papers.

The American Chemical Society represents American chemical science as a whole and therefore it is desirable that the journal of the Society should not become the organ of any particular branch of chemical science. The editor and the Committee on Publications have kept this end in view in the distribution of the articles and have endeavored to put into each number something of interest to many of the special departments of chemical science. Our doors are open for the entrance of those engaged in didactic chemistry, for organic chemists, for technical chemists, for agricultural chemists, for mining and assaying chemists, for general manufacturing chemists, and in fact for every branch of our great science. The journal being thus cosmopolitan brings to every chemist not only matter relating particularly to his branch of study, but also a general idea of what is going on in other fields of activity. He, therefore, who desires to keep abreast of the work of the times and avoid becoming narrow in his views and practices, can not find a better means to this end than membership in our Society. The American Chemical Society has no quarrel with any chemical sect or any institution of learning, but will endeavor to make itself useful to all. It would especially seek to foster a spirit of scientific patriotism in this country, a belief in American science and American scientists, and to diminish, to a certain extent, the blind worship of foreign institutions which, in some instances, has been so characteristic a feature of American workers. I would not say anything to discourage a young man from seeking a part of his education abroad, but I would certainly encourage foreign chemists to seek a part of their education in this country. It is not quite right for the United States to contribute so many students and so few professors. While the American student may find benefit from a course of study abroad, the foreign student would find equal benefit by a residence at some of the great institutions of learning in this country. If professors of chemistry desire to attract students from abroad they must recognize their own country in its scientific institutions. They can not afford to remain outside of the great organized body of American chemists and to send their contributions all to foreign journals if they wish their own institutions to grow in favor at home and abroad. While we are proud therefore, of our large membership, it is evident that for every one who is now a member there are at least two who should become so.

There are nearly 4000 men in the United States who are engaged directly in chemical pursuits, and it is not too much to ask that at least fifty per cent. of this number should become affiliated with the American Chemical Society. We will not consider that we have attained our normal growth if at the end of the next quinquennial period our membership shall not reach fully 2000. To this end let each of our members pledge his word and exert his influence and the work will be accomplished.

I can not close this address without expressing my thanks to the Secretary of the Society for the efficient method in which he has conducted the work of his office, arduous and exacting as it has been, and to the Directors and Councilors of the Society for the support which they have given me in all matters connected with the executive conduct of the presidential office.

In the little which I myself have been able to do, I have had in view only one object; *viz.*, the welfare and prosperity of the Society. It may be that in some cases offence has been given to members of the Society by the manner in which my work has been done, but I am sure that those who have intimate knowledge of the motives which have actuated my conduct will bear witness to the fact that such offence was not given with malice or meaning.

To my successor I may say that he will find the officers, councilors, and directors, remaining as they do mostly unchanged, full of zeal in the work of building up the Society and ready at all times to support him in the conduct of his office.

THE DETERMINATION OF PHOSPHORIC ACID.

BY H. PEMBERTON, JR.

Received January 17, 1895.

THE method of determining phosphoric acid by the alkalimetric titration of the yellow precipitate, has been employed, lately, by a number of chemists and has been made a subject of investigation by the Association of Official Agricultural Chemists. A report upon the subject has been embodied in its last bulletin.

There are a few points regarding this method to which attention should be drawn.

In preparing the standard alkali its strength is, of course, established by testing it against acid of known strength. In doing this, it is important that the indicator used should be phenolphthalein, and *not* methylorange. Potassium hydroxide almost invariably contains alumina, and such a solution gives the neutral reaction with methyl orange *before* it gives it with phenolphthalein. Consequently if methyl orange is used in the standardizing and phenolphthalein is used in the titration of the