

for pigs. The breed most common is small and very compact, and black in colour. Pigs numbered 121,866 in 1856.

The following table gives classifications of holdings in 1875 and 1885:—

| Years. | 50 acres and under. | | From 50 to 100 acres. | | From 100 to 300 acres. | | From 300 to 500 acres. | | From 500 to 1000 acres. | | Above 1000 acres. | |
|--------|---------------------|--------|-----------------------|---------|------------------------|---------|------------------------|---------|-------------------------|---------|-------------------|--------|
| | No. | Area. | No. | Area. | No. | Area. | No. | Area. | No. | Area. | No. | Area. |
| 1875 | 5667 | 66,251 | 1436 | 101,644 | 2043 | 336,383 | 387 | 137,894 | 169 | 110,169 | 12 | 14,744 |
| 1885 | 5607 | 64,899 | 1278 | 94,994 | 1872 | 330,183 | 409 | 154,590 | 174 | 115,089 | 17 | 22,314 |

Thus in 1875 there were in all 9714 holdings with 787,085 acres, and in 1885 9357 with 782,019 acres. According to the latest landowners' Return (1873) Suffolk was divided among 19,276 proprietors, holding 920,268 acres, at a valued rental of £1,784,827, or an average all over of about £1, 18s. 9½d. per acre. Of the owners 12,511 or nearly three-fourths possessed less than one acre each. The following possessed over 10,000 acres each:—Lord Rendlesham, 19,869; George Tomline, 18,473; marquis of Bristol, 16,954; the maharajah Dhuleep H. H. Singh, 14,615; Lord Huntingfield, 11,713; earl of Stradbroke, 11,697; Sir Richard Wallace, 11,223; Lord Henniker, 10,910.

Communication.—The river navigation affords means of communication with different parts, and supplies facilities for a considerable amount of traffic. The county is intersected in all directions by branches of the Great Eastern Railway, which touch at almost every town of importance.

Manufactures and Trade.—The county is essentially agricultural, and the most important manufactures relate to this branch of industry. They include that of agricultural implements, especially at Ipswich, Bury St Edmunds, and Stowmarket, and that of artificial manures at Ipswich and Stowmarket, for which coprolites are dug. Malting is extensively carried on throughout the county. There is a gun-cotton manufactory at Stowmarket, and gun flints are still made at Brandon. At different towns a variety of small miscellaneous manufactures are carried on, including silk, cotton, linen, woollen, and horsehair and cocoa-nut matting. The principal ports are Yarmouth (situated chiefly in Norfolk), Lowestoft, Southwold, Aldeburgh, Woodbridge, and Ipswich. Yarmouth is one of the most important fishing stations on the east coast of England; within the county Lowestoft is the chief fishing town. Herrings and mackerel are the fish most abundant on the coasts.

Administration and Population.—Suffolk comprises 21 hundreds; the boroughs of Beccles (pop. 5721), which has several large maltings; Bury St Edmunds (16,111), the chief town in West Suffolk; Eye (2296), an ancient market town; Ipswich (50,546), the largest town and principal port of the county; Aldeburgh (2106), the birth-place of Crabbe; Southwold (2107), a fishing town and bathing resort; the largest part (5855) of Sudbury (6584), a market and manufacturing town; and small portions of the boroughs of Thetford and Great Yarmouth, which are situated chiefly in Norfolk. The other principal towns are Hadleigh (3237), with a considerable trade in corn and malt; Haverhill (3685) (partly in Essex), of great antiquity, and possessing important silk manufactures; Lowestoft (16,755), a port and fishing station; Stowmarket (4052); and Woodbridge (4544), with some coasting trade. Suffolk is divided into geldable portions, in which the sovereign has the chief rights, and liberties. The liberties are those of St Etheldreda, St Edmund, and the dukedom of Norfolk. The court of quarter sessions is at Ipswich for the eastern division and by adjournment at Bury St Edmunds for the western. There are nineteen petty and sessional divisions. The hundreds of Hartismere and Stow and the borough of Eye are for petty sessional purposes included in the eastern division, and for other purposes in the western. The boroughs of Bury St Edmunds, Ipswich, Great Yarmouth, and Sudbury have commissions of the peace and separate courts of quarter sessions; and Eye and Southwold have commissions of the peace. For parliamentary purposes the county was until 1885 divided into East and West Suffolk, but it now constitutes five divisions, each returning one member, viz., North or Lowestoft division, North-east or Eye, North-west or Stowmarket, South or Sudbury, and South-east or Woodbridge. Bury St Edmunds returns one member and Ipswich two; Eye, which formerly returned one member, was merged in the North-east division of the county in 1885. The county contains 517 civil parishes with parts of 7 others. It is mostly in the diocese of Norwich. From 214,404 in 1801 the population had increased by 1821 to 271,541, by 1841 to 315,073, by 1861 to 337,070, and by 1881 to 356,893, of whom 174,606 were males and 182,287 females. The number of persons to an acre was 0.38 and of acres to a person 2.65.

History and Antiquities.—The district which now includes Norfolk, Suffolk, and a portion of Cambridge, and afterwards formed East Anglia, had in early times, on account of the marshes to the west, practically the character of a peninsula. It was inhabited by the Iceni, who had their capital at Icklingham, in the north-west of Suffolk. Of the numerous barrows and tumuli belonging to this

period mention may be made of those at Fornham St Genevieve and those between Aldeburgh and Snape. Many of the mediæval castles were built on ancient mounds. The district submitted to the Romans during the campaign of Aulus Plautius, and, although the Iceni joined the Trinobantes under Boadicea, the resistance made was ultimately fruitless. A Roman road from London crossed the centre of Suffolk northwards by Stratford St Mary, Needham Market, and Billingford (Norfolk) to Norwich, another passing in a more westerly direction to Thetford. Walton, where important Roman relics have been found, Dunwich (possibly *Silomagus*), and Burgh Castle (probably *Combratonium*), one of the most perfect specimens of a Roman fort in England, enclosing an area of five acres, are supposed to have been Roman fortified stations erected for the defence of the Saxon shore. Other Roman stations were at Stratford St Mary, Thetford, and Icklingham. The capital of the kingdom of East Anglia was at Dunwich in Suffolk. Afterwards East Anglia was divided into Norfolk and Suffolk. Sigebert established an ecclesiastical diocese at Dunwich in 630, and erected a palace and a church partly out of the Roman remains. The earldom of Norfolk and Suffolk was bestowed by the Conqueror on Ralph le Guader. Though Suffolk suffered from incursions of the Danes, they did not effect a complete subjugation of it. The prevailing terminations of the place names are Anglian. The remains of old castles are comparatively unimportant, the principal being the entrenchments and part of the walls of Bungay, the ancient stronghold of the Bigods; the picturesque ruins of Mettingham, built by John de Norwich in the reign of Edward III.; Wingfield, surrounded by a deep moat, with the turret walls and the drawbridge still existing; the splendid ruin of Framlingham, with high and massive walls, originally founded in the 6th century, but restored in the 12th; the outlines of the extensive fortress of Clare Castle, anciently the baronial residence of the earls of Clare; and the fine Norman keep of Orford Castle, on an eminence overlooking the sea. Among the many fine residences within the county there are several interesting examples of domestic architecture of the reigns of Henry VIII. and Elizabeth. Throughout its whole history the annals of Suffolk have been comparatively uneventful. It adhered with Norfolk to the cause of the Parliament. James duke of York twice defeated the Dutch off the coast, viz., Van Trump off Lowestoft on 3d June 1665 and De Ruyter in Southwold Bay on 28th May 1672. Of monastic remains the most important are those of the great Benedictine abbey of Bury St Edmunds, noticed under that town; the college of Clare, originally a cell to the abbey of Bec in Normandy and afterwards a cell to the abbey of Westminister, converted into a college of secular canons in the reign of Henry VI., and still retaining much of its ancient architecture, and now used as a boarding-school; the decorated gateway of the Augustinian priory of Butley; and the remains of the Grey Friars monastery at Dunwich. A peculiarity of the church architecture is the use of flint for purposes of ornamentation, often of a very elaborate kind, especially on the porches and parapets of the towers. Another characteristic is the round towers, which are confined to East Anglia, but are considerably more numerous in Norfolk than in Suffolk, the principal being those of Little Saxham and Herringfleet, both good examples of Norman. It is questionable whether there are any remains of Saxon architecture in the county. The Decorated is well represented, but by far the greater proportion of the churches are Perpendicular, special features being the open roofs and wood-work and the fine fonts.

See Blome's *Description of Suffolk*, 1673; Kirby's *Description*, 1749, 2d ed. 1829; Suckling's *History of Suffolk*, 1846-48; Hervey's *Visitatio of Suffolk in 1561*, ed., with additions, by Dr J. J. Howard, 1866; and Browne's *History of Congregationalism and Memorial of Churches in Suffolk*, 1877. (T. F. H.)

SUFISM. See MOHAMMEDANISM, vol. xvi. p. 594; MYSTICISM, vol. xvii. p. 130; and SUNNITES, p. 659 *sq. infra*.

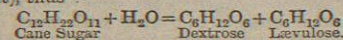
SUGAR. Formerly chemists called everything a "sugar" which had a sweet taste, and acetate of lead to this day is known as "sugar of lead" in commerce and familiar chemical parlance; but the term in its scientific sense soon came to be restricted to the sweet principles in vegetable and animal juices. Only one of these—cane sugar—was known as a pure substance until 1619, when Fabrizio Bartoletti isolated the sugar of milk and proved its individuality. In regard to all other "sugars" besides these two the knowledge of chemists was in the highest degree indefinite, and remained so until about the middle of the 18th century, when Marggraf made the important discovery that the sugars of the juices of beet, carrots, and certain other fleshy roots are identical with one another and with the sugar of the cane. Lowitz subsequently showed that the granular part of honey is something different from cane sugar; this was confirmed by Proust, who found also

that Lowitz's honey sugar is identical with a crystallizable sugar present largely in the juice of the grape. Proust's investigations extended to other sweet vegetable juices also. All those investigated by him owed their sweetness to one or more of only three species,—(1) cane sugar, (2) grape sugar, (3) (amorphous) fruit sugar. Proust's results obtain substantially to this day; a number of new sugars strictly similar to these three have been discovered since, but none are at all widely diffused throughout the organic kingdom.

The quantitative elementary composition of cane sugar was determined early in the 19th century by Gay-Lussac and Thénard, who may be said to have virtually established our present formula, $C_{12}H_{22}O_{11}$. Under FERMENTATION (vol. ix. p. 93) it has been explained how Gay-Lussac (in 1811) came to mis-correct his numbers so as to bring them into accordance with what we now express by $C_6H_{12}O_6 = \frac{1}{2}C_{12}H_{22}O_{11}$. Dumas and Boullay, some years later, found that cane sugar is what Gay-Lussac and Thénard's analysis makes it out to be, while the "corrected" numbers happen to be correct for grape sugar. Dumas and Boullay's research completed the foundations of our present science of the subject. "Sugar" is now a collective term for two chemical genera named *saccharoses* (all $C_{12}H_{22}O_{11}$) and *glucoses* (all $C_6H_{12}O_6$). All sugars are colourless non-volatile solids, soluble in water and also (though less largely) in aqueous alcohol; from either solvent they can in general be obtained in the form of crystals. The aqueous solution exhibits a sweet taste, which, however, is only very feebly developed in certain species.

All sugars and their solutions have the power of turning the plane of polarization of light. In a given solution of a given kind of sugar the angle α through which the plane is turned is governed by the equation $\alpha = \pm [\alpha]_D l$, where l stands for the length of solution traversed (the customary unit of length being the centimetre) and p for the number of grams of dry sugar present in a volume of solution equal to that of (say) 100 grams (3.52 oz.) of water, where, however, "gram" must be taken as merely a convenient word for "unit of weight"; $\pm [\alpha]$, i.e., the special value of α for $l=1$ and $p=1$, is called the specific rotatory power of the sugar operated upon. The sign \pm indicates that the plane of polarization is turned either to the right or to the left according to the nature of the species. For a given species and a given temperature $[\alpha]$ has a constant value. Supposing its value to have been determined by standard experiments and l to be known (or to be kept constant throughout and taken as unit of length), the determination of p for a given solution suffices for the calculation of p . This method is largely used industrially for the assaying of cane sugar.

Sugars, though neutral to litmus and inert towards such substances as carbonates on the one hand and aqueous acids (*qua* acids) on the other, combine with strong bases, such as caustic potash, baryta, and lime, into *saccharates*, and, when brought into contact with the strongest nitric acid (or a mixture of the same with oil of vitriol) (or at the proper temperature) with acetic anhydride, unite with these into nitrates and acetates respectively, with elimination of water. These nitrates, &c., are related to the respective sugar exactly as (to take an analogous case) nitrate of methyl, $CH_3(NO_3)$, is to methyl-alcohol, $CH_3(OH)$; only in the case of a sugar a plural of NO_3 's is capable of entering into every one molecule and turning out so many HO 's; hence sugars are said to be *polyvalent alcohols*. Of the several points of difference between saccharoses and glucoses the most important is that, while the latter remain unchanged when boiled with highly dilute sulphuric or hydrochloric (or certain other kinds of) acid, the former take up water and every molecule breaks up into two molecules of glucose, which in general are of different kinds. Cane sugar, for instance, yields *dextrose* and *levulose* (so called from the direction in which they turn the plane of polarized light), thus—



Cane sugar turns the plane of polarized light to the right; the mixed glucose produced is *levo*-rotatory; hence the process is spoken of technically as involving the *inversion* of cane sugar, and the mixed product is called *invert sugar*. The term "*invert*," however, has come somehow to be used for all decompositions which fall under the above equation; occasionally it is used even in a wider sense, to include any decomposition of a carbo-hydrate (e.g., starch) into two less complex carbo-hydrates.

All sugars are liable to fermentative changes; a special character of the three principal vegetable sugars is that, when brought into contact as solutions with yeast (living cells of *saccharomyces*), under suitable conditions, they suffer vinous fermentation, i.e., break up substantially into carbonic acid and alcohol. Dextrose and levulose break up directly, $C_6H_{12}O_6 = 2C_2H_5O + 2CO_2$. Cane sugar first, under the influence of a soluble ferment in the yeast, gets inverted, and the invert sugar then ferments, the dextrose disappearing at a greater rate than the levulose.

It is remarkable that no sugar has ever been produced artificially even in the sense of being built up from other native organic substances of less chemical complexity. It is easy to produce dextrose from starch, or levulose from inulin, or both from cane sugar, by inversion; but none of these processes is reversible by known methods. Yet the problem of producing cane sugar artificially may in a sense be said to have found a virtual solution at the hands of a German-American chemist, Fahlberg.¹ Fahlberg by subjecting toluene, $C_6H_5CH_3$ (one of the components of coal-tar naphtha), to a series of operations has produced from it a body, $C_6H_4SO_3NH$, which he called *saccharine*.

because he found it to be about 230 times as sweet as cane sugar. This saccharine is a white crystallized solid, only slightly soluble in cold water, but sufficiently so to admit of its incorporation with jellies, puddings, beverages, &c. A mixture of one part of it with 1000 parts of ordinary grape sugar (as produced industrially from starch) is as sweet as the best cane sugar. The substance, though an antiseptic, is said to be perfectly innocuous.

Glucoses.

Of these a pretty large number are now known, but only levulose and dextrose need be noticed here. Both are largely present in all kinds of sweet fruit juices and in honey. In most of these materials they are accompanied by a small proportion of cane sugar, which forcibly suggests that the glucose in fruit juices is really inverted cane sugar. But, in opposition to this surmise, the proportion of cane sugar in oranges increases during the process of ripening, and the source of all fruits—the lemon—contains four parts of cane for every ten of invert sugar; besides, the juices of grapes and sweet cherries contain no cane sugar whatever. According to Stammer, the young leaves of the sugar cane contain abundance of invert sugar, which gradually disappears and gives way to cane sugar as the leaves develop and ultimately dry up. In the living body of man dextrose is constantly being produced from the glycogen of the liver, to be taken up by the blood and oxidized into carbonic acid and water. In certain diseases, however (see NUTRITION, vol. xvii. p. 681), the sugar survives and passes into the urine; as much as one pound avoirdupois may be discharged by a diabetic patient in twenty-four hours. A numerous class of vegetable substances, known as *glucosides*, contain glucose of some kind in the sense that, when decomposed by boiling dilute sulphuric acid or by the action of certain ferments, they split up into glucose and some product—not a sugar—which is characteristic of the respective species. For examples, see FERMENTATION, vol. ix. p. 96.

Dextrose is being produced industrially from starch by inversion (see below), and sold as *grape sugar*. Such *grape sugar*, however, is very impure. For the preparation of pure dextrose rich diabetic urine, honey, and cane sugar are convenient materials. The method recommended by Soxhlet is to dissolve 160 grams (5.64 oz.) of powdered cane sugar in a mixture of 500 c.c. of alcohol of 65 per cent. by weight and 20 c.c. of fuming hydrochloric acid at 45° C. and to allow the solution to stand. After about a week dextrose begins to crystallize out, and, if the mixture is being frequently agitated, the deposit of crystals increases gradually. A small crop of crystals thus obtained suffices for inducing crystallization in a large supply of fresh liquor. Dextrose crystallizes from its highly concentrated aqueous solution—somewhat tardily—in minute soft crystals, united into warts or cauliflower-like masses, which contain 1H₂O of crystal water beside C₆H₁₂O₆. The crystals lose their water at 100° C. From absolute alcohol it crystallizes as C₆H₁₂O₆. It dissolves in 1.2 parts of cold and far less of boiling water. 100 parts of alcohol of 0.837 specific gravity dissolve 1.94 parts at 17° C. and 21.7 parts on boiling. In a given volume of aqueous solu-

¹ See *Amer. Chem. Jour.*, i. p. 170, ii. p. 181, and i. p. 425; short notices in *Jour. Soc. Chem. Ind.*, iv. p. 608, and February 1886.

tion 5 parts of dextrose produce the same degree of sweetness as 3 parts of cane sugar. Dextrose fuses at 146° C. and at 170° passes into glucosan, $C_6H_{10}O_5$, an almost tasteless solid, which when boiled with dilute sulphuric acid is reconverted into dextrose. If a solution of dextrose in absolute alcohol is saturated with hydrochloric acid gas at 0° C., di-glucose, $C_{12}H_{22}O_{11}$, is produced, which, however, is only isomeric with cane sugar (Gautier).

Levulose.—The liquid part of crystalline honey consists chiefly of levulose; but its purification is difficult. From invert sugar it can be extracted, according to Dubrunfaut, by cautious addition of slaked lime at a low temperature. The levulose separates out as a difficultly soluble lime compound, which is separated from the mother-liquor containing the dextrose by pressure and by judicious washing with cold-water. The levulosate of lime is decomposed by the exact equivalent of oxalic acid solution; then the oxalate of lime is filtered off, and the filtrate evaporated on a water-bath. The levulose ultimately remains as a thick syrup, which formerly was supposed not to be susceptible of crystallization; but Jungfleisch and Lefranc have succeeded lately in obtaining crystals from it by means of alcohol. Levulose is very largely soluble in water, and fully as sweet as cane sugar. It fuses at 95° C.; at 170° it passes into levulosan, $C_6H_{10}O_5$, analogous to glucosan.

The following reactions, though studied chiefly with dextrose, apply also to levulose, and, substantially at least, to glucoses generally. If a solution of glucose is mixed with excess of caustic potash or soda, a solution of alkaline glucosate is formed, which, however, has little stability. If the solution is heated, the glucosate is decomposed with formation of dark-coloured (soluble) alkali salts of acid products, which, whatever they may be, are not reconvertible into glucose. Cane sugar, in these circumstances, remains substantially unchanged, and can be regenerated by elimination of the alkali. If a solution of glucose is mixed with (not too much) sulphate of copper, and an excess of caustic potash or soda be then added, no precipitate of cupric hydrate is formed, but an intensely blue solution, which, on standing in the cold gradually, and on heating promptly, deposits a red precipitate of cuprous oxide, Cu_2O , the glucose being oxidized at the expense of the dissolved CuO into soluble alkali salts of little known acids. By means of this (Trommer's) test the least trace of glucose in a solution can be discovered. Cane sugar, in the circumstances, yields cuprous oxide only on long-continued boiling. Fehling has brought this test into the following more-convenient form, which, besides, admits of quantitative application: 34.65 grams (1.22 oz.) of sulphate of copper, $CuSO_4 + 5H_2O$, and 173 grams (6 oz.) of Rochelle salt (double tartrate of potash and soda) are dissolved in a solution of 70 grams (2.46 oz.) of solid caustic soda, and the intensely blue solution produced is diluted to 1000 c.c. Every c.c. of Fehling solution oxidizes about 5 milligrams (.077 grain) of dextrose (not of glucose generally). To determine an unknown weight of glucose, its solution is added to an excess of suitably diluted Fehling solution at a boiling heat, which is maintained for a sufficient time to oxidize the glucose as completely as possible,—the requisite time depending on the nature of the glucose. The cuprous oxide precipitate is allowed to settle, is then collected on a filter, and weighed directly or indirectly. From its weight the weight of the glucose is calculated,—a standard experiment with a known weight of the respective kind of pure glucose furnishing the factor. A less exact but more expeditious method is to dissolve the sugar to be analysed in water, to dilute to a known volume (not less than 200 c.c. for every gram of glucose), and to drop this solution from a burette into a measured volume of dilute Fehling solution at a boiling heat until the blue colour is just destroyed, i.e., the copper just precipitated completely as Cu_2O . This method is largely used in sugar-houses in the assaying of crude cane or beetroot sugars.

Saccharoses.

Of these only cane sugar, milk sugar, and maltose can be noticed here. The highest qualities of commercial cane sugar are chemically pure. Pure cane sugar crystallizes from its supersaturated syrup in colourless, transparent monoclinic prisms (exemplified in colourless candy sugar). The crystals are barely, if at all, hygroscopic; they are rather hard, and when broken up in the dark give off a peculiar kind of bluish light. Sp. gr. 1.593 at 4° C. The aqueous solution, saturated at 4° C., contains p per cent. of dry sugar. For

| | | | | | |
|---------------|------------|------------|------------|------------|------------|
| $t = 0^\circ$ | 10° | 20° | 30° | 40° | 50° |
| $p = 65.0$ | 65.9 | 67.0 | 69.8 | 75.8 | 82.7 |

From 50° upwards the solubility increases at such a rate that a given quantum of water dissolves any quantity of sugar if the mixture is constantly kept boiling. Accordingly a sugar syrup when boiled down deposits nothing, but passes gradually into the condition of fused sugar when the boiling-point merges into the fusing-point of sugar, which lies at 160–161° C. Even a cold-saturated solution of sugar has the consistence of a syrup. Absolute alcohol hardly dissolves sugar at all; aqueous alcohol dissolves it the more largely the greater its proportion of water. Fused sugar freezes into a transparent glass, which is colourless if pure, but in practice generally exhibits a yellowish hue, and, if really anhydrous, remains

glassy for an indefinite time. Barley-sugar and certain other confections are substantially fused sugar; but from their mode of manufacture they retain a trace of enclosed water, which constantly dissolves particles of the surrounding sugar glass to redeposit them in the less soluble form of crystals, so that barley-sugar in the course of time loses its transparency through conversion into an aggregate of minute crystals. If fused sugar is kept at a few degrees above its fusing-point for some time, it passes into an alloy, $C_6H_{12}O_6 + C_6H_{10}O_5$, of dextrose and levulosan (see above). At higher temperatures it loses water and passes into anhydrides not reconvertible into cane sugar, which are known in the aggregate as "caramel,"—a most intensely brown viscous solid, easily soluble in water and in aqueous alcohol, with formation of intensely coloured solutions. Caramel (often made of dextrose) is much used as an innocent colouring agent for sauces, liqueurs, &c. A pure solution of cane sugar is said to remain unchanged on boiling (it being understood, of course, that local overheating be carefully avoided); but continued contact with even so feeble an acid as carbonic induces at least partial inversion. The statement of the unchangeability of sugar solution on boiling seems hardly credible, because a syrup boiling at all considerably above 100° C. contains plenty of molecules at temperatures above 160° C., which are bound to suffer irreversible conversion into dextrose and levulosan (or levulose), and even, if hot enough, caramelization. In ordinary practice, at any rate, sugar solutions on boiling do behave as indicated by this theory. Cane sugar, as already stated, unites with alkalis, alkaline earths, and other of the more strongly basic metallic oxides into saccharates. A soluble saccharate of lime, which is readily decomposable by carbonic acid and even by filtration through bone charcoal, plays a great part in the manufacture of sugar. The following strontium salt must be named, because it at least promised some years ago to occupy a similar position industrially. According to Scheibler, if strontia hydrate, $Sr(OH)_2 + 8H_2O$, is added to a boiling 15 per cent. solution of cane sugar, then as soon as 2SrO is added for every $C_{12}H_{22}O_{11}$ the salt $C_{12}H_{22}O_{11} + 2SrO$ separates out as a sandy powder, and after addition of 2.5 times SrO almost all the sugar is precipitated. The precipitate is easily washed and decomposed by water and carbonic acid, with formation of insoluble carbonate of strontia (from which the hydrate can be reproduced) and a solution of cane sugar. The ultimate molasses produced in sugar making or refining, though they refuse to deposit crystals under any conditions, contain some 30 to 40 per cent. of real cane sugar; Scheibler's process applies to them,—to put the industrial bearings of the discovery in the proper light,—and it has led to quite a series of patents for the production of strontia; but, as far as we know, it has failed to take root in the sugar industry.

Milk Sugar occurs in the milk of mammals, and it is doubtful whether it occurs anywhere else, although Bouchardat once proved its presence in a sample marked as sugar obtained from *Sapota Achras* (the sapodilla of the West Indies). It is made industrially in Switzerland as a by-product in the making of cheese. It passes into the whey, from which it is extracted by evaporation to a small volume, decolorization with animal charcoal, and crystallization. From the commercial product the pure substance can be obtained by repeated recrystallization from water, and ultimately by precipitation from the aqueous solution by alcohol. Milk sugar as it crystallizes from water under the ordinary conditions forms hydrated crystals of the composition $C_{12}H_{22}O_{11} + H_2O$; under certain conditions anhydrous crystals separate out. The hydrated crystals have pretty much the aspect of candy sugar, but they are less transparent, far harder, quite free from every *soupeur* of hygroscopicity, and far less sweet. They dissolve in six parts of cold and in 2.5 parts of boiling water; the solutions are not syrupy. Milk sugar is hardly soluble in alcohol. The ordinary crystals, as the formula shows, have the composition of a glucose; indeed milk sugar solution behaves to caustic alkalis and to Fehling solution as if it were a glucose. But the hydrated crystals lose their water at 130°, with formation of a residue reconvertible into the original substance by the mere action of water; besides, milk sugar is susceptible of inversion into dextrose and a specific galactose. The optical behaviour of a milk sugar solution varies according as it is derived from the ordinary crystals or the anhydride produced at 130°, and according to the time which has elapsed since its preparation; but if it stands sufficiently long the specific rotatory power assumes ultimately the same (constant) value. Milk sugar solution when brought in contact with yeast does not suffer vinous fermentation; but certain *Spaltpilze* induce a fermentation involving the formation of alcohol and of lactic acid. This process is utilized by the Kirghiz in the production of their native drink, "koumiss," made from mare's milk (see MILK, vol. vi. p. 305). Milk sugar is used in medicine as a diluent for dry medicines. Homoeopaths use it by preference. A solution of milk sugar in certain proportions of water and cow's milk is used occasionally as a substitute for mother's milk.

Maltose does not occur in nature; it is largely produced along with dextrin when starch paste is acted upon by dilute sulphuric

acid or the ferment called "diastase," which is supposed to be the active agent in malt. For its preparation 2 kilograms (4.40 lb) of potato starch are made into a paste with 9 litres (15.84 pints) of water over a water-bath; after allowing it to cool down to 60° or 65° C., an infusion of from 120 to 140 grams (4.23 to 5 oz.) of malt made at 40° C. is added. The mixture is kept at from 60° to 65° for an hour; it is then boiled and filtered. The filtrate is evaporated to a syrup, which is exhausted twice with alcohol of 85 per cent. by weight and then once with absolute alcohol. The dextrin (mostly) remains; the maltose passes into solution. The alcoholic extracts are evaporated to a syrupy consistence and allowed to stand. The absolute alcohol extract soon yields a crop of impure crystals of maltose, which are used to induce crystallization in the other two syrups. In regard to the somewhat tedious methods of purification we refer to the handbooks of chemistry. Maltose crystallizes (from alcohol on spontaneous evaporation) in fine needles of the composition $C_{12}H_{22}O_{11} + H_2O$. The H_2O goes off at 100° C. Maltose is less soluble in alcohol than dextrose, to which it is otherwise very similar. To caustic alkalis and Fehling solution it behaves exactly as dextrose does. Like it, it suffers vinous fermentation under the influence of yeast. When boiled with dilute sulphuric acid it breaks up into (so to say) dextrose and dextrose. Maltose plays an important part in the brewing of alcoholic malt liquors. (W. D.)

History.

The original habitat of the sugar-cane is not known, but it seems to have been first cultivated in the country extending from Cochinchina to Bengal (De Candolle). Sugar reached the West from India, and at a comparatively late date. Strabo (xv. i. 20) has an inaccurate notice from Nearchus of the Indian honey-bearing reed, and various classical writers of the first century of our era notice the sweet sap of the Indian reed, or even the granulated salt-like product which was imported from India, or from Arabia and Opona (these being entrepôts of Indian trade), under the name of *saccharum* or *σάκχαρον* (from Sanskr., *sarkara*, "gravel," "sugar"), and used in medicine. The art of boiling sugar was known in Gangetic India, from which it was carried to China in the first half of the 7th century; but sugar-refining cannot have then been known, for the Chinese learned the use of ashes for this purpose only in the Mongol period, from Egyptian visitors.¹ The cultivation of the cane in the West spread from Khuzistán in Persia. At Gundé-Shápur in this region "sugar was prepared with art" about the time of the Arab conquest,² and manufacture on a large scale was carried on at Shuster, Sús, and Askar-Mokram throughout the Middle Ages.³ It has been plausibly conjectured that the art of sugar-refining, which the farther East learned from the Arabs, was developed by the famous physicians of this region, in whose pharmacopœia sugar had an important place. Under the Arabs the growth and manufacture of the cane spread far and wide, from India to Sús in Morocco (Édrisi, ed. Dozy, p. 62), and were also introduced into Sicily and Andalusia.

In the age of discovery the Spaniards became in their turn the great disseminators of the sugar cultivation; the cane was planted by them in Madeira in 1420; it was carried to San Domingo in 1494; and it spread over the occupied portions of the West Indies and South America early in the 16th century. Within the first twenty years of the 16th century the sugar trade of San Domingo expanded with great rapidity, and it was from the dues levied on the imports brought thence to Spain that Charles V. obtained funds for his palace-building at Madrid and Toledo. In the Middle Ages Venice was the great European centre of the sugar trade, and towards the end of the 15th century a Venetian citizen received a reward of 100,000 crowns for the invention of the sugar mill, and towards the end of the 16th century a Venetian citizen received a reward of 100,000 lb of sugar being shipped to London in 1319 by Tomasso Loredano, merchant of Venice, to be exchanged for wool. In the same year there appears in the accounts of the chamberlain of Scotland a payment at the rate of 1s. 9½d. per pound for sugar. Throughout Europe it continued to be a costly luxury and article of medicine only, till the increasing use of tea and coffee in the 18th century brought it into the list of principal food staples. The increase in the consumption is exemplified by the fact that, while

in 1700 the amount used in Great Britain was 10,000 tons, in 1800 it had risen to 150,000 tons, and in 1885 the total quantity used was almost 1,100,000 tons.

In 1747 Andreas Sigmund Marggraf, director of the physical classes in the Academy of Sciences, Berlin, discovered the existence of common sugar in beetroot and in numerous other fleshy roots which grow in temperate regions. But no practical use was made of the discovery during his lifetime. The first to establish a beet-sugar factory was his pupil and successor, Franz Carl Achard, at Cunern (near Breslau) in Silesia in 1801. The processes used were at first very imperfect, but the extraordinary increase in the price of sugar on the Continent caused by the Napoleonic policy gave an impetus to the industry, and beetroot factories were established at many centres both in Germany and in France. In Germany the enterprise came to an end almost entirely with the downfall of Napoleon I.; but in France, where at first more scientific and economical methods of working were introduced, the manufacturers were able to keep the industry alive. It was not, however, till after 1830 that it secured a firm footing; but from 1840 onwards it advanced with giant strides. Now it is an industry of national importance, especially in Germany, controlling in the meantime the market against the cane-sugar trade. While cane sugar was practically without a rival, the cultivation was in general highly profitable, but it was conducted under tropical skies, largely by slave labour and entirely removed from scientific supervision. The staple produced at the plantations was raw sugar, which was sent to Europe to be refined. It was not till the pressure of the competition with beet sugar began to make itself felt that planters realized the necessity for improving their methods of working. It has now been found possible to apply many of the processes and appliances devised in connexion with the production of beet sugar to the extraction of its older rival.

Manufacture.

CANE SUGAR MANUFACTURE.—The sugar-cane (*Saccharum officinarum*) is a species of grass, the stalks or canes of which reach a height of from 8 to 15 feet, and attain a diameter of 1½ to 2 inches. The stalks are divided into prominent joints or internodes, the long sheathing alternate leaves springing from each joint. As the canes approach maturity they throw up a long smooth hollow joint termed the *arroyo*, whence springs the flower head, consisting of beautiful feather-like loose panicles. The points are filled with a loose spongy fibrous mass, saturated with a juice which is at first watery but afterwards becomes sweet and glutinous. As the joints ripen, the leaves wither and fall away and the stem becomes externally smooth, shining, and hard, containing much silica. The varieties of sugar-cane in cultivation are very numerous, and are distinguished from each other by external colour, length of internodes (3½ to 10 inches), height to which they grow, richness in juice, and many other characters. The four principal classes cultivated in the West Indies are the Creole or country cane, the Tahiti cane, the Batavian cane, and the Chinese cane. An average sample of Tahiti cane at maturity contains—water, 71.04 per cent.; sugar, 18.00; ligneous tissue and pectin, 9.56; albumen, colouring matter, and insoluble salts, 1.20; silica, 0.20. The sugar-cane requires a rich, well-drained, but moist soil. It is propagated by slips taken from the upper part of the canes, which are planted at intervals about 5 feet apart or in close-set rows 6 feet apart. In the West Indies the planting takes place between June and October, and in the case of the Creole variety the canes are ready for cutting down by the beginning of January in the second following year. When mature the canes are cut down close to the ground, the remaining leaves and upper shoot removed, and the stalks immediately taken to the mill for crushing. The stocks left are liberally manured with crushed remains and ashes of former crops, combined with nitrogenous manures, and are covered over; they then send up a crop of new stems, termed *rattoons*. The system of ratooning can be continued for several years, but the canes so treated go on declining in size and in yield of sugar. The yield of canes, of course, varies within wide limits; but 20 tons per acre may be regarded as a good average crop.

Cane-Crushing.—The juice is extracted by pressing the canes in a sugar-mill between three, or sometimes five, heavy close-set rollers of iron, placed horizontally in a powerful framework or checks. In a three-roller mill they consist of a *cane*, *top*, and *meggars* roller respectively. The top roller is set above and between the other two, and under its periphery is a fixed metal plate called the *trash turner*, which guides the cane coming from between the cane and top rollers into the bite between top and meggars rollers. Generally the cane roller is screwed up to within half an inch of the top roller, while the free space between top and meggars rollers is considerably less. The mill is set in motion by steam power, and the canes are fed by hand on a travelling band or carrier into the rollers. If a thick feed is placed at one side and little at the other, one portion passes through imperfectly crushed, while the other severely strains the mill and may either stop the machinery or cause a breakdown by some portion giving way. The yield of

¹ Lucan, iii. 237; Seneca, *Epist.*, 84; Pliny, *H.N.*, xii. 8 (who supposes that sugar was produced in Arabia as well as in India); *Peripl. Mar. Erythr.*, § 14; Dioscorides, ii. 104. The view, often repeated, that the saccharum of the ancients is the hydrate of silica, sometimes found in bamboos and known in Arabian medicine as *Iskshir*, is refuted by Yule, *Anglo-Indian Glossary*, p. 654; see also *Note et Exr. des MSS. de la Bibl. Nat.*, xxx. 267 sq.

² Marco Polo, ed. Yule, ii. 208, 212. In the Middle Ages the best sugar came from Egypt (Kazwini, i. 62), and in India coarse sugar is still called Chinese and fine sugar Cairene or Egyptian.

³ So the Armenian *Geography* ascribed to MOSES OF CHORENE (q.v. for the date of the work); St. Martin, *Mém. sur l'Arménie*, ii. 372.

⁴ *Istakhrî*, p. 91; *Yakût*, ii. 497. Tha'alibi, a writer of the 11th century, says that Askar-Mokram had no equal for the quality and quantity of its sugar, "notwithstanding the great production of Irak, Jorjan, and India." It used to pay 60,000 pounds of sugar to the sultan in annual tribute (*Lataif*, p. 107). The names of sugar in modern European languages are derived through the Arabic from the Persian *shakar*.