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The Invention of Nutrients – William Prout, Digestion and Alimentary Substances in the 1820s

Abstract

The early history of nutrient research leads back to the turn of the 19th century and the milieu of chemically interested physicians. William Prout, a physician in London, is supposed to be the first who developed a concept of nutrients or alimentary substances as he called them. The paper introduces Prout's life, states his work and contributions to the development of chemistry and concentrates on Prout's use of chemical analysis as a way of understanding human digestion. It will be shown in detail how he came to introduce the term "alimentary substance". The aim of the paper is to show from the point of view of the history of knowledge that nutrients are not so much the building blocks of our food but merely experimental laboratory entities. Hence, as technologically produced objects of knowledge they cannot be considered independently from the style of research, theory or apparatus, which brought them into life.

Keywords
Nutritional theory
Chemical medicine
Digestion
Definition nutrients
Milk
Early 19th century
Great Britain

Introduction

Nutrient – this is one of the most dazzling buzzwords of the modern diet. Take any nutritional science textbook and there will be the commonly used but rarely illuminative information: nutrients are "substances that are needed in the diet for the normal function of the body."[1] According to the FAO "Codex Alimentarius", nutrient means any substance, which provides energy, or which

[1] Jim MANN, Stewart A. TRUSWELL, *Essentials of Human Nutrition* (2nd ed., Oxford, 2002), p. 1.

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is needed for growth, development and maintenance of life, or a deficit of which will cause characteristic bio-chemical or physiological changes to occur.[2]

What kinds of substances are meant concretely is by no means evident. Textbooks offer several definitions. Some talk of chemicals, compounds or elements; others of nourishing ingredients or natural substances in the sense that every body consists of them. Moreover, there exist different classifications.[3] Today, at least six classes of nutrients are said to be essential for human nutrition, insofar as the body is unable to provide them by itself. Classifiable as those that provide energy are carbohydrates, fats and proteins. Nutrients that support metabolic processes in the body are water, minerals and vitamins. From a purely chemical point of view, every one of these main or key nutrient groups will be subdivided into certain micronutrients, e.g. minerals in iron, calcium, phosphorus, and so on.[4] Therefore, the term "nutrient" can refer to organized substances as well as to chemical entities. But any scientifically accepted classification of nutrients is likely to be arbitrary due to the fact that modern science and the food industry constantly create new kinds of nutrients: "intelligent nutrients", "anti-fat nutrients", "cancer-fighting nutrients", "young again nutrients".[5] On the modern food markets new labels introduce new food preferences and remind the consumer that a selected nutrient intake will support a healthy lifestyle.

Nutrient declarations therefore are diffuse and inconsistent, and things become even more complicate with respect to the fact that every nutrient is related to specific physiological functions. Whether one consumes Vitamin C with orange juice, potatoes, or tablets makes no difference as long as one gets enough of it, e.g. to avoid colds. Calcium aids in the development of strong bones and teeth. Iron is a factor in red blood cell formation, and so on. Phrases like these make clear that "nutrient" is not only a scientific or technical term; in certain discourses about health, nutrients become value-laden terms expressing positive or negative opinions toward the subject of nutrition. Moreover the term encourages choice making, if not the wish for optimal decision-making. In fact, the question of balancing nutrients to meet one's nutritional needs, health and well-being has become a core activity of the doctor-yourself society (in the sense of a society, in which people use biomedical information in order to treat their bodies by themselves).[6] Both as a part of science history and in its

[2] Codex Alimentarius – Joint FAO/WHO Food Standards Programme (Roma, 2001), p. 5.

[3] See MANN/TRUSWELL, *Essentials...*; Robert E.C. WILDMAN, Denis M. MEDEIROS, *Advanced Human Nutrition* (Boca Raton et. al., 2000), p. 38.

[4] About the substances of carbohydrates for instance, see WILDMAN, MEDEIROS, *Advanced Human Nutrition...*, p. 79ff.

[5] These are just a few examples of phrases one gets with googling the term "nutrient".

[6] For the example of the help-yourself marketing of vitamins, see Rima D. APPLE, *Vitamania. Vitamins in American Culture* (New Brunswick, 1996); Beat BÄCHI, *Volksdroge Vitamin C: Pharmazeutische Produktion, Vermarktung und Gesundheitspolitik (1933-1953)* (Zürich, 2009).

larger historical context, the nutrients-balancing culture remains a substantial modern development. It has changed the way most people judge nutrition and a healthy body, and it has changed the way many people eat.[7]

Methodological considerations

If there exists a problem of definition today, from a historical perspective this is by no means new. Although justifying nutrients instead of food nowadays is reasonably familiar, the revision of the nutritional value of selected food by determining specific nutrients, however, seems to be the never ending story of nutritional research. Several times in history, nutritional theories and dietary regimes have been completely revised according to new findings.[8] In fact, the definition and redefinition of nutritious substances has become the core business of modern nutritional research since its beginning as experimental science in the early 19th century. On the one hand, the history of nutrients is strongly related to the cumulative influence of chemical operations in the study of the transformation of matter within the human and animal body. But, on the other, it cannot be solely reconstructed on the basis of an experimental practice. Similar to the recent tendency of constructing new categories of nutrients, 19th century researchers, too, made claims about the physiological function and nutritious value of a certain substance, claims that could not be validated by experiment.

The older historiography of organic chemistry and nutritional sciences tended to describe the history of nutrients as *discoveries* of certain nutritious substances. Authors organized the historical material in roughly the same way around the different substances.[9] One finds chapters on proteins, lipids,

[7] See Marion NESTLE, *Food Politics: How the Food Industry influences Nutrition* (Berkeley/Los Angeles, 2002).

[8] One of the best-known stories refers to the observation that a dietary regime solely based on the nutrients carbohydrates, proteins and fat can cause deficiency diseases. This was the insight, nutritionists got from vitamin research. See Elmer V. MCCOLLUM, *The Newer Knowledge of Nutrition. The Use of Food for the Preservation of Vitality and Health* (New York, 1923), p. 4.

[9] This is not only to be said of older studies such as: Fritz LIEBEN, *Geschichte der physiologischen Chemie* (Hildesheim/New York, 1970 [1st ed., Wien, Leipzig 1935]); Elmer V. MCCOLLUM, *A History of Nutrition. The Sequences of Ideas in Nutrition Investigations* (Boston, 1957); Nikolaus MANI, "Die wissenschaftliche Ernährungslehre im 19. Jahrhundert", in E. HEISCHKEL-ARTELT (ed.), *Ernährung und Ernährungslehre im 19. Jahrhundert* (Göttingen, 1976), p. 22-75. More recent studies also arrange their material this way. See for instance: Aaron IHDE, *Development of modern chemistry* (3rd ed., Toronto/Ontario, 1984). In Chapter 13, Ihde describes proteins etc. as natural products (according to the fact that they are not synthesized substances). See also: *The Cambridge World History of Food*, ed. by K. F. KIPLE, K. C. ORNELAS (Cambridge, 2000). After three parts dedicated to different kinds of food, the Cambridge History of Food organizes its chapters in part four around nutrients, starting with vitamins and minerals, followed by chapters on "Proteins, Fats and Fatty Acids" and "Deficiency diseases". Joseph S. FRUTON, *Proteins, Enzymes and Genes. The Interplay of Chemistry and Biology* (New Haven/London, 1999); Kenneth J. CARPENTER, *Proteins and Energy.*

carbohydrates, vitamins, minerals, combined with descriptions of the development of the concepts of metabolism, fermentation, respiration and so on. Although ambitious and very precise in detail, the scope of all these works is limited to histories of discoveries that follow the line of biochemical textbooks.

In opposition to this tradition, in this paper I prefer the term "invention" for two reasons:

Because nutrients can seldom be found in a natural form, to develop knowledge about human nutrient requirements is impossible without the aid of laboratory experiments. Nutrients do not exist in nature; they have to be produced by chemical analysis. Therefore they can be defined in a Bachelardian sense as technically constituted phenomena. In the words of Hans-Joerg Rheinberger, who recently discussed the term "phenomenotechnique" of the French philosopher of science Gaston Bachelard: "What tends to be perceived as a fact, as something given in the real world, has to be seen as a result of and even derives its existence from a circuit that is at the same time material and discursive. Technophenomena are theoretically invested entities."[10] Following these considerations, I would argue that nutrients are both, laboratory entities and outcomes of mainly speculative theories about the physiological meaning of the outcomes of chemical research. As such, the definition of nutrients was a precondition of the coming into being of modern metabolic concepts and those sciences at the intersection of medicine, physiology and chemistry that explore different pathways of metabolism as cellular processes. The definition of nutrients was in this respect the starting point of a scientific tradition that views the body as a complex biochemical system operating within and between cells.

In order to explore these arguments, I will go back to the 1820s, the period in which for the first time the term "nutrient" appeared in a scientific context. I shall discuss the work of a doctor and chemist, William Prout (1785 – 1850), whose writings are of interest because he is said to be the first who classified the key nutrients to be found in the analysis of milk.[11] For Prout, however, the consideration of nutrition was not at the centre of his work, and he was by no means interested in the development of dietary regimes. Instead, his work gives an idea of how and why nutritional research became so influential after 1840, the period when Justus von Liebig published his influential theory of metabolism.

It was the interplay of physiology and chemistry, or the question how physicians could use chemical analysis in order to understand bodily processes that brought nutrition to the fore. But Prout's work cannot easily be evaluated

A Study of Changing Ideas in Nutrition (Cambridge, 1994).

[10] Hans-Joerg RHEINBERGER, "Gaston Bachelard and the Notion of 'Phenomenotechnique'" in *Perspectives on Science* 13 (2005) 3, pp. 313-328.

[11] According to IHDE, *Development...*, p. 427.

as a kind of pre-history. He was not a forerunner who prepared the way for the metabolism theories of Liebig and others. In fact, he stood at the watershed of what the historian of chemistry Ursula Klein has called the two cultures of organic chemistry. The way in which natural things were ordered changed radically between the 1820s and the 1840s. Organic chemistry (or plant and animal chemistry) of the late eighteenth and early nineteenth century, Klein argues, "was a scientific culture that shared many features with the natural historical enterprises of the time."[12] Chemists used the dominant biological, medical and artisan classifications for the objects under investigation.[13] In the case of Prout, the theoretical concept that guided his work was not yet "metabolism" but "digestion". The difference was epistemologically far-reaching, insofar as the first was based on the notion of chemically defined entities, while the latter treated anatomically found organs, liquids and tissues.[14] Yet along with the application of recent theories of matter and the exploration of new technologies of analysis, the old medical framework was challenged and this led Prout to formulate a new order of nutritional substances.

Prout's Career: Medicine and Chemistry

By way of background, let me first present some biographical data on William Prout. The purpose of this short introduction in his life is to provide information about his intellectual background, the various kinds of research he undertook, and the reputation that he enjoyed in his lifetime.[15] Born 1785 in a Gloucestershire farmer's family, William Prout grew up in the countryside with only an elementary education. Until the age of seventeen, he worked with his father on the family land. He became dissatisfied with his educational deficiencies and started to organize his own education by engaging clergymen. It was Reverend Jones, running seminars in Redland, Bristol, who suggested that the young man, with his obvious interest in chemistry, should become a doctor. In 1808, at the age of twenty-three, Prout went to Edinburgh for three years, first to Edinburgh High School and then to the, at that time eminently

[12] Ursula KLEIN, *Experiments, Models, Paper Tools. Cultures of Organic Chemistry in the Nineteenth Century* (Stanford, 2003), p. 79.

[13] See Allen G. DEBUS, *Chemistry and Medical Debate van Helmont to Boerhaave* (Canton, MA, 2001).

[14] The term metabolism had not been coined before the end of the 18^{th} century. Slowly established around 1800 it was only rarely used in the next decades. See Johannes BÜTTNER, "Von der *oeconomia animalis* zu Liebigs Stoffwechselbegriff" in Johannes BÜTTNER, Wilhelm LEWICKI (eds.), *Stoffwechsel im tierischen Organismus: Historische Studien zu Liebigs "Thier-Chemie"* (Seesen, 2001), p. 74.

[15] See William H. BROCK, *From Protyle to Proton. William Prout and the Nature of Matter, 1785-1985* (Bristol/Boston, 1985).

respectable, University of Edinburgh. Here, Prout attended stimulating courses in chemistry, botany, physiology and the history of medicine, judged as pre-clinical sciences that are as important as the art of healing. At that time, the medical faculty taught its pupils in a mindset without the traditional hierarchy of physician, surgeon and apothecary.[16] After finishing a dissertation on fevers, he was granted the degree of MD in June 1811. One year later, he obtained a license from the Royal College of Physicians, which allowed him to set up his own practice in London.

But Prout's ambitions went in other directions. Beside the fact that it was not easy to acquire wealthy patients in order to establish a new medical practice, he also was not really satisfied with the idea of spending his life as a doctor in London. In order to announce himself as a man of science, he delivered a course of lectures on animal chemistry at his home in 1814. These lectures brought him into contact with some important surgeons and chemists in London, among them the Swiss-born Alexander Marcet, physician at Guy's hospital, an authority on urinary calculi and a correspondent of the Swedish chemist Jöns Jakob Berzelius.[17] Like Prout, Marcet gave courses to medical students on animal chemistry with accompanying experiments. Both men shared an interest in applying chemical analysis to animal substances and in using the results for diagnosis and medical treatment. Marcet became a close friend of Prout. Prout's attempts to become a member of the clubs and societies, which were devoted to chemical and physical investigations, were finally rewarded. In 1814, he was elected to the Medical and Chirurgical Society; in 1819 he became a Fellow of the Royal Society and in 1821 of the Royal College of Physicians. Furthermore, he served two terms as vice-president of the Medical Society of London. Because of an increasing deafness, caused by an intense earache he suffered in youth, he shunned the scientific societies more and more from the beginning of the 1830s onwards. And when in 1848 he became a victim of the cholera outbreak of that year, his health grew steadily worse. Prout died on 9 April in 1850.

From 1814, the year he married and settled down in a new home in London[18], Prout became quite well known within the community of scientists and physicians. In fact, his town practice developed quite well and allowed him to do private research in his home laboratory. Even though he performed his offices as a professional physician and became the father of a growing family, Prout continued to analyze animal materials. He was an early

[16] To the Scottish chemical community see Jan GOLINSKI, *Science as Public Culture. Chemistry and Enlightenment in Britain 1760-1820* (Cambridge, 1992), chapt. 1.

[17] On Marcet see Louis ROSENFELD, "The chemical work of Alexander and Jane Marcet" in *Clinical Chemistry* 47 (2001), pp. 784-792.

[18] The Prouts had their first child in 1815 but the daughter survived only a few months. There were six further, healthy children.

riser and did some of his scientific work before breakfast at 7 in the morning. The remainder of the day was devoted to his patients.

Primarily a physician with an extensive town practice, a good deal of his chemical interests were directed to urinary disorders, diabetes and digestion. A series of papers, which originated in the analysis of a snake's excreta in 1815 and ended with the analysis of fossil feces in 1829, were dedicated to these subjects. But not only materials of reptiles, birds and several other animals, were the sources of Prout's analyses. His growing reputation as a physician who specialized in urinary complaints led him, like Marcet, to take an interest in urinary diseases, especially the chemical composition of painful stones in the kidneys and bladder. Urinary diseases figured prominently in this period, and chemistry promised to give fruitful explanations about the composition of healthy and pathological urine.[19] A growing number of practitioners asked for his help and packages with urine samples arrived daily from the country for analysis. Prout's work on urine led him not only to the discovery and announcement of several acids (purpuric acid, homogentisic acid), he also developed a method of producing pure urea (this method became the standard technique described in 19th century textbooks), published a routine for testing urine which could easily be performed by the general practitioner, and finally he itemized the necessary apparatus for uroscopy.

For historians of chemistry, Prout became a prominent figure for two other reasons. First, Prout was a skilled technician. While older historiography of organic chemistry mainly paid attention to the confusion over nomenclature, atomic weights, vitalism and classification models, recent historiography emphasizes much more the tremendous technical difficulties organic analysts faced in that period. As Brock pointed out: "Prout spent twelve years of his life searching for an apparatus and a technique which could provide accurate analysis of organic materials, but he was never satisfied that he had solved the problem..."[20] One has to bear Prout's duties as a medical practitioner in mind; thus he could only work at a slow pace. But despite all of the interruptions caused by daily demands, he developed several instruments by himself. Prout used both kinds of analysis commonly used since the 18th century in order to study organic materials: on the one hand, the more qualitative analysis of substances by resolution into either their proximate (immediate) principles, or on the other hand, the more quantitative elementary analysis, first introduced by Lavoisier and then enhanced by Gay-Lussac, Thénard and others. Prout adapted the more sophisticated techniques of elementary analysis, because he like his contemporaries proved them to be more important for the

[19] Already in the late 18th century, several chemists, like for instance Antoine Francois Fourcroy and Nicholas Vauquelin, undertook investigations in the composition of urine and developed procedures for the isolation and the study of urea. See ROSENFELD, The chemical work..., p. 700.

[20] BROCK, *From Protyle to Proton...*, p. 20.

development of organic chemistry. It was for his complicated combustion apparatus that Prout was awarded the Royal Society's highest honour – the Copley Medal – in 1827, a technique that continued in use in England even after the successful introduction of Liebig's method.

Prout's constructions illustrate that he was really up to date with the organic analysis of his time and that he was well aware of the interplay of instrumentation and organic theory. As we shall see later, he knew quite well the benefits and limits of chemical experiments for explaining processes of metamorphosis within the body. Yet, despite his obsession with chemistry, Prout was remarkably sober in realizing that urinary diseases could not easily be cured by chemotherapy. "Instead of administering chemical, and perhaps harmful, remedies, Prout approached the bedside like an Hippocratic physician", stated Brock.[21] Chemistry could serve the needs of diagnosis, but must be carefully applied to therapy.

The second reason why Prout became well known within chemistry is due to a two-sided hypothesis resulting from elementary analysis. In two papers in the *Annals of Philosophy* (1815, 1816) he expressed the idea that first, hydrogen was the prime matter from which all known elements were constructed, and secondly, the atomic weights of all chemical elements are whole-number multiples of the atomic weight of hydrogen. Following Dalton's atom theory[22], "Prout's Hypothesis", as it was called later, was perhaps his most widely known contribution to chemistry. It stimulated discussion and forced interest in the determination of accurate atomic weights. I will not go into this story in more detail. After 1816, Prout did not follow this line of research. Instead of testing the validity of the multiple weights and his hypotheses, he devoted all of his research to the composition of organic substances, questions "which I was exceedingly anxious to verify"[23], and which interested him much more in order to learn something about the laws of organic matter and transformations.

Digestion and the *simple alimentary substances*

Between the years 1815 and 1823, Prout devoted much of his attention to the chemical processes during digestion. In a pure chemical sense, one of his main contributions to this subject was the discovery of hydrochloric acid in the gastric juice, which took place in the year 1823. The starting point of his interest in digestion, however, had been an *Inquiry into the Origin and*

[21] Ibid., p. 32.

[22] When Dalton announced his theory in 1807, all chemists believed that matter was made up of minute particles, but all of them were thought to be of the same stuff. Dalton, however, suggested that each element had atoms irreducibly different from those of other elements. Thus, elements combined atoms in definite simple and multiple proportions. As we shall see, in regard to organic substances, Prout did not believe in the ultimate nature of the so-called elements, so that organic transmutations could take place.

[23] As he wrote in 1822, quoted in BROCK, *From Protyle to Proton...*, p. 109.

Properties of the Blood, an investigation that was published in 1816. In this paper about "sanguification" he explains that "blood begins to be transformed, or developed from food, in all its parts from the first moment of its entrance into the duodenum, or even, perhaps, from the first moment of digestion, and that it gradually becomes more perfect as it passes through the different stages to which it is subjected, till its formation be completed in the sanguiferous tubes, when it represents an aqueous solution of the principal textures and other parts of the animal body."[24]

With the problem of "sanguification" Prout referred to a centuries-old question of medical practice and physiological theory. Since antiquity, digestion and the sanguification of food stood at the centre of basic theories about the human or animal physiology.[25] Today the term "digestion" refers only to the functions of the alimentary canal. Up to the beginning of the 19th century, however, it was a much broader term, implying all stages of blood formation and carrying away substances that were no longer needed by the body. Sometimes even the bodily secretions were included in this basic process of bodily fluids and matter transformation, a view that is important in order to understand what Prout meant about milk (as will be shown later).

The whole process of blood formation started with a sufficient appetite, a sure signal that the previous meal had been completely processed. The next stage was the chewing of the food in the mouth, a first step in breaking down the food and lubricating it for easy passage through the throat. Then, the food would enter the stomach, where it is pulverized, sufficiently moistened and transformed into chyme, a thickly creamy fluid. According to the Hippocratic corpus and Galenic theory, after this process had been completed "concoction" begins, which means that the food will be cooked by the inherent animal heat and putrefied. Since the late 17th century, chemical interpretations that saw powerful acids at work and interpreted the process in terms of fermentation, dissolution or sublimation, more and more superseded the idea of concoction. But these iatrochemical explanations of digestion came into conflict with the merely mechanical explanations of the Cartesian physiology that described the stomach as a hollow muscle that kneads the food particles and finally dissolves them by the force of moving fibers. Thus, since the beginning of the eighteenth century, there had been a debate about the relation of chemical and mechanical processes during digestion. Although many physicians preferred

[24] William PROUT, "Inquiry into the Origins and Properties of Blood" in *Annals of Medicine and Surgery* (1816) 1, p. 20.

[25] See DEBUS, *Chemistry and Medical Debate...*, Ken ALBALA, *Eating right in the Renaissance* (Berkeley/Los Angeles: 2002), pp. 54-62; Sir Michael FOSTER, The Physiology of Digestion in the Eighteenth Century, in Sir Michael FOSTER, *Lectures on the History of Physiology during the Sixteenth, Seventeenth and Eighteenth Centuries* (New York, 1970), pp. 200-223.

the Cartesian view of motions, fluids and solids, influential medical chemists like Hermann von Boerhaave took up the cudgels for chemistry.[26]

When Prout started his work, this debate was by no means finally settled. This becomes quite clear if one reads the irritated comments of the culinary expert Jean Anthelme Brillat-Savarin, who wrote in 1825: "The manner in which digestion operates in the stomach, whether by concoction, maturation, fermentation, or gastric, chemical, or vital dissolution, has been the subject of prolonged and heated discussion."[27] To him, some of the things in all these physical processes happen and the mistake, he stated, lies in seeking a single attribute or agent. But Prout, in contrast, was an obsessive chemist who believed that chemistry in the hand of the physician can "prove one of the most powerful instruments he can possess."[28] Hence, he was interested to review the whole process of digestion and blood formation, which in regard to the standard theory he divided into four parts: digestion (confined to the stomach), chymification (confined to the duodenum), chylification (confined to the lacteals) and sanguification proper (confined to the blood vessels).

Each of the four stages became the object of intensive study. Prout extracted the contents of the gastrointestinal tracts of several animals (e.g. dogs, rabbits, pigeons, an ox) from different parts and at different times after feeding. Because of the heterogeneous character of the fluids, he subdivided them into different juices and substances. Then he analyzed their composition in order to find any traces of the contents of the blood. The comparative analyses of the contents of the duodenum, caecum, colon and rectum confirmed the presence of "incipient albumen", so that Prout concluded that the infinite diversity visible in the composition of organic bodies is not due to an infinite variety of different substances, but to the modifications of a few primary substances.

Although his results were "distinctly odd", as Brock characterized them, Prout nevertheless believed in the pure and simply chemical character of the matter transformations going on during digestion. Chemists were able to study the reactions of bodily fluids outside the body and the substances deriving from that process. Prout admitted as evidence that some of the bodily changes, e.g. the precipitation of the stomach content with a portion of bile of the same animal, could be reproduced under laboratory conditions. And when, in 1823, he demonstrated that there was a considerable

[26] See Barbara ORLAND, "The fluid mechanics of nutrition. Herman Boerhaave's synthesis of circulation physiology", in Barbara ORLAND, Emma C. SPARY (eds.), "Assimilating knowledge. Food and Nutrition in Early Modern Physiologies", Special Issue of *Studies in History and Philosophy of the Sciences* 4 (2011) forthcoming.

[27] Jean Anthelme BRILLAT-SAVARIN, *The Physiology of Taste* (Toronto, Ontario, 2004), p. 178.

[28] PROUT, Inquiry into the Origins, p. 12.

amount of unsaturated hydrochloric acid in the stomach of several animals, he became even more confident about the chemical character of digestion.[29] Examinations of fluids ejected from patients with dyspepsia confirmed its presence in man.

On the other hand, however, this did not mean that chemists could explore every detail of what is going on inside the body. For instance, in regard to the fourth stage of actual sanguification, Prout was persuaded that Lavoisier was right in suggesting a relation between the assimilation of food and the process of respiration, and that animal heat was an important factor. Prout also believed that one function of respiration was to convert chyle into blood by the removal of unwanted carbon. But what happened in detail remained unclear. Therefore, Prout thought that "from the vital character of the processes, we shall probably ever remain ignorant of their precise nature."[30] Already in 1822 Prout had collected so much material that he decided to write a book on digestion to be called *Observations on the Functions of the Digestive Organs, especially those of the Stomach and the Liver; with Practical Remarks on the Treatment of some of the Diseases to which these Organs are Liable.* Although this book was never published, much of its content went into another book in 1834, to which I will refer later. Instead, Prout directed his attention back to urinary diseases; for him diabetes was a main urinary disease.[31]

Another paper on organic analysis, for which he won the Copley Medal of the Royal Society, was published in 1827. It was announced to be the first of three papers dedicated to the fundamental alimentary principles: the saccharine, the oily and the albuminous. However, only this first essay appeared about what Prout called the saccharinous principle. In this paper, it becomes clearer that Prout was a chemist, believing in the technical character of digestion, and at the same time a vitalist, believing in vital principles or agents that could not be explored by chemistry. The intention of the paper was to introduce the exact composition of three basic principles "in which the alimentary matters employed by the more perfect animals can be comprehended" and to give "some preliminary observations on the analysis of organized bodies".[32] Thus, the task was two-fold: on the one hand, the author wanted to discuss

[29] At this time, several other scientists in France and Germany were engaged in similar stomach analyses. In 1824, Friedrich Tiedemann and Leopold Gmelin independently confirmed the presence of hydrochloric acid in the stomach. See Leopold GMELIN, "On the nature of acid and saline matters usually existing in the stomachs of animals", *Philosophical Transactions of the Royal Society of London.* Series B, 114 (1824), pp. 45-49.

[30] PROUT 1819, quoted in BROCK, *From Protyle to Proton...*, p. 113.

[31] The second and revised edition of his book on this subject was released in 1825. William PROUT, *An Inquiry into the Nature and Treatment of Diabetes, Calculus and other Affections of the Urinary Organs* (2nd ed., London, 1825).

[32] William PROUT, "On the Ultimate Analysis of Simple Alimentary Substances; With some Preliminary Remarks on the Analysis of Organic Bodies in General", *Abstracts of the Papers Printed in the Philosophical Transactions of the Royal Society of London*, vol. 2 (1815 – 1830), pp. 324-326.

the validity of organic experimentation, and on the other, some basic results deriving from experiments were to be devised theoretically. In the long term, however, *On the Ultimate Analysis of Simple Alimentary Substances* became famous only in regard to its theoretical statements. Generations of nutritionists have traced back the term "nutrient" to this paper.

In any case, Prout introduced for the first time his theory of digestion related to what he called "the simple alimentary substances". As mentioned before, Prout believed in the existence of "essential principles" in the composition of organic bodies. Since his early analyses of urine he constantly repeated that urea nitrate (a crystalline derivate from urine), table sugar, sugar of milk, and diabetic sugar (existing in the blood and urine of persons suffering from diabetes) showed so few differences that one could think of just one primary and simple saccharine principle. Now, in this paper he went further and declared that all those substances in which hydrogen and oxygen unite are all alimentary, or capable of becoming so, and that they are chiefly derived from the vegetable kingdom. Therefore he named all saccharine substances "vegetable aliments". All sugars, but also starch (as a merorganized sugar) or amylaceous bodies, vinegar, lignin or woody fibre were grouped under this name.

Because both other classes of bodies, the oily and the albuminous, are not considered in this paper (and the announced essays on them not published), I now turn my attention to Prout's publication of 1834, in which these arguments are further developed.[33] In the chapter headed "Alimentary Substances" Prout once again talks about the infinite diversity of aliments in nature. He now describes it as "the system of universal voracity", because the more perfect animals are not only able to consume materials from the vegetable kingdom but animals can also be food for each other. Due to his techniques, the chemist is able to show that organized matters, however apparently dissimilar, are often nearly related. Beside the saccharine group, he now explains the character of the oleaginous and albuminous bodies as the two other classes of alimentary substances. Oleaginous bodies, existing in both the vegetable and animal kingdom, are very easy to detect. Although occurring in an infinite variety of forms, they are all composed of olefiant gas (a heavy hydrogen gas discovered in 1796) and water, or have a reference to that composition. Much more complicated is the case of albuminous matters, he went on. They only can be found after boiling any part of the animal body in water. Then one always finds two portions, one soluble in water, and forming together with the water a jelly or gelatinous matter, the other remains insoluble, indeed becomes harder the longer it is boiled. From the identity of its composition, this hard matter is quite similar to the white of an egg. Therefore it is named

[33] William PROUT, *Chemistry, Meteorology and the Function of Digestion Considered with Preference to Natural Theology* (London, 1834).

albumen, and because it exists only in the flesh and blood of animals, it belongs to the animal kingdom. "Such are the three great staminal principles from which all organized bodies are essentially constituted."[34]

The distinction of these three classes of bodily substances was by no means new. Many animal chemists from the late 18th century were engaged in classifying what were called immediate principles of plant or animal bodies, and oily, fatty and albuminous compounds belonged to them.[35] New, however, was their definition as alimentary substances. But why did Prout correlate his findings with nutrition and food? The answer can be found in his "system of universal voracity". This is, as one reviewer of Prout's work perfectly stated in 1840, a kind of universal "machinery of digestion".[36] And in fact, it was his physiological theory of digestion that led Prout to rethink his chemical findings about the organization of the animal body in regard to the problem of nutrition. The essence of his "system of universal voracity" was that all lower organisms convert those elements denominated by him as "essential" into certain substances, which are reducible to a few "proximate principles". The organisms higher than these, by preying on those below them in the scale of life, find a material already assimilated to that of their own structure. (Plants, for instance, have already assimilated carbonic acid gas). Therefore, "the more perfect animals are exonerated from the toil of the initial assimilation of the materials composing their frame (...) Hence the assimilating organs do not require that complication, which they otherwise would have needed."[37]

That these are highly speculative assertions is rather obvious. But Prout went even further and explained not only the relation of the two kingdoms of the vegetable and the animal in terms of digestion. In this "beautiful arrangement in the mode of nutrition" the lower organisms were generally speaking a kind of staple food for the wants of the higher, and with such material the existence of a greater number of animals and a greater variety among them becomes possible. In other words, the "system of universal voracity" was a kind of master technology in the economy of nature. It allowed nature to cultivate diversity, although the system was based only on very few staminal principles. These were capable of readily passing into one another and susceptible to transmutation into new principles under certain laws (for instance, the saccharine principle is readily convertible into acid, or, under certain circumstances, into a modification of the oleaginous principle – alcohol). One important consequence of higher animals feeding on the lower is therefore

[34] PROUT, *Chemistry, Meteorology...*, p. 475.

[35] To the simple substances in organic chemistry of the 18th century see Ursula KLEIN, Wolfgang LEFEVRE, *Materials in eighteenth-century science: a historical ontology* (Chicago, 2007), pp. 127-134.

[36] *The Museum of Foreign Literature, Science and Art*, vol. XI, new series, May to August 1840, (Philadelphia, 1840), p. 311.

[37] PROUT, *Chemistry, Meteorology...*, p. 471.

that their food must consist of one or more of the staminal principles. "A diet, to be complete, must contain more or less of all the three."[38]

Milk and Natural Theology

Before completing the story, let me first say some words about the origin of this book. Prout was one of eight authors chosen by the Royal Society of London to receive £8,000 awarded by the Earl of Bridgewater to write a book, in which "the Power, Wisdom and Goodness of God as manifested in the Creation" is illustrated.[39] Maybe in respect to the wishes of the donor, maybe because he himself was a deeply religious man[40], in any case, in the Bridgewater Treatise Prout presented himself as a natural theologician and his theory of digestion for the first time as a subject of God's design. Chemistry, as he points out in the introduction, could be perfectly explained with the argument of design, because it "is a branch of knowledge founded solely on experience, for the phenomena of which we can assign no reason."[41] What the chemist can experience about the changes in the composition of bodies is, first, changes in weight as a modification of force, secondly, the subservience of those mechanical contrivances and operations everywhere existing in organized beings, and thirdly, "the laws of nature" that devise "all the beautiful adjustments and adaptions of noxious and conflicting elements most wonderfully conspiring together for good."[42] Thus, chemistry forms the connecting link between those branches of knowledge, which are founded on quantity, and those that are derived solely from experience. Physiology in most parts, however, is removed from the logic of quantity, and instead depends entirely on observation. Thus, the animal chemist can sometimes say, what must be, and more often, what may be. That is to say, the degree of probability leads to the beautiful design of a God who restricted his power through easily recognizable laws of nature.[43]

It is important to note that it is only in his introductory chapters, where he developed a highly speculative molecular theory of matter, that Prout referred to the design argument. In the actual discussion of the phenomena

[38] Ibid., p. 477.

[39] Quoted in BROCK, *From Protyle to Proto...n*, p. 61.

[40] Brock argues that there is no reason to doubt Prout's religious sincerity. Others, like John Tyndall, however did. See BROCK, *From Protyle to Proton...*, p. 64.

[41] PROUT, *Chemistry, Meteorology...*, p. 10.

[42] PROUT, *Chemistry, Meteorology...*, p. 14.

[43] Of course and as mentioned above, Prout, like his contemporaries, believed in the difference of organized beings from inorganic materials. In general, he explained such differences by a principle of organization, a vital force and so on. But, like the argument of design, this was not meant as a ponderable entity but envisioned as a general cause of life and organization. Against this background, the animal chemist could explore the activities of this vital agency.

of digestion, all theological arguments are mainly dismissed. Here, the rhetoric is far more but not strictly that of a textbook. In general, the Bridgewater Treatises were addressing a public desire for self-education and willingness to learn more or less abstract facts of the scientific enterprise. Thus, it was much more a liberal study or popularization. And, as David Knight has put it, in this context natural theology served as a powerful vehicle.[44]

If the considerations about digestion left theology behind, there existed, however, one important exception, the issue of milk. Prout was led to take his comprehensive view of the essence of aliment by reflecting on the composition of milk. In connection with his paper from 1827 he already noticed: "Observing that milk, the only article actually furnished and intended by nature as food, was essentially composed of three ingredients, viz. Saccharine, oily, and curdy, or albuminous matter, I was by degrees led to the conclusion that all the alimentary matters employed by man and the more perfect animals, might, in fact, be reduced to the same three general heads; hence I determined to submit them to a rigorous examination in the first place, and ascertain, if possible, their general relations and analogies."[45]

In the Bridgewater Treatise he further developed this argument by remarking that all other foods of animals exist for themselves. Only milk and the apparatus by which milk is secreted "were designed, and made what they are, by the great Creator of the universe; and on no other supposition, can their existence be explained."[46] Every known kind of milk is a mixture of the three staminal principles. "In milk, therefore, we should expect to find a model of what an alimentary substance ought to be – a kind of prototype, as it were, of nutritious materials in general."[47] Man, dissatisfied with the spontaneous productions of nature, has instinctively copied Nature's great model in his cookery. He always formed in every possible manner, and even in the utmost refinements of his luxury, this great alimentary compound by adding oil or butter to bread, or by combining sugar, eggs and butter.

At this point, the issue of digestion strikes another note, and the author suddenly speaks tartly to his readers. Referring to the many dyspeptic beings that pass half of their days in misery, Prout advises them to listen to reason: "Providence has gifted man with reason; to his reason, therefore, is left the choice of food and drink, and not to instinct, as among the lower animals: it thus becomes his duty to apply his reason to that object; to shun excess in quantity,

[44] David KNIGHT, "Communicating Chemistry: The Frontier between Popular Books and Textbooks in Britain during the First Half of the Nineteenth Century" in Bernadette BENSAUDE-VINCENT, Anders LUNDGREN (eds.), *Communicating Chemistry. Textbooks and their Audiences, 1789 – 1939* (Canton, MA, 2000), p. 196.

[45] The issue of milk was to have been explained in his unpublished book on digestion. John Elliotson instead quoted Prout's explanation in 1828. BROCK, *From Protyle to Proton...*, p. 57.

[46] PROUT, *Chemistry, Meteorology...*, p. 479.

[47] Ibid., p. 478.

and what is noxious in quality; to adhere, in short, to the simple and the natural; among which the bounty of his Maker has afforded him an ample selection; and beyond which he deviates, sooner or later, he will suffer the penalty."[48]

Postscript

Prout's presumptions about the nutritious value of milk rapidly ascended to a kind of universal rule of a healthy nutrition. Already the reviewer of the Bridgewater Treatise understood the message quite well that milk should have a prominent place on the table. One has to bear in mind that this argument, contrary to hypotheses of the alimentary principles, could be easily integrated into the old framework of a dietary regime according to digestion. Milk is naturally fitted for the purposes of the animal economy, without undergoing any essential change in its composition. Therefore, it can be easily assimilated in the body, was the argument.[49] Dietary Regimes and considerations about defective nourishment of that time even discussed foods and not nutrients. In this manner, Prout's argument merged with the enlightened view that maternal breast-feeding implemented nature's plan for mother and child.[50] Work on the definition of the constituents of milk, on the other hand, went on and emerged along with the establishment of nutritional sciences and milk chemistry from about the 1840s. Nutrient norms, in the sense of standardized definitions of milk constituents, however, remained a highly controversial field of scientific, technical, commercial and legal negotiations. Not until the first International Food Congress in Geneva in 1908 did the different parties involved come to an official definition of the composition of milk.[51]

The connection between milk and natural theology found its recipients, too. During the 19th century, evolutionists took over the argument that milk is the universal food of the world, "a product of Reproduction"[52], as well as religious authors and historians, who more and more mentioned that because man is a mammal, milk has been universally used throughout history.[53] In

[48] Ibid., p. 510.

[49] See *Penny Cyclopaedia of the Society for the Diffusion of Useful Knowledge*, Vol. XV (Massage – Murid, London, 1839), p. 218.

[50] See Barbara ORLAND, "Wissenschaft, Markt und Erfahrung. 'Natürliche' versus 'künstliche' Säuglingsernährung im 19. Jahrhundert", in Marguérite BOS et al. (eds.), *Erfahrung: Alles nur Diskurs? Zur Verwendung des Erfahrungsbegriffes in der Geschlechtergeschichte* (Zürich, 2004), pp. 291-306.

[51] More on scientific trials to explore and police the material quality of milk can be found in Peter ATKINS, *Liquid materialities: a history of milk, science and the law*, Critical Food Studies (Farnham, Surrey, Burlington, 2010).

[52] Henry DRUMMOND, *The Lowell Lectures on the Ascent of Man* (Whitefish, MT, 2004 [1st ed., New York, 1894]), p. 131.

[53] James HASTINGS, *Encyclopedia of Religion and Ethics* (New York/Edinburgh, 1916), p. 635.

the first instance, however, the argument of milk as the universal food of humankind was willingly embraced by the modern milk industry that rapidly developed after the middle of the 19th century.[54] Milk reformers and milk traders altered the natural theological argument into the industrial vision of completeness. The physical properties of milk, its full content of all important nutrients, was modeled into the "Story of Nature's Perfect Food" and as such was advertised to the modern, scientifically informed consumer. Milk, as Melanie DuPuis put it, stood at the basis of the urban reformer's dream to reunite a populace with its "natural" diet, designed by God.[55] And in fact, the consumption of this "perfect" food became a major food habit of modern industrialized societies.

Prout's second claim, that is the view of the living being as "a laboratory, within which a number of chemical operations are conducted"[56] from which man can learn how to improve human nutrition, became true too. Still in his lifetime a growing number of chemists, among them Jean Baptiste Boussingault, Jean Baptiste Dumas, Gerrit Mulder, Justus von Liebig, took up the question, developed more sophisticated laboratory technologies and confirmed the presence of specific nutritious substances.[57] Now, these substances became targets for quantitative study. Within a few decades, publications galore from all over Europe appeared, seeming to consist of little more than endless tables of percentages. Compositional formulas were given, based on the data, and, although there was little certainty about the meaning of these results, the body – food interface was more and more modeled as an input-output system.

To mention just one book, in 1842 Justus von Liebig published his "Animal Chemistry".[58] In this extremely influential book he grouped foods according to their chemical content and function. Liebig, who disliked Prout and therefore did not quote him, described albuminous or nitrogenous foods as "plastic" and considered them as the muscle material that provides growth, motion and power. All the non-nitrogenous foods were denominated as "respiratory" foods, which meant that their breakdown maintained the body temperature. As we know, Liebig began to teach that the "plastic" and the "fuel" constituents of foods represented the essentials of a nutritionally

[54] See ATKINS, *Liquid materialities...*; Barbara ORLAND, "Milky Ways. Dairy, Landscape and Nation Building until 1930" in Carmen SARASUA, Peter SCHOLLIERS (eds.): *Land, Shops and Kitchens. Agriculture and Technology in Historical Perspective,* Comparative Rural History of the North Sea Area, vol. 6 (Turnhout, 2005), pp. 212-254.

[55] See Melanie DUPUIS, *Nature's Perfect Food. How Milk became America's Drink* (New York/London, 2002).

[56] PROUT, *Chemistry, Meteorology...*, p. 414.

[57] See Harmke KAMMINGA, Andrew CUNNINGHAM (eds.), *The Science and Culture of Nutrition, 1840-1940* (Amsterdam, 1995).

[58] Justus von LIEBIG, *Animal chemistry, or, Organic chemistry in its applications to physiology and pathology* (London, 1842).

adequate diet. However, even Liebig did not use the term "nutrient" and he also spoke of "metamorphism" instead of "metabolism" to describe the matter transformations going on within the body. Not before the 1860s were these terms established. As far as I know, Theodor Bischoff and Carl Voit were the first who presented a full definition of the term "nutrient" in the modern sense.[59]

Nevertheless, the idea of chemically defined alimentary substances was very influential among physicians. Up to 1840, the common sense approach to diet and nutrition related to the mechanics of digestion remained dominant. The results of experimental physiology and chemistry did not influence the physician's opinions about the right diet. But then, one can clearly determine the growing influence of chemistry in physicians' dietary instructions. In this respect, Jonathan Pereira's *Treatise on food and diet* of 1843 marks a turning point in the medical views on diet. Pereira, a physician of the London Hospital engaged in the reform of the diets of the public houses, included a chapter on scientific investigations. As he pointed out, this was "rendered necessary by the discussions which have been going on, for many months past in the public journals and elsewhere, respecting the amount of food proper to be supplied to paupers, prisoners and others. The subject has in this way forced itself on the attention of all grades of society; and professional men and others must have long felt the want of a work giving an account of the dietaries in use in Public Establishments..."[60]

As I argued at the beginning, today's performative image of nutrients epitomized as providing health substances directs the attention to processes of inscriptions. Pereira's statement, as just one among many others, clearly gives an idea of why the concept of alimentary substances or nutrients became so influential. The science of eating fitted with the needs of public health reformers to manage pauperism. On the other hand, the message addressed to the bourgeois audience was slightly different. In this respect, magazines reporting on progress in chemical research promoted modernity. In the face of scientific progress, the old fashioned practices of eating and drinking seemed to be incorrect. "If the viands have been savoury and easy of assimilation, the theories as to the choice and action of them have been singularly crude and undigested", wrote one reviewer of Liebig's *Animal Chemistry* in 1848, who also mentioned Prout's work.[61] Ignorance of true principles produces diseases; sentiments, smell, taste or the appearance of food are not good guides. The author reflected on the new findings of science, and went on to claim that the same could be said for appetite. This, too, seemed to be

[59] Theodor L. W. BISCHOFF, Carl VOIT, *Die Gesetze der Ernährung des Fleischfressers durch neue Untersuchungen festgestellt* (Leipzig/Heidelberg, 1860).

[60] Jonathan PEREIRA, *A Treatise on Food and Diet* (New York, 1843), preface.

[61] *The Dublin Review*, Vol. XXV, Sept. and Dec. 1848 (London, 1848), p. 179.

no longer a guide to the healthfulness of foods. Like the early modern maxim "you should eat what you are" (which meant that the temperance and complexion of body and food were related) appetite lost its significance. Instead, people should learn to distinguish the proximate principles of animal and vegetable substances.