Rev. CENIC Cienc. Biol.; vol. 51. (1):057-068. Año. e-ISSN: 1221-2450

REVIEW BIBLIOGRAPHIC

CHARLES-LOUIS BARRESWIL
Contribution to physiology

CHARLES-LOUIS BARRESWIL
Contribución a la fisiología.

Jaime Wisniak [a]

a Department of Chemical Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel 84105 wisniak@exchange.bgu.ac.il

Recibido: 28 de enero de 2020; **Aceptado:** 14 de febrero de 2020;

ABSTRACT

Charles-Louis Barreswil (1817-1870) was a French chemist who studied, alone or with Claude Bernard, physiological phenomena such as the comparative nutritional power of different foods, the digestion process, the composition of gastric juice, the elimination of urea in animals deprived of their kidneys, the presence of sugar in the liver, the composition of the egg and its digestion, the presence of sugar in urine, etc. The nutritional power of a food determined if it was assimilable (i.e. sugar and albumen) or not (i.e. gelatin); in the first case it disappeared completely from the blood and could not be detected in the secretions. Together with Bernard they came to the wrong conclusion that lactic acid was the main component of gastric fluid. Bernard and Barreswil found that after nephrectomy the body had a limited capacity of eliminating the urea as ammonia salts by means of the intestinal fluids. They also discovered that sugar was present in large amounts in the tissues of liver, independently of the nature of the food basket, that egg white contained sugar and was alkaline while yolk had little or no alkali. Barreswil also developed a very accurate saccharimetry method, which eventually led to the Fehling liquor used for differentiating between aldehyde and ketone groups, as well as for testing reducing and non-reducing sugars. He also discovered the existence of calcium saccharate in molasses.

Keywords: digestion; gastric juice; physiology; sugar; urea.

RESUMEN

Charles-Louis Barreswil (1817-1870) fue un químico francés que estudió, solo o con Claude Bernard, fenómenos fisiológicos tales como el poder nutricional comparativo de diferentes alimentos, el proceso de la digestión, la composición del jugo gástrico, la eliminación de la urea en animales privados de sus riñones, la presencia de azúcar en el hígado, la composición del huevo y su digestión, la presencia de azúcar en la orina, etc. El poder nutritivo de un alimento determinaba si era asimilable (azúcar y albumen) o no (i.e. gelatina); en el primer caso la sustancia desaparecía completamente de la sangre y no podía ser detectada en las secreciones. Barreswil y Bertrand concluyeron, equivocadamente, que el ácido láctico era el componente principal del jugo gástrico. Bernard and Barreswil descubrieron que después de una nefrectomía el cuerpo tenía una capacidad limitada de eliminar la urea en forma de sales de amoníaco mediante los fluidos intestinales. Asimismo, descubrieron que los tejidos del hígado contenían cantidades abundantes de azúcar, independientemente de la dieta alimenticia, que el blanco de los huevos contenía azúcar y era alcalino mientras que la yema no era alcalina. Barreswil también desarrolló un procedimiento sacarimétrico que eventualmente llevó al desarrollo del licor de Fehling, usado para distinguir entre los grupos aldehído y cetona, así como para diferenciar entre azúcares reductores y no reductores. También descubrió la presencia del sacarato de calcio en las molasas.

Palabras clave: azúcar; digestión; fisiología; jugo gástrico; urea.

INTRODUCTION

Life and career

There is very little information about the early life of Charles-Louis Barreswil. The details given below are mainly from a short biography read by Jean-Jacques Peumery to the French Society of History of Medicine (Peumery, 1986). Charles-Louis Barreswil was born on December 13, 1817, in Versailles, France, the son of Madeleine Desiree Cambon and Cyr Magloire Barreswil, head of pound at the château de Versailles and former sergeant of the National Guard. Charles-Louis studied chemistry in Paris, first under Pierre-Jean Robiquet (1780-1840), a member of the Académie des Sciences, and then under Théophile-Jules Pelouze (1807-1867), a member of the Collège de France and the Académie des Sciences. In due time Barreswil was appointed head of the laboratory of Pelouze. From 1843 on he started publishing the results of his researches in the Journal de Pharmacie et Chimie, to which he contributed most of his papers. Between 1843 and 1848 he worked closely with the physiologist Claude Bernard (1813-1878) and the results of this collaboration led to four common publications (Bernard & Barreswil, 1844ab, 1847, 1848). Barreswil taught chemistry at the École Municipale Turgot and later at the École Supérieure de Commerce in Paris. Around 1865 he abandoned his academic activities and devoted all his efforts to social and philanthropic work, particularly the protection and improvement of the working conditions of young workers.

Barreswil passed away on November 22, 1870, in Boulogne-sur-Mer.

Scientific contribution

Barreswil wrote about 40 papers and books (i.e. Barreswil, 1852bc; Barreswil & Davanne, 1854; Barreswil & Girard, 1854, 1861-1864; Barreswil & Lacroix, 1865; Barreswil & Sobrero, 1843) on the subjects of inorganic, organic, and industrial chemistry, physiology, photography, etc. In addition to the subjects described below he studied the dyeing properties of aloetic acid (Barreswil, 1843c); synthesized a new oxygenated acid of chrome (Barreswil, 1843d, 1847) and a new iron oxide (Barreswil, 1843f), determined the chemical constitution of iron gallates and tannates (Barreswil, 1843g); studied the reaction of boric acid with sulfur dioxide (Barreswil, 1845b); the decomposition of water by metals (Barreswil, 1845d); the phylloxera disease in vines (Barreswil, 1857a); and sugar production (Barreswil, 1850c); he explained the apparent anomalies observed during the distillation of mercury (Barreswil, 1846c); developed a procedure for tissue impression (Barreswil, 1850b); a new gas meter based on substituting the common water with certain liquids that are not likely liable to be vaporized (Barreswil, 1856); a method for recognizing wool in the presence of silk (Barreswil, 1857b) and another for visualizing endosmosis (Barreswil, 1851a); photography and its chemistry (Barreswil & Davanne, 1854); etc.

Physiology

Nutritional Substances

Bernard and Barreswil used a very simple procedure for determining the comparative nutritional power of different foods: the substance tested was dissolved in *gastric fluid* and, after some hours, injected in the jugular vein of an animal (i.e. dog or rabbit). If the substance was assimilable (for example, sugar and albumen), it disappeared completely from the blood and could not be detected in the secretions. The same substances, dissolved in *water* so as not to suffer artificial digestion, were not assimilable and appeared in their original state in the secretions, (i.e. urine). These artificial digestions were an image of the phenomenon occurring during natural digestion (Bernard & Barreswil, 1844a).

Bernard and Barreswil used sugar, albumen, and gelatin to demonstrate the practical value of their procedure. The first series of experiments were conducted with artificial digestion. Aqueous solutions of sugar, of albumen, and of gelatin from isinglass, each containing 0.5 g of the tested material, were injected into the jugular veins of three dogs. After three hours the urine of each dog was examined. In the urine of the first dog the sugar was found unchanged; in that of the second the albumen was clearly present, and in that of the third, the ordinary reagents manifested the presence of gelatin. Similar quantities of these three substances were then dissolved, separately, in 15 g of fresh gastric juice extracted from the stomach of a dog, followed by digestion for six hours 38° to 40 °C, and then injected into the veins of three dogs. After three hours, the urine was drawn from the bladders and examined. No sugar or albumen was found in the urine of the first two dogs but a substantial amount of gelatin appeared in the urine of the third dog. The second series of experiments was conducted with three dogs each one fed only one of these three substances. The results were the same as before: the urine of the first two dogs did not contain sugar or albumen, the urine of the third one showed the presence of gelatin. As a further test, Bernard and Barreswil repeated the experiment on themselves. After fasting they ate, separately, sugar, albumen, and gelatin. Once again, sugar and albumen was not detected in their urine, but gelatin always found in this excretion (Bernard & Barreswil, 1844a).

Digestion

In 1844 Bernard and Barreswil published a long paper discussing the chemical phenomena occurring during digestion, particularly the nature of the acids participating in the process. Surprisingly, they rejected the presence of HCl, the main component of gastric juice, and concluded that the main acid was lactic (Bernard & Barreswil, 1844b). Some of their arguments and experiments were as follows. In a previous publication they had demonstrated experimentally that gastric juice not only dissolved the food ingested but also prepared it for the subsequent assimilation stages (Bernard & Barreswil, 1844a). Before pursuing this search they thought indispensable to know the constitution of the juice. Acidity of the juice was one of its essential properties; it was known that the juice neutralized by an alkali or an alkaline carbonate lost all its digestive properties, which could be restored by reestablishing the acid reaction. It was also known that acidity was not the only source of activity, it also was lost by heating which altered one of its components. Presently there were two possible explanations for the cause of acidity; one assumed that it was due to calcium biphosphate, the other, that the juice contained a free acid (acetic acid, phosphoric acid, HCl, or lactic acid). The presence of the biphosphate was justified by the fact that addition of an excess of calcium carbonate did not result in the release of CO_2. The experimental evidence of Bernard and Barreswil indicated that the lack of release of CO_2 resulted from the acid being highly diluted, a fact that allowed its absorption in the liquid. Adding lime to concentrated gastric acid resulted in a notable effervescence. Bernard and Barreswil distilled gastric acid at gentle heat and observed that the passing fraction was not acid, as should have been with a volatile acid such as acetic. This same argument seemed to indicate that HCl, more volatile that acetic acid, could not be a component of gastric juice. Nevertheless, it was known that distillation of aqueous HCl resulted in the passing of only pure water until almost the end of the process (Bernard and Barreswil did not provide a citation for this strange claim, see below). Bernard and Barreswil tested the veracity of this fact by distilling gastric juice to dryness. They found that the distillate reacted with silver chloride only near the end of the process. This was not a definite proof because the acid could have originated from the decomposition of a chloride. Addition of a minute amount of oxalic acid to gastric juice resulted in the precipitation of

calcium oxalate; this result was not present even with a highly diluted solution of HCl. The concentrated gastric juice residue was highly acid and effervesced with calcium carbonate; nevertheless, it continued being acid even after addition of an excess of calcium carbonate. This result pointed to the possible existence of phosphoric acid, a non-volatile compound. Analysis of the results suggested the presence of lactic acid, an acid that would pass towards the end of the distillation and not form precipitates with silver nitrate (Bernard & Barreswil, 1844b).

Bernard and Barreswil distilled water acidulated with lactic acid, to which a little sodium chloride has been added, and observed three clearly defined stages, similar to those observed during the distillation of gastric juice: (1) a first fraction containing only pure water; (2) a following acid fraction which did not precipitate silver salts; and (3) the last fraction carrying HCl. Bernard and Barreswil assumed that this HCl originated from chlorides decomposed by lactic acid. It was known that starch boiled with HCl lost the property of turning blue with iodine. This effect was not observed when starch was boiled with lactic acid. They found that boiling starch with HCl in the presence of an excess of lactic acid left the starch unaltered, as if it had been boiled solely in lactic acid. To Bernard and Barreswil this result indicated clearly that HCl could not exist in a free state in the presence of an excess of a lactate. All these results indicated that the activity of gastric juice was clearly due to the presence of lactic acid. In addition, Pelouze had investigated the properties of lactic acid and reported that it formed soluble salts with calcium, barium zinc, and copper, a double salt with calcium having a deeper color than the simple salt, and that the calcium salt was soluble in alcohol and precipitated by ether the salt from the alcoholic solution (Pelouze, 1844). All these characters were also present in gastric juice.

In 1979 Thomas J. Sernka carried a critical analysis of this publication of Bernard and Barreswil (Sernka, 1979). Sernka claimed that one of the main reasons of the failure of the authors to recognize the presence of chlorine was the fact that the large concentration of chlorides presents in gastric juice resulted in silver chloride forming *soluble* chloride complexes instead of a precipitate, and also on not reporting quantitative data for their experiments and results. In addition, it is now known that the distillation of an aqueous solution of HCl contains both components in the full range of composition and not only one of them, as claimed by Bernard and Barreswil (Kao, 1970).

Elimination of urea

According to Bernard and Barreswil the question of the origin of urea had long been resolved; urea was present in blood and the role of the kidneys with respect to it was only one of elimination of the chemical. Extirpation of the organ resulted in suppression of the discharge of urea in the urine and its accumulation in the blood (Bernard & Barreswil, 1847). Nevertheless, the attention of Bernard and Barreswil had been caught by a fact of different nature: the long time lapse (several days) that occurred between the time of nephrectomy and the moment the level of urea in the blood began to increase. There was a clear loss of urea that needed to be explained. The experimental results of Bernard and Barreswil seemed to indicate that after nephrectomy the body used other accidental means to get rid of the excess of urea. Experiments on lower animals had produced the following results: (1) after nephrectomy the intestinal fluid of the all the animals contained a large amount of ammonia products, and (2) urea was not always present in the blood of the treated animals. For example, it was not found in three dogs that had began to languish 58 to 60 hours after the operation. It was clear that the increase in ammonia was a consequence of the extirpation of the kidneys. It was of interest to determine if the ammonia increase took place immediately

after extirpation and if it remained at the same level or started to diminish the moment that urea appeared in the blood. In other words, were these two appearances interconnected? In order to answer this question Bernard and Barreswil extracted the two kidneys of a medium size dog, in good health state, opened a connection to the stomach or the animal, and during two months they sampled and analyzed the gastric juice of the animal. They repeated this experience with a dog of the same species that had not been subject to nephrectomy. During all this period of time the gastric fluid of the healthy animal showed only traces of ammonia. The first sample of blood, withdrawn 36 after the extirpation, showed no traces of urea. The second sample, which was taken during the agony of the animal, presented urea in huge amounts. The stomach fluids contained ammonia but not in the form of urea; they were probably ammonia phosphate or lactate (Bernard and Barreswil, 1847).

These results led to the following conclusions: (1) after removal of the kidneys, the amount of the intestinal secretions, particularly the gastric one, increased substantially in quantity and changed their type; instead of being intermittent and being formed at the time of the digestive operation they were generated in a constant manner, in the same manner as the urine, both fasting and during digestion; (2) independently of this increase, it also appeared the intervention of a new element, that of ammonia as a salt; (3) the production of these ammonia salts in the gastric juice became apparent some hours after nephrectomy. These salts did not affect the digestive properties of the gastric fluid; (4) the elimination of large amounts of ammoniacal fluid by the intestine persisted as long as the animal remained alive but as soon as the animal began to weaken and languid the intestinal secretions diminished, and when they ceased the urea began to accumulate in the blood; (5) it was reasonable to accept that these intestinal secretions substituted the urinary secretion, in its abundance and in the nature of the new chemicals present in the load; and (6) These results indicated that after nephrectomy the intestine took over the role of the kidneys during a certain period of time; afterwards, the intestinal system did not have the vitality to continue this function and the materials of the urine started to accumulate in the blood. This accumulation resulted in the weakness of the animal and was a forced consequence of the removal. The above effects pointed to the functional solidarity between the urinary organs and the gastro-intestinal apparatus. The intestine and the kidneys were the two ends of the nutrition system. The gastro-intestinal organs prepared the nutrition materials and introduced them into the blood and the kidneys eliminated the non-assimilable components (Bernard & Barreswil, 1847).

Sugar in the liver

In a short communication published in 1848, Bernard and Barreswil notified the Académie des Sciences that they had found that sugar was present in large amounts in the tissues of the liver and that sugar could not be found under physiological conditions in any other organ (Bernard & Barreswil, 1848). This fact distinguished the liver in relation to the other organs involved in human economy. Sugar was always present in the liver even in animals deprived completely of sugar or feculent matter, even when on a diet based on meat alone. The presence of sugar was completely independent of the nature of the alimentation. Bernard and Barreswil presented the Académie with a sample of alcohol obtained by fermentation of sugar extracted from the liver (Bernard and Barreswil, 1848).

Eggs

Barreswil analyzed the different components of an egg and its digestion, and reported the following results (Barreswil, 1849): (a) the egg white of chicken contained sugar and was alkaline; the alkalinity was due to sodium carbonate; (b) the yolk of egg contained little or no

alkali; its emulsive properties did not depend upon the alkali but on a product analogous to that in pancreatic juice; (c) the yolk was not acid but could become so after a change; (d) the gastric reaction and the properties of the gastric juice were produced by organic acids and not by HCl; (e) the alkali and sugar present in the white of an egg could disappear, mutually destroying each other, a fact that explained the discrepancy in the results obtained by different methods; (f) the change in the albumen of the egg and analogous substances was proportional to their dilution. This effect was due to the circumstances that favored, more or less, the solution of the ferment (enzyme) (Barreswil, 1849).

In a following paper Barreswil gave a more detailed description of the above information (Barreswil, 1850a). The presence of sugar in the egg white was easily proved by mixing it with diluted alcohol, placing the coagulum over a piece of cloth, filtering the liquid, and testing for sugar with Barreswil reagent (cupric tartrate and alkaline potassium). Much had been written about the causes of the alkalinity or acidity of animal or vegetable fluids, particularly of the albumen of the egg or of serum, and many arguments were contradictory. Barreswil proceeded as follows: he boiled egg white with absolute alcohol, separated by filtration the resulting liquid, and treated it with a stream of hydrogen. Afterwards he mixed it with baryta water and left it to itself. After a day he separated the precipitate formed, washed it with boiling water and noticed that it effervesced with acids, a proof that it contained carbonate. Barreswil tried unsuccessfully to detect the presence of sugar in the yolk of egg. This result meant that it was not present in the yolk, that the same organs that secreted the white did not secrete yolk, or the destruction of the sugar was faster in the yolk. Similarly, he was unable to show that the yolk contained sodium carbonate, a surprising result because he believed this carbonate was responsible for the emulsive properties of yolk. This finding had led him to look in the yolk for a compound analogous to the one present in the pancreatic fluid, known to be emulsive. For this purpose, he treated the yolk with ether exempt of alcohol, separated the liquid from the oily phase formed, and observed that this liquid had emulsive properties similar to those of he pancreatic fluid. Treated with amygdalin it provoked the same reaction as emulsin, a result that proved that nature used the same mechanism in animals and vegetables: next to starch and fatty matter it provided vegeto-nitrogen substances destined to generate the ferments capable of dissolving the starch and emulsifying fat (Barreswil, 1850a).

Barreswil found that fresh yolk was not acid; it showed no action on litmus paper, but did after some time in contact with air. The pancreatic juice showed the same acidification process when in contact with fatty material. The acid formed was lactic acid, which supported the idea of Bernard and Barreswil that gastric juice was composed of lactic acid. Barreswil also discussed the disappearance of the sugar present in eggs. He believed that this effect was due to the simultaneous presence of sodium carbonate and air. Experience indicated that starch sugar disappeared under the action of air in the presence of alkalis. This result was similar to what could occur during an analysis: two substances could disappear by mutual reaction. Sugar could ferment by spontaneous destruction; when egg white was exposed to air, it disappeared faster than when it was diluted. Red currant water decomposed from one day to the next, while red currant jam was stable for years. Egg albumin and similar substances decomposed faster when they were in a more diluted state; all other conditions being equal, these substances decomposed faster under conditions that increased the solubility of the ferment (Barreswil, 1850a).

Sugar in urine

In 1851 Alvaro Reynoso reported the presence of sugar in the urine of animals subjected to the action of chloroform or ether, and in animals asphyxiated by strangulation or by immersion in water (Reynoso, 1851). According to Reynoso, several physicians had studied the function of the medulla and concluded that it was the central focus and regulating organ of the respiratory movement. For example, Jean Pierre Flourens (1794-1867) believed that a very limited part of the medulla was the true site of respiration. In rabbits, this site was located immediately above the eighth pair (Flourens, 1851). Bernard had punctured the rabbits slightly above this point and rendered them diabetic. He had explained this result assuming that the resulting excitation had led the liver to produce a larger amount of sugar, which could not be consumed by respiration and, as a result, had passed into the urine (Bernard, 1851). Alonso believed that the real reason was that the puncture had resulted into partial or total paralysis of respiration under which the *normal* sugar could not be burned and hence was passed into the urine. To prove this assumption, he had stopped the respiration of animals by asphyxiation or by anesthesia. The anesthesia experiments with herbivore or carnivorous animals showed that their respiration was more active because they were circulating blood with more unburned sugar. Not all asphyxiated rabbits presented signs of diabetes probably because this technique led to other perturbation phenomena of the animal economy. Thus, a living animal that did not breath was diabetic. Bernard had already proved that the urine of a fetus always contained sugar (Alonso, 1851, 1853).

According to Barreswil, Reynoso's paper was quite satisfactory but did not explain Bernard's finding that a puncture of the vagus nerve led to the presence of sugar in urine, except if the puncture had actually taken place in the respiration site located in the medulla by Flourens. He believed that it would be of interest to repeat Reynoso's experiments in animals deprived of vegetable foods and in animals fed vegetables and sweet foods, for comparison purposes. These experiments would help solving the question of the purpose of sugar in the blood. Was it a necessary product or an accident of animal economy, originating exclusively from certain foods or the result of an elaboration by the liver, independently of the feeding mode (Barreswil, 1851c)?

In an additional paper, Barreswil mentioned that Reynoso had reported the results of additional experiments about the influence of certain treatments on the presence or disappearance of sugar in animal economy (Barreswil, 1852a). Thus he had found that the use of compounds of lead and arsenic, as well as of quinine sulfate, led to the appearance of sugar in the urine. Barreswil believed that this additional information allowed modifying the explanation of the phenomenon. Barreswil and Bernard had already found that adding a considerable amount of sugar to the blood did not result in its appearance in the urine. This result seemed to prove that the sugar was not directly oxidized (burned) in the blood but that it was first split, by some kind of fermentation (Barreswil, 1852a).

Crystallizable sugar in beetroot and other sweet substances

In 1838 the *Société d'Encouragement pour l'Industrie Nationale* (an organism established in 1801 to promote the French industry) offered a prize of 3,000 francs for a successful method of quantitative estimation of sugar. Barreswil participated in the competition presenting a new saccharimetry process based on the modification of a fact reported by Karl Trommer (1806-1879) in 1841. Trommer found when a sweet solution was treated with a few drops of cupric sulfate and then of KOH, and the mixture heated to near boiling, the non-crystallizable sugar, or molasses, present in the liquor reduced the copper salt and

precipitated a red copper oxide, while crystallizable cane sugar had no action on the sulfate. This simple procedure allowed distinguishing between both kinds of sugar, even in solutions of grape sugar containing only one part of sugar in one hundred thousand of solution (Trommer, 1841). Barreswil method was based on the following facts: (1) crystallizable sugar was unable to reduce the cupric oxide contained in an alkaline liquid but did when treated with sulfuric acid and then boiled for a few minutes. This procedure converted it completely into glucose, which reduced the copper oxide, and (2) the amount of cuprous oxide reduced was proportional to the amount of sugar present. Barreswil procedure permitted determining quantitatively the amount of cane sugar (crystallizable) and glucose, when these substances were present alone or mixed in a solid product like raw commercial sugar, or in a liquid like beet juice and the must extracted from cane sugar.

The Société requested from a scientific committee headed by Eugène Melchior Péligot (1811-1890) to evaluate Barreswil proposal. The committee reported as follows (Péligot 1844): In order to find the quantity of crystallizable sugar contained in a liquid, exclusive of other organic products, it is necessary to prepare an alkaline solution of cupric oxide by mixing cupric sulfate, neutral potassium tartrate (to avoid decomposition of the solution on boiling), and KOH. The resulting deep blue liquid, the *test liquid*, is filtered and remains clear and limpid for a long time. The test liquid is calibrated by determining how much of it is discolored completely by a solution of a known amount of pure and dry sugar-candy, raised to a boiling temperature and treated with of a few drops of sulfuric acid. A known amount of the calibrated liquor is then poured into a capsule of porcelain or glass and mixed with an appropriate amount of highly concentrated KOH. This step is necessary for increasing the density of the liquid and facilitating the complete precipitation of the copper oxide. The solution being tested, diluted with a given quantity of water, is added drop-wise by means of calibrated burette into the hot solution of copper oxide. A yellow precipitate of copper hydrate is formed, which turns red and falls to the bottom of the vessel. The blue color of the solution becomes weaker while the copper precipitates as cuprous oxide. The titration process is completed when the liquid becomes completely colorless. The amount of sugar present in the liquid being tested is calculated from the liquid volume employed to discolor the solution. Péligot remarked that the critical part of the operation was to determine the precise moment the precipitation of the copper oxide was finished; this could be judged by the color disappearance, or the end of precipitation of the turbid yellow solid that preceded the deposit of the copper oxide. Péligot wrote that addition of an excess of sugar to the test liquor, after the complete separation of the oxide of copper, produced the well-known brown color resulting from the reaction of alkalis upon the non-crystallizable sugar (Péligot, 1844).

When the liquid being tested contained both crystallizable sugar and molasses, the analytical procedure was carried in two steps. First, the proportion of molasses was determined without addition of sulfuric acid since only this material reduced the copper solution. Then, another portion of the sweet liquid was boiled with the sulfuric acid in order to convert all the crystallizable sugar into molasses. This allowed determining the total amount of sugar (molasses) present. The difference between the two results indicated the quantity of crystallizable sugar contained in the mixture of water, ordinary sugar, and molasses. Péligot commented that Barreswil procedure was extremely simple; when a liquid contained only crystallizable sugar, it was possible to determine its amount in 15 minutes within 2 to 3%. It also allowed determining the presence of only traces of molasses. The accuracy was smaller when the mixture contained molasses and sugar, as happened with cane or beetroot juice kept in the air for some time, or in fraudulent mixtures of brown sugar and granulated molasses.

Péligot went on to describe the disadvantages of Barreswil method. The main one was that it was only applicable to pure solutions of sugar, or a mixture of sugar with molasses. It would give erroneous results if the substance being analyzed contained tartaric acid, dextrin, sugar of milk, etc., which acted nearly in the same manner as crystallizable sugar. The same error would be introduced by any organic matter capable of reducing the alkaline solution of oxide of copper. In spite of its advantages the Barreswil process was not a definite answer to the question. For this reason the judging committee decided to award it only on third (1,000 francs) of the total prize and a silver medal. It is also decided that the question should be left open for further improvements until the meeting in 1845, and the reward reduced to 2,000 francs. In 1849, Hermann Christian von Fehling (1812-1885), in the test the bears his name, substantially improved Barreswil procedure (Fehling, 1849).

In 1845 Barreswil reported that mixing a concentrated sugar solution with a concentrated solution of cupric sulfate resulted, after some time, in the formation of a white and slightly blue precipitate of a combination of both reagents, containing one equivalent of anhydrous cupric sulfate and one of candy sugar, and four of water (Barreswil 1845a). Treatment of the compound with baryta water resulted in the precipitation of crystallizable sugar, cupric oxide, and sulfuric acid. Treatment with a stream of CO_2 eliminated any excess of baryta present. Heating an aqueous solution of the compound resulted in the precipitation of cuprous oxide and metallic copper. Heated slowly up to 140 °C resulted in the elimination all the water and a residue of anhydrous cupric sulfate and carbon. Barreswil reported that the result of the heating process was not simple; it could lead to the formation of diverse products, among them a compound that he believed was analogous to ulmin. This intermediate was able, like animal carbon, of eliminating the vegetable coloring matter present in the raw material. Heating the compound abruptly to a temperature below 140 °C resulted in substantial swelling; additional heating led to ignition and burning and formation of a residue of cuprous oxide and metallic copper (Barreswil, 1845a).

Calcium saccharate

Barreswil mentioned that the molasses of alkaline beetroot sugar were the ones that produced the largest effervescence with acids, even after being boiled (Barreswil, 1851b). These molasses did not contain non-crystallizable sugar and were composed of crystallizable sugar, of organic substances differing from sugar, and of salts. The foreign substances, which prevented the sugar from crystallizing, could be easily separated, wholly or in part from the mixture, either by lead oxide, which precipitated certain foreign substances and left the sugar in a great state of purity (Scoffern, 1849), or by baryta which precipitated the sugar and left the foreign substances in solution (Dubrunfaut, 1851). Both processes had been successfully tried on a large scale, the former principally with cane sugar and the latter with beetroot sugar. The only objection was the poisonous nature of the reagents; more work was necessary to obviate this inconvenience or find innocuous materials to carry on the process (Barreswil, 1851b).

Barreswil collected the gas released and noticed that it was composed mainly of CO_2, a surprising result since it was known that this material contained calcium salts that were not supposed to be carbonates. The only plausible explanation was that the carbonate was soluble in sugar or in one of the impurities of the molasses. For this reason he decided to search for the presence of calcium carbonate in the diverse substances that were known to be present in the molasses. The result of his experiments led him to discover that calcium carbonate was soluble in a compound of sugar and lime, as proved by the following facts: (1) streaming a current of CO_2 through a solution of sugar and lime did not make it turbid

immediately; (2) addition of a mixture of calcium chloride and sodium carbonate to a solution of the lime and sugar compound did not cause precipitation; and (3) addition of a solution of ammonium chloride to a solution of calcium carbonate in the saccharate caused an immediate precipitate of pure calcium carbonate (the ammonium chloride was used to saturate the free lime of the saccharate). According to Barreswil the fact of the solubility of calcium carbonate in the saccharate indicated the formation of a double salt. Further experiments proved the existence of this double salt but Barreswil was unable to isolate in the pure state. He could only prepared it in the presence of an excess of calcium saccharate. He speculated that this double salt could participate in some of the physiological processes in animal economy (Barreswil, 1851b).

Guanine - silvery scales of bleak

Barreswil wrote that the white of the silvery scales of the fish *Alburnnus alburnus* was an organic material, which in a pure state was an immediate principle employed in the fabrication of false pearls (Barreswil, 1861). Barreswil determined the physical and chemical properties of a sample he had received from Liebig's laboratory and reported that this substance was insoluble in water, ammonia, and acetic acid, and soluble in sulfuric, nitric and chlorhydric acids. The pertinent salts crystallized in a very characteristic manner; the sulfuric salt was soluble in water and evaporation of the nitric solution produced a yellow compound that turned red in the presence of KOH. Its behavior under the influence of fire or KOH was also very characteristic. According to Barreswil, all these properties made it identical with the guanine that Julius Bodo Unger (1819-1885) had separated from guano, the excreta of sea birds (Unger, 1846; Barreswil, 1861). Barreswil closed this note saying that in a coming publication he would provide the elemental analysis of the substance; unfortunately he did not do it.

Lithography

In 1853 Noël-Paymal Lebebours (1807-1873), Barreswil, and Rose-Joseph Lemercier (1803-1887) communicated to the Académie des Sciences the details of a new process for photography in stone that they had developed the previous year (Lebebours, Barreswil, & Lemercier, 1853). The process consisted in preparing a negative in paper and then producing a positive on lithographic stone. The negative was obtained by any method, the most rapid being preferable. The positive was produced by a fatty or resinous coating laid on the stone and capable of being rendered soluble in some solvent by the action of light (and perhaps oxygen). The negative was laid upon the lithographic stone thus prepared and covered with a glass plate. The whole was then exposed to the sun, the stone washed with the solvent, and then treated by the ordinary process of lithography. Lebebours, Barreswil, and Lemercier had employed bitumen for coating the stone and sulfuric acid as the solvent. They expected in this manner to reproduce engravings, lithographs, etc. (Lebebours, Barreswil, & Lemercier, 1853). This process was eventually the source of a patent for “an application of photography to lithography and, by extension, to zincography and even to engraving”.

BIBLIOGRAPHIC REFERENCES

Barreswil, C. L. (1843c). Sur les Propriétés Colorante de l'Acide Aloétique. *J. Pharm., 3*, 450-451.

Barreswil, C. L. (1843d). Sur un Nouvel Acide Oxygéné du Chrome. *Compt. Rendus, 16*, 1085-1086.

Barreswil, C. L. (1843f). Premier Mémoire sur la Coloration des Sels. Nouvel Oxyde de Fer. *J. Pharm., 4*, 455-458.

Barreswil, C. L. (1843g). Sur la Constitution Chimique des Gallates et Tannates de Fer et des Teintures à Base de Fer. *Compt. Rendus, 17*, 739-742.

Barreswil, C. L. (1845a). Note sur un Composé Nouveau de Sulfate de Cuivre et de Sucre. *J. Pharm., 7*, 29-30.

Barreswil, C. L. (1845b). Faites pour Servir à l'Histoire de l'Acid Borique. *J. Pharm., 7*, 462-465.

Barreswil, C. L. (1845d). Observations sur la Décomposition de l'Eau par les Métaux sous l'Influence de Proportions très-Petites de Diverses Dissolutions Métalliques. *Compt. Rendus, 21*, 292-293.

Barreswil, C. L. (1846c). Sur les Anomalies Apparentes que Présente la Distillation du Mercure. *J. Pharm., 9*, 256-258.

Barreswil, C. L. (1846d). Sur l Existence d'un Nouvel Oxacide de l'Azote, et sur la Théorie de Fabrication de l'Acide Sulfurique. *Compt. Rendus, 23*, 609-611.

Barreswil, C. L. (1847). Mémoire sur un Nouveau Composé Oxygéné du Chrome. *Ann. Chim. Phys.* [3], *20*, 364-369.

Barreswil, C. L. (1849). Faites Divers de Chimie Appliquée à la Physiologie. *Compt. Rendus, 28*, 761.

Barreswil, C. L. (1850a). Faites Divers de Chimie Appliquée à la Physiologie. *J. Pharm., 17*, 114-145.

Barreswil, C. L. (1850b). Résumé de la Méthode d'Impression des Tissus. *J. Pharm., 17*, 271-276.

Barreswil, C. L. (1850c). Note sur l'Industrie des Sucres. *J. Pharm., 17*, 351-355.

Barreswil, C. L. (1851a). Explication Proposé pour le Phénomène de l'Endosmose. *J. Pharm., 19*, 126.

Barreswil, C. L. (1851b). Sur la Solubilité du Carbonate de Chaux dans le Saccharate. *Compt. Rendus, 32*, 469-470; *J. Pharm., 19*, 330-331.

Barreswil, C. L. (1851c). Présence du Sucre dans les Urines. *Compt. Rendus, 33*, 416-417.

Barreswil, C. L. (1852a). Sur la Présence du Sucre dans l'Urine. *J. Pharm., 21*, 27-28.

*n*il. C. L. (1852b). *Documents Académiques et Scientifiques Pratiques et Administratifs sur le Formate de Quini*

Barreswil, C. L. (1852c). *Rapport sur les Propriétés Thérapeutiques du Tannate de Quinine de L.-C.-A.* Bailliére, Paris.

Barreswil, C. L. (1856). *Improvement in Gas Meters*. British patent sealed August 8.

Barreswil, C. L. (1857a). Note sur la Maladie de la Vigne. *J. Pharm.*, *31*, 355-366.

Barreswil, C. L. (1857b). Note sur un Moyen de Reconnaitre la Présence de la Soie en Mélange avec la Laine et d'en Déterminer la Proportion. *J. Pharm.*, *33*, 123-125.

Barreswil, C. L. (1861). Sur le Blanc d'Ablette que Sert à la Fabrication de Perles Fausses. *Compt. Rendus, 53*, 246; *Liebig's Ann. Chem., 122*, 128.

Barreswil, C. L. & Davanne, A. (1854). *Chimie Photographique*. Mallet-Bachelier, Paris.

Barreswil, C. L. & Girard, A. (1861-1864). *Dictionnaire de Chimie Industrielle*. Dezobry, Paris.

Barreswil, C. L. & Lacroix, E. (1865). *Répertoire de Chimie Appliquée. Compt. Rendu des Applications de la Chimie en France et à l'Étranger*. Hachette, Paris.

Barreswil. C. L. & Sobrero, A. (1843). *Appendice à tous les Traités d'Analyse Chimique Recueil des Observations Publiées depuis Dix Ans sur l'Analyse Qualitative et Quantitative*. Fortin & Masson, Paris.

Bernard, C. (1851). Sur les Causes de l'Apparition du Sucre dans l'Urine. *C. R. Mém. Soc. Biol., 3*, 144-145.

Bernard, C. & Barreswil, C. L. (1844a). Recherches Physiologiques sur les Substances Alimentaires. *J. Pharm., 5*, 425-428.

Bernard, C. & Barreswil, C. L. (1844b). Sur les Phénomènes Chimiques de la Digestion. Second Mémoire: Analyse du Suc Gastrique. *Compt. Rendus, 19*, 1284-1289.

Bernard, C. & Barreswil, C. L. (1847). Sur les Voies d'Élimination de l'Urée après l'Extirpation des Reins. *Ann. Sci. Nat.* (Zoologie), *7*, 302-306.

Bernard, C. & Barreswil, C. L. (1848). De la Présence du Sucre dans le Foie. *Compt. Rendus, 27*, 514-515.

Dubrunfaut, A. P. (1851). Note sur les Sucrates Insolubles et sur leur Application à la Fabrication du Sucre Cristallisable. *Compt. Rendus, 32*, 498-501.

Fehling, H. (1849). Die Quantitative Bestimmung von Zucker und Stärkemehl Mittelst Kupfervitriol. *Liebig's Ann. Chem., 71-72*, 106-113.

Flourens, M. J. P. (1851). Sur le Pointe Vital de la Moelle Allongée. *Compt. Rendus*, *33*, 437-439.

Kao, J. (1970).Vapor-liquid Equilibrium of Water-Hydrogen Chloride System. *J. Chem. Eng. Data*, 15, 362–367.

Lebebours, N. P., Barreswil. C. L., & Lemercier, R. J. (1853). Ouverture d'un Paquet Cacheté Déposé dans à la Séance du 28 Juin 1852. *Compt. Rendus, 37*, 878-879.

Péligot, E. (1844). Rapport Fait à la Société d'Encouragement sur le Concours Relatif à la Découverte d'un Moyen Saccharimétrique Propre à Faire Connaitre Promptement la Quantité de Sucre Contenue dans la Betterave ou dans Tout Autre Produit Sucré. *Bull. Soc. Encourag.*, Année 43é, #480, 266-270; *J. Pharm., 6*, 301-304.

Pelouze, J. (1844). Sur l'Acide Lactique. *Compt. Rendus, 19*, 1218-1227.

Peumery, J. J. (1986). Charles-Louis-Arthur Barreswil (1817-1870) et les Sciences Médicales. Communication présentée à la séance du 31 mai 1986 de la Société française d'histoire de la médecine.

Reynoso, A. (1851). Présence du Sucre dans les Urines. *Compt. Rendus, 33,* 416-417.

Reynoso, A. (1853). *Mémoire sur la Présence du Sucre dans les Urines et sur la Liaison de ce Phénomène avec la Respiration*. Masson, Paris.

Scoffern, J. (1849). On the Combined Use of the Basic Acetates of Lead and Sulphurous Acid in the Colonial Manufacture and the Refining of Sugar. *Brit. Assoc. Rept.* (part 2), 42-43.

Sernka, T. J. (1959). Claude Bernard and the Nature of Gastric Acid. *Perspec. Biol. Med., 22*, 523-530.

Trommer, K. (1841). Unterscheidung von Gummi, Dextrin, Traubenzucker und Rohrzucker. *Liebig's Ann. Chem., 39*, 360-362.

Unger, B. (1846). Über die Zusammensetzung des Harnoxyds. *Liebig's Ann. Chem., 58*, 18-20.