

## Historical Background: Nutrition

### Introduction

As an emerging branch of science, trophology explores the means and effects of combining foods for maintaining a balanced nutrition and avoiding metabolic diseases. Even with the concern about the adequacy of one's diet in terms of vitamins, proteins, starch, fruit and carbohydrates, nutrition must be understood beyond eating as a necessity.

The roots of trophology, as a science, lie in historic scientific and sociological accomplishments. Initially, the key experiments to verify the links among consumption, energy, and work were conducted within the context of the sociological turmoil of the Industrial Revolution, a time when humans were seen as a resource or, perhaps, more precisely, as living machines. The consequences of industrialization with its new innovations during the late 18<sup>th</sup> and early 19<sup>th</sup> century in Europe and North America, such as the mechanization of textile manufacturing, forced countries to employ more workers to manage the increased workload. The challenge of converting raw material and supplies into new goods was coupled with that of providing suitable nourishment for the rising number of workers.

The groundwork for determining the mathematical relationship between raw materials and products and between food consumption and workload was laid by Hermann von Helmholtz (Helmholtz, 1915)<sup>1</sup> in 1847 in his formulation of the law of the conservation of energy—the belief that every physical force stood in equilibrium with an equivalent counter-force. In terms of physiology, the laws of energy conservation and energy conversion stand next to the experiments of Max Rubner who measured the energy converted from food into heat and mechanical work (Rubner, 1902). Several other scientists worked on a theory of nutrition and work to enhance human performance in industry and the military. Of equal importance was prevalence and cause of diseases and the need for cures, which had not yet been assimilated into a theory of trophology. The two most common deficiency diseases were beriberi (a word derived from the language of Polynesian natives meaning “I can't move, I can't move”) and scurvy, an illness well known to seamen. It took researchers until 1912 to uncover the nutritional component the vitamin—the “vital amin”—the lack of which was the cause of both diseases.

### Consumption

The well-known adage “No army can march on an empty stomach” illustrates the equilibrium between food consumption and work, but not, necessarily, the work typical for a soldier. Ancient sources written by Roman quartermasters around 100 AD reveal that Roman legionnaires lived on an average ration of some 850 grams of grain per day, complemented by meat, vegetables, and fruit (Roth 1995). The figures for the amount of food transported by the Macedonian troops of Alexander II, in his 13-year campaign against the

Persian Empire four centuries earlier, equate to comparable rations (Hanson 1999, pp. 165 ff.).

The accounts originating in the civilian life of Egyptian workers in Mesopotamia show a monthly ration of three bar of grain, resulting in an average of 700 grams of flour per worker per day (Huber 2006, pp. 303 – 330). Considering their work was possibly not as strenuous as that of the Macedonian or Roman infantry soldier, the figures, covering a time span from 1000 BC to 100 AD produce a reliable average of the daily nourishment requirement. The records all show that grain and meat were the basis of the daily diet of the workers.



Hermann von Helmholtz (1821 – 1894)



Max Rubner (1854 – 1932)

## Work and Feeding the Poor

Benjamin Thompson (1753 – 1814), known as Count Rumford after 1792,<sup>1</sup> was an American-born British officer who had fought on the British side during the American War of Independence. After gathering both political and military experience in England's struggle with its renegade colonies, he returned to England in 1782.<sup>2</sup> Put on half-pay, he soon left England to search for a new position among the armies of Europe and did so in Bavaria, where the Prince-elector hired him to conduct reforms on both the military and the social system of his country. Thompson took his leave from the British Army, was granted knighthood for his services to the British crown, and took up his new post in Munich on March 11, 1784.

From 1784 to 1788, he worked on the reform program in Bavaria. He made an extensive investigation of the military and social systems of the two dominating countries in central Europe, Austria and Prussia, and compared the conditions and costs of the armed forces in these countries to those in Bavaria. In late 1788, he presented a reform program to the Elector of Bavaria. He stressed three particular aims to guide the reforms:

1. to end the discrimination and exclusion of the soldier as a professional,
2. to increase the number of troops hired and raise the wages paid to every soldier without raising the annual budget of the Bavarian Army, and
3. to permit the armed forces to serve in a civilian capacity in peacetime.

The second and third aims, especially, led to Thompson's major contribution in terms of feeding the masses. Since he proposed not to increase the budget of the Bavarian army while increasing the number of troops and their wages, he had to find a means to reduce costs. The first measure was to lower the costs of the soldiers' uniforms by employing Munich's beggars in the recently founded *militärisches Arbeitshaus* (military workhouse). His plan also tackled the beggar problem by educating the beggars and encouraging them to become independent and make a living.<sup>3</sup>

<sup>1</sup> Thompson's title Count Rumford refers to the American town in New Hampshire where he married his first wife. The town is called Concord today (see Bouton 1857).

<sup>2</sup> Thompson served as *Under-Secretary of State for the Colonies* until 1781 and as Colonel of the King's American Dragoons until this regiment was withdrawn to England.

<sup>3</sup> Rumford accounted that 7% of the inhabitants of Munich made a living from begging in the streets even though a large number of those beggars were obviously sane and able to work (see Möhl 1903, p.33).

## Suppe No. II.

Zutaten	Gewicht	Kostenbetrag	
	lb	£.	Rth. gr. pf.
2 Viertel Perlgräupen	70	18	1 16 9
2 Viertel Erbsen	65	20	1 5 3
8 Viertel Kartoffeln	230	8	— 14 9
Brotstücke	69	20	3 9 6
Salz	19	26	— 10 3
Weinessig	46	26	— 12 7
Wasser	982	30	— — —
<b>Summe d. Gewichts</b>	<b>14851</b>	<b>20</b>	
Für Brennholz, Mägde und Bedienten, Reparaturen	—	—	1 3 9
<b>Summe der täglichen Ausgabe, wenn 1200 Menschen befestigt sind:</b>			9 1 10

Die obige Summe (9 Rthlr. 1 gr. 10) mit 1200, als der Zahl der vertheilten Suppenportionen, dividiert, beträgt für jede Portion ungefähr 2 Pfennige.

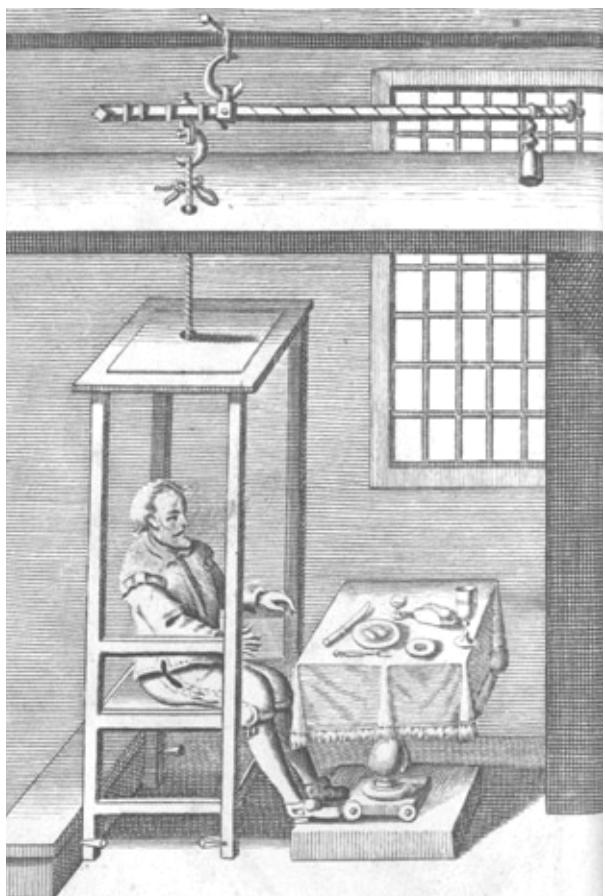
Figure 1: Original recipe of Rumford Soup No. 2. The first refinement made was to substitute parts of the barley with potatoes. The soup became considerably cheaper by the use of potatoes.

Attached to the workhouse was a soup kitchen, which soon became the key facility of the workhouse. Thompson figured out that he could prepare a meal for all the workers that would cost less than any individual would spend to nourish himself. The workers received a free lunch in the soup kitchen consisting of 20 ounces of soup. Thompson developed and published various recipes to prepare as much as 1200 portions of soup at one time, which became known as "Rumford soup." Initially, it was a mixture of pearl barley, peas, salt, vinegar, and water, but later it was refined with the addition of potatoes and sliced bread.<sup>4</sup>

Even though it provided a sound basis of carbohydrates (from the potatoes and the barley) and protein (from the peas), there was, however, some criticism about the Rumford soup. While it had a highly filling effect on the consumers, it did not nourish them well – at least not the adults. Today's calculations indicate that the first version of Rumford soup provided 570 calories, and the second version, with the substitution of potatoes for some of the pearl barley, provided only 420 calories.<sup>5</sup> Considering, by modern standards, that the

<sup>4</sup> The publication of the recipe included the cost for the fuel used in the kitchen and the wages of the cook and the clerks who served the soup to the recipients (Thompson 1804, pp. 274 & 276).

<sup>5</sup> Families were encouraged to bring their children to the military workhouse, where they could attend school and



**Figure 2:** Santorio Santorio in his weighing chair

adult daily intake should be approximately 2000 calories, it is evident that the Rumford soups were efficient only in feeding someone at a low cost but not in meeting the daily nutritional requirement, especially for a solid day's work in the military workhouse. In this respect, it failed to fulfill Rumford's plan to nourish his workers. Welfare organizations, however, adopted the Rumford soup recipe and used it to support homeless people and those unable to work during the Napoleon wars.<sup>6</sup>

### Balancing Input and Output

Santorio Santorio (1561 – 1636) was an Italian physician who published his treatise *Ars de statica medicina* in 1614. The book deals mainly with research on human metabolism and was, in part, based on experiments Santorio conducted on himself. On the opening page of his book, one finds an illustration of the ex-

help with minor tasks if they wanted to do so (see Redlich 1971, pp. 184 – 216).

<sup>6</sup> Today, a broad variety of "Rumford's soups" exist whose recipes may not have much in common with the soups originally devised by Thompson for use in the soup kitchens of the workhouses.

perimental setup used. It shows Santorio sitting on a scale (a so-called weighing chair) and a table with cutlery and dishes next to him. Over a period of some 30 years, he documented the weight of what he ate and drank (*ingesta*), as well as the excrement (*excreta*), and accounted for the difference between those two as *insensible perspiration* (Toellner 2000, p. 2371). He found out that the "weight" of the insensible perspiration—2.5 pounds per day on average—was greater than one of his excrements. Santorio accounted for a number of factors such as illness, age, physical activity, nourishment, and sleep, which could increase or decrease the insensible perspiration. Additionally, he invented measurement devices to determine pulse and body temperature. His findings are the first results from a long-term study on human metabolism.

### Energy in Combustion

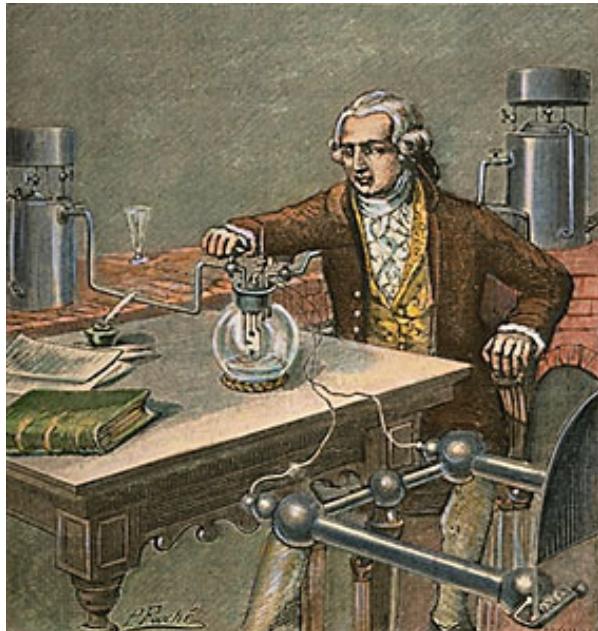
Whereas Santorio concentrated on the *weight* of the nourishment he consumed, French scientist Antoine Laurent de Lavoisier (1743 – 1794) focused on *heat and combustion*.<sup>7</sup> The definition of heat was still driven by the ideas of the phlogiston theory. Although this theory was subsequently abandoned in Lavoisier's time, Lavoisier, himself, contributed a major part to this scientific revolution. He strongly believed in the fact that mass was conserved in chemical reactions, an idea originating from the scientific endeavors of the Enlightenment. The idea of mass conservation was the key to one of his most important findings in chemistry, namely, oxidation.

Lavoisier realized that when a metal became rusty, the mass of the calcified metal ("calx", usually weighed in powdered form) had a greater weight than the original piece of metal. Lavoisier also found that the process could be reversed, that is, when the calx was reduced to the metal by heating, its weight decreased. The phlogiston theory could not explain these changes of masses because heat, according to prevailing ideas, was an imponderable (weightless) element. Lavoisier developed the idea that the composition of air might be the key to the changes in mass and aligned his experiments with this theory.

The theory of combustion could not be further developed until Lavoisier and Priestley, a British chemist, combined their respective scientific findings. The two respected one another mutually even though they had different opinions on the nature of combustion.

<sup>7</sup> The Encyclopedia Britannica honors Lavoisier's accomplishments by calling him "Father of Modern Nutrition," online version

<http://www.britannica.com/EBchecked/topic/332700/Antoine-Laurent-Lavoisier>, dated March 21, 2012



**Figure 3:** Lavoisier experimenting to determine the composition of water. *Photograph*. Encyclopædia Britannica Online

Priestley's views were strongly related to the phlogiston theory, but he controlled his experimental environment better than Lavoisier. Priestley was keenly aware that the air produced during an experiment was different from normal air.<sup>8</sup> Lavoisier repeated the experiment of heating common red *precipitate* of mercury in the same manner as Priestley but paid closer attention to the gas produced in the process. Following his analysis, he found the difference between the experimental gas and fresh air, isolating the element involved in the calcification process and called it oxygen, referring to the Greek words for "making something sharp" (freely interpreted as "acid producer because of the sour taste of acids). Although Priestley had conducted the same experiment, he had not identified oxygen as an element; instead, he characterized the gas produced as "de-phlogistated air," strictly following the phlogiston theory. Lavoisier used his newly found knowledge to include oxygen as part of a chemical reaction and was able to extend his theory to the effects of calcination and combustion.

### Energy in Food

Today, the word calorie is synonymous with energy. Many products in modern supermarkets identify the contained energy in kilocalories and the amount of car-

bohydrates, fat, and protein in a diagram printed on the product's packing.<sup>9</sup>

The etymology of the word "caloric" goes back to the time of Lavoisier and the phlogiston theory when heat was considered to be an imponderable chemical element inherent in every body. The idea of heat as an element has been abandoned, but the word energy still reflects this very notion. It is an expression originating from the Greek language meaning "inherently affecting,"<sup>10</sup> which was introduced by William Rankine in 1853. Rankine defined energy as "a power to change in opposition to resistance." He, furthermore, distinguished between "actual or sensible" energy (e.g., energy of movement) and "potential or latent" energy (Rankine, 1853, pp. 109–117).

Mid-nineteenth-century science was intensely occupied with the necessity of workers acquiring energy for their work in factories. After von Helmholtz's publication on the conservation of the "living force,"<sup>11</sup> it seemed obvious working men had to convert their food into mechanical work and that these two sides of an equation, yet entirely unknown, should, nonetheless, be equal. The energy could seemingly be provided by any kind of food because some types of food were apparently able to substitute for one another. This was most convenient if one looked upon nourishment as a fuel that had to be converted into work, as the transformation process was now nothing more than the energy gain of a chemical reaction, independent of the nourishment in its physical form. In this way, the physiology could be understood by means of analytical chemistry.

The German physiologist and hygienist, Max Rubner, worked in the domain of thermodynamics for several decades and eventually presented experimental results by which he intended to prove the validity of the physical law of energy conservation for human or animal subjects. He defined heat as a measure for the intensity of life processes.

To support his idea, Rubner designed an experimental setup to control the products of the energy conversion processes in an animal's body. The animal calorimeter shown in the picture above was an isolated chamber into which a single dog was placed. This chamber was equipped with measurement devices for pressure and temperature and also for the proportions of oxygen and carbon dioxide in the chamber. The

<sup>9</sup> In 1860, Max Rubner declared that one calorie is the amount of energy needed to heat up one gram of water from 4 to 5 degrees centigrade (see Ziegler 1922, pp. 520 – 526).

<sup>10</sup> Duden, Fremdwörter, Eintrag Energie

<sup>11</sup> The term "living force" was then still used synonymously with today's "energy."

<sup>8</sup> Experiment conducted by Joseph Black in 1750 in which he discovered carbon dioxide.



**Figure 4:** Rubner's animal calorimeter on display during the exhibition "Energie = Arbeit" in Berlin 2010; photography made by Elke Jung-Wolff; reproduction by courtesy of Stiftung Brandenburger Tor, Berlin (Copyrights Stiftung Brandenburger Tor)

chamber offered little space for movement so that the dog could not waste his energy in floundering. The idea was that all the energy given to the animal by the food supply had to be turned into heat since conversion into mechanical work would not be possible. Rubner concluded that the entire energy contained in the food was eventually converted into heat (diet-induced thermogenesis).<sup>12</sup>

After the amount of energy stored in the carbohydrates, fat, and proteins had been determined, Rubner made efforts to distinguish between the ability of the human body to convert its energy into heat and mechanical work. The idea was to identify the substance which was least converted into heat because that would mean that the rest of the energy could be converted into mechanical work. He identified proteins as the substance where the heat-to-energy ratio was least favorable in terms of producing work from food. If one was a follower of the general idea of the industrial age with the human body at the intersection of energy, cost, and workload, this was very convenient. The major source

<sup>12</sup> Elizabeth Neswald, private communication



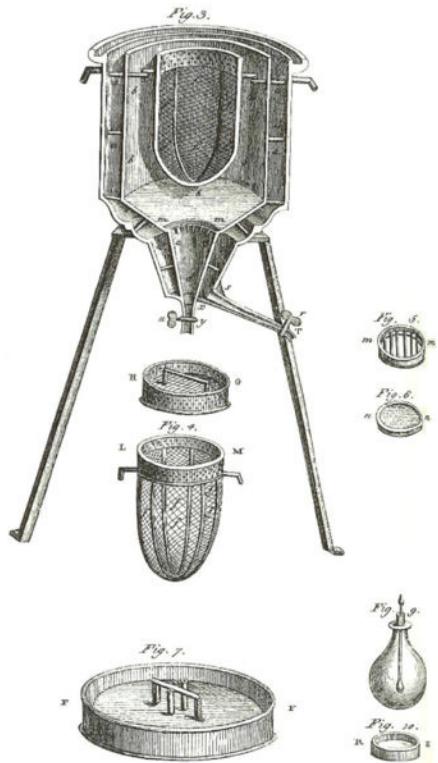
**Figure 5:** Commemorative stamp of Justus von Liebig, issued by the Bundespost (German Federal Postal Service) in 2003, Liebig's 200<sup>th</sup> birthday. Von Liebig is positioned between the Meat Extract, a precursor to today's instant soups, and the five-bulb device (formerly called Kali-Apparat, Potassium Apparatus), by which the amount of carbon within an unknown substance could be determined.

for proteins was meat, which was expensive compared to grain or potatoes, the latter being the major sources for carbohydrates (Rubner, 1902). Since workers should convert their food into work, it seemed obvious that meat was not necessary for a balanced diet. Consequently, meat, an expensive commodity, should be given as brain food only to persons who did intellectual work.

If one takes into account that at times the human body does not need energy for converting it into mechanical work, one would come to an alternate conclusion. The history of Liebig's meat extract shows that meat is not the perfect brain food, as such. In the mid1800s, chemistry professor Justus von Liebig became well known among the community of chemists. Most of the experiments he conducted were in the area of the new organic chemistry, a branch which scientists thought could not be studied outside of living organisms.<sup>13</sup> Investigators in organic chemistry were trying to determine the composition of almost any organic substance. Liebig invented an apparatus, called the five-bulb device, with which he could determine the amount of carbon in any organic substance.

He was, however, best known for his work on the physiology of animals and also on agricultural chemistry. Liebig's key assumption was that, in principle, the process of fat generation during digestion could be demonstrated entirely by means of laboratory chemistry. Although heavily debated during his lifetime, the assumption turned out to be correct; hence, Liebig was

<sup>13</sup> Friedrich Wöhler changed this in experiments between 1824 and 1828 when he synthesized the organic substances oxalic acid and carbamide.



**Figure 6:** Ice-calorimeter in the design of Laplace and Lavoisier (1780). Ice was filled into the partition wall to isolate the chamber from the laboratory environment and also into the main chamber (with the basket). The target containing or developing heat was placed in the basket and melted the ice. The amount of drained water was equivalent to the heat developed in the reaction.

the first scientist who successfully linked chemistry, physiology, and medicine.

His important contribution to the world of nutrition, Liebig's meat extract, was a byproduct of his attempt to help a friend overcome a serious illness. In 1853, Emma Muspratt, daughter of an English friend of Liebig's, suffered severely from typhoid fever during her stay in Munich, where Liebig had held a professorship since 1852. She was unable to eat, and her bowels were incapable of processing solid food. Liebig knew that there was no standard method to nourish someone suffering from typhoid fever and determined that the only way to nourish the patient would be by introducing a meat extract into her body. The extract was made by grinding chicken meat which was then placed into an aqueous solution of hydrochloric acid. After 12 hours, Liebig filtered the remains of the meat from the liquid that contained the protein almost intact. He then neutralized the acid and had Emma Muspratt drink it. She recovered within a short period of time (Judel 2003, pp. 6–15). Because the production of the extract was highly elaborate, the meat extract could not be turned

into a commercial success. It was, however, produced and sold by the Munich pharmacist von Pettenkofer as a remedy for sick persons who were unable to eat.

### Physical and Physiological Calorific Value

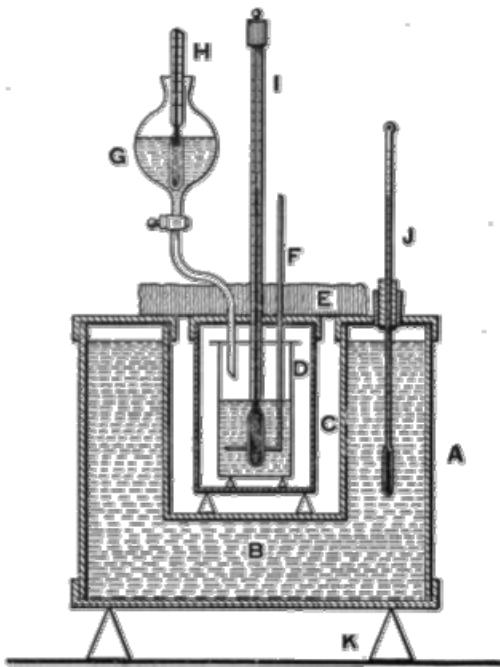
Knowing about the existence of oxygen was not sufficient for explaining the reasons for food components being combusted within the body, at least not until Antoine Lavoisier was able to design experiments in which he concluded that some form of combustion must take place within the human body.

The development of heat in chemical processes was the key point of interest to the French scientists Simon Laplace and Antoine Lavoisier. They invented the ice-calorimeter, a sophisticated device to determine the quantity of heat developed by an animal, or which was found latent in solid bodies (Laplace & Lavoisier 1780, p. 355). The heat was used to melt down ice, and the amount of water originating from the process was, in turn, equivalent to the amount of heat originating from the chemical reaction.

Together with his assistant, Armand Séguin, Lavoisier also conducted experiments on how inhaled air is changed by combustion during physical work. He devised an experimental setup where a test person would inhale atmospheric air by means of a full-face mask during the measurements. This mask was especially devised to lead the exhaled air into a flask containing alkali liquid. The carbon dioxide in the flask initiated a chemical reaction in which an indissoluble alkali carbonate was generated. The exhaled air could be observed in the flask as bubbles, and the alkali carbon dioxide precipitated during the process and accumulated on the flask's bottom.

The experiment was conducted in two different ways, first, with a person at rest and, second, with a person at work. Lavoisier already assumed that the purpose of the human respiration process was to produce heat rather than to supply oxygen for the body. Consequently, he compared the output of the exhaled gases to the inhaled gases, in addition to the person's temperature. The final conclusion from the experiments with Séguin was that animals combusted organic material by means of the inhaled oxygen.

Calorimeters, in general, measure the heat developed by chemical reactions. Laplace and Lavoisier had already documented that animals turn organic substances into heat. The next step was to determine how much heat could be developed by any substance, the heat being measured in calorimeters by burning the substance in question to ashes. The heat that is developed in addition to the heat supplied to the reaction is the *physical* calorific value.



**Figure 7:** Calorimeter, Nevil Monroe Hopkins, *Experimental Electrochemistry* (1905). This calorimeter was used to measure the heat developed during the reaction of two liquids. The drain container D is also the reaction chamber into which the second liquid from storage container G is conveyed. Two thermometers, I and J, are introduced into the reaction chamber and the insulating wall to control the heat developed by the chemical reaction.

The calorimeter in the style of Hopkins (see Fig. 7) determines the amount of energy released through a chemical reaction by pouring the reacting liquids into a common reaction chamber. Two thermometers are used to monitor the alteration of temperature during the reaction.

The physical calorific value is not entirely relevant as far as matters of the human metabolism are concerned. The calorific value of any nourishment varies for every species that consumes it; hence, the relevant value here is the physiological calorific value. It can be roughly determined by burning the excrement of the animal or human in question and comparing this value with the physical calorific value of the food consumed. The difference will then be the physiological calorific value. It has to be noted, though, that the physiological calorific value cannot be regarded to be an exact value. It varies not only from species to species but is, more or less, a personal value of the animal (or human) who is being tested.

### Nutrition for Prevention of Deficiency Diseases

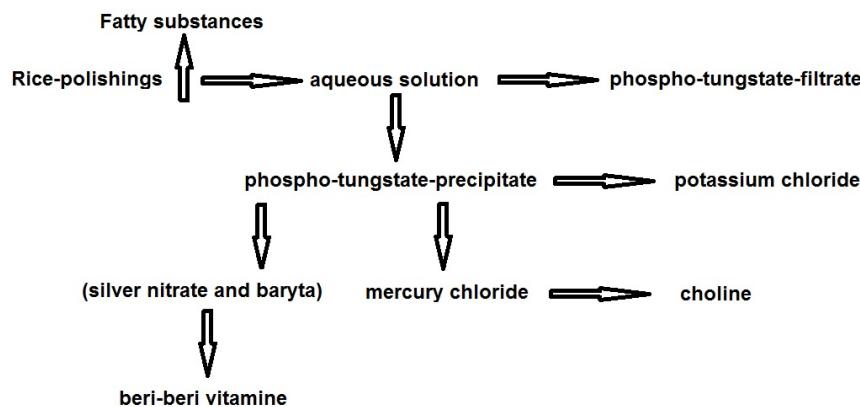
One of the oldest diseases known to seafarers is scurvy, today known to be caused by lack of Vitamin C. The

oldest reports about sailors who suffered from this deficiency disease date back to the days of antiquity in Egypt. It was well known that men aboard trading ships became sick, but the reason was unknown. Due to the necessity of having to operate as a viable unit, ships had large amounts of zwieback and brined meat onboard because these could be stored over a longer period of time. These products, which would deliver a good basis for the energy needed every day, could be supplemented with fish or cheese; however, with the latter being prone to spoil within a short time, a substitute was needed when these had been consumed.

A cure for scurvy was not found until the 18<sup>th</sup> century when a Scottish physician named James Lind (1736 – 1812) found a treatment to overcome this sickness (Lind 1753, pp. 192–196). He conducted an experiment on a dozen persons who were apparently affected by scurvy and showed most of the already well-known documented symptoms. He divided the patients into six pairs and gave them each a specific diet in order to test the effects of nutrition and also of hygiene. After 14 days, Lind was able to conclude that the only group who had overcome all of the scurvy symptoms was the one who had oranges and lemons on their specific menu. He left it to the experience of others to confirm the efficacy of these fruits, meaning he was well aware of having found a cure but not of determining the reason for the high effectiveness of the cure.

The research on beriberi, a deficiency disease caused by lack of Vitamin B<sub>1</sub>, was even more successful. It began with different assumptions about the possible causes of the illness and was founded on wrong conclusions on why it can be cured. The principal scientist investigating beriberi was the Dutch Christiaan Eijkman (1858 – 1930) who had the chance to explore the cause and cure of beriberi in what today is called a large-scale study. After advanced training in Germany, where Koch had recently identified bacteria as the cause of tuberculosis and cholera, Eijkman was convinced that beriberi was caused by generic germs, as well, and tried to prove it in a carefully controlled study (Allchin 1996). The state of Java, where Eijkman conducted his experiments, had, at that time, some 280,000 prisoners. Eijkman ordered a diet of rice for these prisoners: one of polished rice, one of unpolished rice, or a mixture of both. He then recorded the incidences of beriberi among the various groups of prisoners (Eijkman 1897, pp. 187 – 194). Other factors concerning hygiene which could have caused illnesses, such as ventilation or permeability of floors to water, had been ruled out.

Eijkman concluded that the prisoners who lived on the polished-rice diet were much more affected by beriberi than the others. From an older study, he had de-



**Figure 8:** Sketch of Funk's distillation process to obtain the beriberi vitamin. He states in his 1912 publication, that an analogue process could also be used to precipitate the scurvy vitamin. Figure reproduced from Funk 1912, p. 347.

terminated that the white rice contained the germ that caused beriberi and that the red coating, which was removed by polishing the rice, provided an antitoxin. This point is crucial to understanding why successful experiments can still lead to wrong conclusions. Since then, it has been shown that beriberi is a deficiency disease resulting from a permanent lack of an essential nutrient and not one caused by an active, infection-causing germ.

Casimir Funk was probably the first researcher who was able to coalesce all of the effects of deficiency diseases into a constructive theory (Funk 1912, pp. 341–368). He accounted for scurvy, beriberi, and many other diseases as those which break out if “an unvarying diet is partaken of for long periods” because of the “deficiency in a substance which is necessary for the metabolism” (Funk 1912, p. 341). Funk stated that all but one of the diseases covered in his 1912 paper could be cured simply by adding a new class of organic substances, which he called vitamins (short form for vital amin, referring to the chemical structure of the new substance), to one’s diet. He distinguished the vitamins already discovered by contemporary researchers by stating which disease each cures; for example, today’s vitamin C would have been the “scurvy vitamin” and vitamin B<sub>1</sub>, the “beriberi vitamin.” Funk also illustrated the method and the amount of the beriberi vitamin that could be precipitated from an aqueous solution, as well as the chemical formula for the vitamin.

He also gave an illustration of its curative effects by administering a dose of the beriberi vitamin to birds suffering from beriberi. A minute dose of 40 milligrams was sufficient to cure a pigeon in a very short time, and it also prevented the reappearance of beriberi for a time span of seven to twelve days even when the pigeon was placed on a polished-rice diet again. Two things seemed

to be obvious from this experiment: first, the vitamin as a curative agent seemed to have activated the curative process, and second, the body is able to store and utilize the vitamin efficiently.

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