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FRANCIS GANO BENEDICT'S *REPORTS OF VISITS TO FOREIGN LABORATORIES* AND THE CARNEGIE NUTRITION LABORATORY

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Summary: *Between 1907 and 1932/33 Francis Gano Benedict, director of the Carnegie Nutrition Laboratory, made seven extended tours of European metabolism laboratories. Benedict compiled extensive reports of these tours, which contain detailed descriptions and hundreds of photographs of the apparatus, laboratories and people that Benedict encountered. The tours took place during significant decades for physiology, covering the rise of American physiology, the effect of the First World War on European laboratories and the emergence of an international community in metabolism studies. This essay provides an introduction to Benedict's Reports of Visits to Foreign Laboratories and their central themes, situating them within the history of American physiology and the Carnegie Nutrition Laboratory. It concludes with an assessment of these volumes as a source for the history of early twentieth-century nutrition physiology.*

Key words: *Francis Gano Benedict, physiology, laboratory history, Carnegie Nutrition Laboratory, metabolism research.*

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Introduction[1]

In 1907 Francis Gano Benedict, physiologist and biochemist, was appointed director of the newly established Carnegie Nutrition Laboratory (CNL) in Boston. In this year he undertook the first of what was to become a series of seven extended tours of European institutions involved in metabolism research. From 1907 to 1933 Benedict travelled to Europe every three years, excepting the war and immediate post-war period, visiting established, new and lesser known laboratories at universities and vocational schools, medical clinics, agricultural experiment stations and government, industrial and private research centres in Great Britain, most Continental and several Eastern European countries, Scandinavia and Russia.

Benedict compiled extensive reports of these visits for the Carnegie Institution of Washington (CIW).[2] They are replete with hundreds photographs of laboratories, equipment and apparatus, physiologists and their assistants, technicians and families, lecture handbills, cuttings from foreign newspaper interviews and articles describing his tour, hand-drawn diagrammes and sample protocols. The volumes provide a unique and detailed synchronic and diachronic history of metabolism research laboratories, their personnel, research programmes and apparatus over a twenty-five year period from Benedict's particular, changing and subjective perspective as a beginning, established and, eventually, leading American laboratory director.

The purpose of this essay is to provide a preliminary exploration of these volumes and their main themes. It will summarize the focal point of each European tour, beginning with Benedict's survey of the material conditions in European laboratories on his first tour, his attempts to network with European scientists on his second, and his emergence as an established metabolism researcher by his third visit. The post-war visits are described in a single section, since they are dominated by Benedict's observations of the effect of the First World War on European science and scientists.

Although Benedict played a crucial role in establishing the study of metabolism in the United States, he and the CNL have received little attention in the history of science or medicine.[3]

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1. I thank the Max Planck Institute for the History of Science for its generous support of this project, and the colleagues at the MPI, Gordon McOuat and the anonymous referees for their criticism and suggestions.

2. The *Reports* are held in the Francis Gano Benedict papers, 1870s-1957. GA 7. Harvard Medical Library, Francis A. Countway Library of Medicine, Boston, Mass., Boxes 6 and 7. They have been digitised by the Max Planck Institute for the History of Science as part of The Virtual Laboratory: http://vlp.mpiwg-berlin.mpg.de. A map of the tours can be found in E. Neswald, (2010), "An American Physiologist Abroad: Francis Gano Benedict's European Tours", The Virtual Laboratory 2010. http://vlp.mpiwg-berlin.mpg.de/references?id=art77.

3. Benedict is only briefly mentioned in the seminal works of Kenneth Carpenter and Harvey Levenstein. K. Carpenter, *Protein and Energy. A Study of Changing Ideas in Nutrition*, Cambridge: Cambridge University Press 1994; H. Levenstein, *Revolution at the Table. The Transformation of the American Diet*, Berkeley: University of California Press 2003. The only extensive consideration of his research to date is in M. Hamin, *Tables Turned, Palates Curbed: Elements of Energy, Economy, and Equilibrium in American Nutrition Science, 1880-1930*, Diss. University of Pennsylvania 1999, esp. chp 7.

Research into the history of American nutrition has focussed largely on the activities of Benedict's predecessor, Wilbur Olin Atwater, and Atwater's work with the United States Department of Agriculture, while studies on the activities of the CIW concentrate on its projects in astronomy, geophysics and genetics. While a history of the CNL or a detailed description of Benedict's contributions to metabolism research must be reserved for a later date, by presenting Benedict's *Reports*, this essay hopes to draw attention to a neglected figure in the history of nutrition and to contribute to an appreciation of the role and difficulties of trans-Atlantic interactions both in metabolism research and, more generally, in the history of physiology.

American Nutrition Research and the Carnegie Nutrition Laboratory

Benedict's tours, laboratory and strategies developed within a specific constellation of American physiology, government and social interest in research on human and animal nutrition and debates on the lack of basic research in the United States. In the nineteenth and early twentieth century, American physiology was highly dependent on European physiology. American universities had no established research tradition, and students interested in laboratory techniques and research methods travelled to European centres for their degrees and for advanced training (Frank, 1987). This generation also viewed travel as crucial later in their careers as a means of keeping in touch with developments in the discipline, since research science was not yet widely established at American universities. Most basic research was conducted under the auspices of the US government and concentrated on such politically and policy-relevant areas as geological surveys and astronomy (Rheingold, 1972). Research on agriculture, including human nutrition, was undertaken under the direction of the United States Department of Agriculture. In the early 1880s, Wilbur Olin Atwater, an agricultural and biochemist, travelled to Leipzig, Berlin and Munich, where he learned the techniques of calorimetry and respiration gas analysis in the laboratory of Carl Voit, Germany's leading nutrition scientist. Appointed director of the Storrs Agricultural Experiment Station, professor at Wesleyan University and for a few years Director of the Office of Experiment Stations for the USDA, Atwater conducted chemical analyses of American foodstuffs, organised extensive surveys of food consumption and developed with his Wesleyan colleague, the physicist Edward Bennet Rosa, a respiration calorimeter for the study of human nutrition and metabolism. The respiration calorimeter of Atwater and Rosa was the first apparatus that could prove the conservation of energy in human metabolism, and, that humans were, in essence, energy transformation machines in which energy input equalled energy output.[4]

4. Energy conservation in the metabolism of dogs had been proven by Max Rubner in the 1880s. See M. Rubner, "Die Quelle der tierischen Wärme", *Zeitschrift für Biologie* 20 (1893): 73–142.

In 1895 Francis Gano Benedict, a German-trained American chemist, became Atwater's assistant at the Storrs and Wesleyan laboratories.[5] When Atwater and Rosa acrimoniously parted ways, Atwater turned to his technically highly skilled assistant to refine the calorimeter, conduct complex experiments and develop additional apparatus. Through the 1890s and into the first years of the twentieth century, Atwater and Benedict conducted metabolism experiments at the Wesleyan lab, while Atwater directed a nationally dispersed crew of researchers who studied animal nutrition, the digestibility of foodstuffs and human nutrition practices through extensive dietary surveys of groups ranging from the Harvard rowing crew to Chinese migrant workers in California, the rural poor of Virginia and Maine lumbermen.

In 1902 the trustees of the Storrs Experiment Station withdrew their financial support for this research programme. By then, Atwater could turn to another organisation, however – the privately-endowed Carnegie Institution of Washington. Founded in 1902 by steel magnate Andrew Carnegie amidst debates about perceived deficits in American scientific research productivity and education, the CIW was endowed with 10 million dollars and followed the mission of supporting basic research in the sciences.[6] The trustees of the institution decided to achieve this goal through the establishment of private research laboratories.

In its first years, the CIW provided Atwater with grants to continue his metabolism experiments at Wesleyan, while the trustees considered and then approved the establishment of a Carnegie laboratory for research on human nutrition. As the country's leading nutrition scientist, Atwater was the natural choice for director, but in 1904 he was severely disabled by a stroke, and he died a few years later. After some discussion, the trustees nominated Benedict in his place. The official appointment took place in 1907, after a year of planning and negotiations.

After courting both New York and Boston as potential sites for the new institution through 1906, Benedict eventually decided on Boston and purchased property neighbouring Harvard Medical School. He cited several reasons for this choice, including climate and the proximity to medical schools and hospitals.[7] If Carnegie and the trustees of the CIW had originally intended a complete separation of their laboratories from the universities, close and friendly relationships had advantages. Benedict negotiated with Harvard the use of its

5. The most extensive biographical information on Benedict can be found in the obituary written by E. DuBois and O. Riddle, "Francis Gano Benedict (1870-1957). A Biographical Memoir", *Biographical Memoirs*. National Academy of Sciences 1958, 65-99.

6. See for example: [C.W. Eliot], "The New Education. Its Organization", *Atlantic Monthly* 23/136 (1869), 203-220; C. Snyder, "America's Inferior Position in the Scientific World", *North American Review* 174 (Jan./June 1902), 59-72; S. Newcomb, "Conditions which Discourage Scientific Work in America", *North American Review* 174 (Jan./June 1902), 145-158. See also J. Trefil and M.H. Hindle, *Good Seeing. A Century of Science at the Carnegie Institution of Washington 1902-2002*, Washington DC: Joseph Henry Press 2002; H.S. Miller, *Dollars for Research. Science and its Patrons in Nineteenth Century America*, Seattle and London: University of Washington Press 1970.

7. FGB Papers, Box 2, Folder 26: BNL, Locations Studies and Reports (1903-1906), Benedict to Robert Woodward, 23 April 1906.

utilities and academic infrastructure, (heating, electrical systems, generators, libraries). From the medical school, he hoped for a steady supply of varied experimental and clinical subjects, qualified personal to assist and medical students to work in the labs or as volunteers for experiments. It was already clear by the early planning stage that, Benedict intended to continue developing the methods he had learned and perfected in Atwater's laboratory and to adopt many elements of Atwater's laboratory and project organisation, but that the CNL was to have a different focus than the research programme that Atwater had directed under the auspices of the USDA. While Atwater had concentrated on nutrition, public health and household economics, Benedict was primarily interested in metabolism and in establishing predictive norms for clinical use and for the identification of pathological conditions.

During Benedict's thirty years as its director, the CNL conducted an extensive programme of plotting normal human basal metabolism from birth to death in both sexes. This project eventually provided metabolic norms that were widely accepted in the first half of the twentieth century and, in some cases, with modifications, are still used as guidelines in contemporary metabolism predictions (Frankenfield et al, 1998). The CNL collaborated with numerous American and foreign visiting and associated researchers and other Carnegie laboratories in studies of metabolism during different physical activities and in diabetes, the affects of reduced diet, fasting and alcohol on metabolism and the metabolism of several species of animals. In his final decade at the CNL, Benedict directed a project to assess racial differences in metabolism, which, although fraught with the ubiquitous early twentieth-century racist assumptions, was ideologically undogmatic in the interpretation of its inconclusive results. Technical expertise and precision measurement were Benedict's *forte*, and the CNL produced numerous papers on the methods and techniques of respiration calorimetry and the measurement of variables.[8] It is perhaps in the measurement techniques and standards of precision, as well as the comprehensiveness of his metabolism plotting project that Benedict's most significant contributions to the scientific history of nutrition and metabolism research lie. Scientific researcher was only one of Benedict's roles, however, and in his *Reports*, he assumes a variety of persona, presenting himself as laboratory director and representative of the CIW, as scientific diplomat and liason officer, ethnographic observer, international research coordinator and technical expert.

On the Road in the Service of the Carnegie Nutrition Laboratory: *The Reports of Visits to Foreign Laboratories*

Professional, information-gathering foreign travel was included in the original plans for the new laboratory. In a memorandum to Robert S. Woodward, trustee of the CIW, composed in 1906, Benedict detailed the predicted budget needs of his new laboratory. In-

8. See the bibliography in DuBois and Riddle, "Biographical Memoir".

cluded was his recommendation that the CIW provide the not unsubstantial sum of $750 for him to visit "all the laboratories in American and in Europe where research work on nutrition is being carried out."[9] The CIW approved $1000,[10] and it continued to provide funding for European and American travels for Benedict and members of his staff until at least 1933.

Reports of these visits were compiled by Benedict and the travelling member of staff, but, with the exception of Benedict's seven tours and the report composed by one of his assistants, Walter Miles, in 1920, these reports have not yet been located, and their content and format are unknown.[11] The aims and character of Benedict's visits changed significantly over the quarter century of the *Reports*, reflecting changes in the status and interests of the CNL and in the capacities and interests of European nutritional physiology. In following, I will give a brief chronological overview of the *Reports*, before summarizing some of their recurrent themes. Benedict prefaced each *Report* with an introduction, explaining the main purposes and interests of the trip. Although these descriptions were most likely at least in part instrumental and written with the financial backers in mind, they were composed after the tour, as Benedict compiled his notes into a coherent report, and they define a thematic core of each visit.

Benedict's first three tours were undertaken in the early years of the CNL – in 1907, after funding had been secured, a site found and some apparatus ordered, but while the building was still under construction; in 1910, after research had begun; and in 1913, by which time the laboratory had established its research programme, its researchers had gathered considerable technical expertise and it had begun developing an international reputation. The reports of these three trips reflect specific concerns of each phase.

1907: Constructing the ideal laboratory

Benedict's first European tour took him from Bonn through Switzerland and Southern Germany to Budapest, St. Petersburg and Finland, from Scandinavia to Scotland and England and back across the channel to France. It concluded in Berlin, the central location for metabolism research in Europe and the site of several laboratories involved in studying animal and human metabolism. On this tour he visited a total of eighteen European cities and forty-five laboratories at university physiological institutes, hospitals and private sanatoria, agri-

9. FGB Papers, Box 2, Folder 26: BNL, Locations Studies and Reports (1903-1906): Letter and report from Benedict to Woodward, April 23 1906: "Suggestions Regarding Location, Equipment, Force, and Estimate of Cost of a Laboratory for Research in Human Nutrition. Memorandum to accompany estimates of cost", 4.

10. FGB Papers, Box 3, Folder 86: R. S. Woodward Correspondence, Woodward to Benedict, 26 Feb 1907.

11. The reports are typed on carbon paper and were dictated to his secretary. While only one copy of Benedict's *Reports* has been located, copies of Miles' *Report of Visits to Foreign Laboratories (1920)* have been found at the Yale University Medical Historical Library and the Archives of the History of American Psychology.

cultural, veterinary and medical schools. The explicit purpose of the tour was to gather information about the various possibilities of laboratory construction. Benedict justified the trip in his *Report*:

> In making this tour, the first thought was to secure all possible suggestions regarding the interior equipment of laboratories especially fitted for investigations in metabolism, calorimetry, and physiological chemistry. The second important commission was to enable the Director to become acquainted and, so far as feasible, to become familiar with all existing forms of apparatus for studying gaseous exchange, animal calorimetry, and general methods of research into human and animal nutrition (Benedict, 1907, 1-2).

Such an information-gathering visit was viewed as a necessary prerequisite to setting up the Boston laboratory.[12]

Benedict's description of the tour offers significant insights into the material culture of early twentieth-century laboratories. When negotiations ended in 1907, he was in the enviable position of being able to build a well-funded laboratory from scratch, including designing the building and designating the use and allocation of space, determining the best placement of gas, water and lighting fixtures, acquiring all laboratory furnishings and all laboratory apparatus and equipment. His attention was thus directed not only, as is to be expected, at the more elaborate equipment, such as calorimeters, respiration and gas analysis apparatus and variations in minor apparatus such as pumps and thermometers. Nor was his interest purely educational, although he did observe and describe in great detail the various experimental techniques and procedures of the laboratories he visited. He also especially noted the seemingly trivial details of these labs, weighing various options with the aim to combine them into an ideal laboratory set-up.

If descriptions of instruments and apparatus are commonplace, Benedict's *Report* reveals the small and at first glance insignificant details that have great effects on laboratory practice, on the convenience and ease of conducting experiments and keeping track of procedures. On the basis of his observations of existing laboratories, Benedict discussed and compared the advantages and disadvantages of various materials for covering table surfaces and floors, looked at the spatial distribution of workspaces, assessed means for making table heights adjustable, considered the most convenient locations for water faucets and stopcocks, studied drawer, cupboard and shelving arrangements and materials, power, heating and water supply systems and methods of decreasing the effects of vibrations. His considerations of these seemingly trivial details emphasise the extent to which they could affect and either enable or inhibit the flow of experimentation. They

12. Benedict to Woodward, April 23 1906: "Suggestions".

provide a basic material structure, within which experimentation takes place, but which become so self-evident for the researchers and seem so unimportant to most visitors that they disappear from laboratory reports and descriptions. Benedict's *Report* of 1907 shifts these questions to the foreground. Significantly, he did not seek to imitate the set-up of an existing lab, but to view as many alternatives as possible, in order to combine them into an *ideal* lab.

In light of Benedict's attention to detail in visiting other laboratories, it is perhaps ironic that he provided so little information about the choices he made for his own. Nonetheless, some information can be gleaned from his annual reports to the CIW and from professional correspondence. Through his prior work at Wesleyan and visits to US laboratories, he was aware of metabolism laboratory needs, and most architectural decisions about the CNL building were made prior to his first tour. Benedict incorporated some features that he had seen in European laboratories, such as flexibility in internal furnishings, with workspaces and shelving installed as needed, and the use of enameled lava as a tabletop material, which he imported at considerable expense from a quarry in France.[13] In addition, he examined a great number of major and minor apparatus, both on this tour and on the ones following. Although the CNL constructed its own calorimeters and respiration apparatus, Benedict purchased much specialised minor equipment and auxiliary apparatus that he had seen on his tours such as nose clips, pellet-making machines, manometers, gas analysis apparatus and precision measurement instruments from European instrument makers, laboratory workshops and equipment companies.

1910: In pursuit of tacit knowledge

By Benedict's second tour in 1910, construction was finished and active research work had begun at the CNL. It had amassed a respectable collection of apparatus for metabolism research – as Benedict claimed, one of the most complete collections in the world (Benedict, 1908: 161). Although he continued to appraise new and unknown apparatus and modifications, on this tour the communicative necessities of physiological research are the main focus. The CNL was the only research laboratory devoted solely to the study of human metabolism, and Benedict viewed the establishment of this laboratory as the internationally leading centre in this field as a part of the mandate bestowed upon him by the CIW.

The 1910 *Report* thematises in particular the importance of direct personal interaction for the coordination of research programmes across laboratory boundaries, the formation of scientific communities and the exchange of experiential knowledge. Metabolism experiments were time-consuming and difficult to execute. Benedict described the need to co-

13. For a description of the laboratory building, see: F.G. Benedict, "Nutrition Laboratory", in *Carnegie Institution of Washington Year Book* 7 (1908), 158-162; for enameled lava acquisition see NLF, Box 1, File 8. Benedict to John Woodward, 22 June 1908; NLF, Box 1, File 13, Benedict to Woodward, 18 November 1908.

ordinate experiments and research in order to avoid unnecessary duplication, to facilitate the verification of results, avoid the repetition of procedural errors and to organize cumulative and mutually supportive experimentation across laboratories. Informal interaction functioned, in addition, Benedict claimed, to cultivate the "personal element" of friendship and trust, instead of contentious rivalries, thus encouraging the free exchange of ideas, criticism and tentative results.[14] International exchanges of researchers served to raise the prestige of the hosting laboratories and standardize research methods beyond national boundaries.

The exchange of researchers was not only important for community-building and standardization. Benedict was well aware of the crucial role played by tacit knowledge in experimentation. He explained, "while a scientific investigator may write a description of his apparatus in the most beautiful language, he will, without fail, inadvertently overlook certain important minor details, which, though they may not affect the principle or the apparatus, nevertheless play a very important role in the successful conduct of experiments with it" (Benedict, *Report 1910*, 1). It was thus vital to personally inspect the equipment and observe it in use. Benedict participated in and observed experiments, received detailed explanations of how apparatus functioned and compared different versions of the same apparatus. The photographs in this large *Report* show not only apparatus taken from various angles, but also document valve constructions, ventilator connections, motors and pumps, the spatial distribution of tubes and containers for gas collection and analysis – possible variations in the experimental system. Combined with written descriptions, supplemented by reports of discussions with physiologists about their techniques and by observation of experiments in process, they provided Benedict with a translation into his own experience of experiments and apparatus that he read about in published research papers.

1913: Among equals

While Benedict justified the first tours with the new status of the nutrition laboratory and the need to gather information on apparatus and techniques, by 1913 the CNL was well-established and these justifications were no longer applicable. Instead, he emphasised the reciprocity of information exchange, with the CNL now able to contribute on equal grounds:

> The main object of the European trip, therefore, is to keep in touch with the different workers in the lines of research in which we are interested and to seek new ideas and methods for use in our own investigations. A second point of almost equal value is to disseminate information regarding our own researches […]. Such intercourse is of mutual benefit and renders possible a *entente cordiale* between ourselves and the laboratories visited (Benedict, *Report 1913*, 6-7).

14. FGB Papers, Box 7, F. G. Benedict, *Report of Visits to Foreign Laboratories 1910*, 2.

Instruments, apparatus, personnel and techniques were part of this exchange, and Benedict used these trips to recruit visiting researchers and assistants. The CNL's first official foreign visitor was the Austrian researcher, W. Falta, who collaborated there with the visiting American scholar, E. Joslin, in studies of diabetes (Benedict, 1909: 183-84). As the laboratory became more widely known, it was visited by researchers from nearly all European countries – both junior researchers and established scientists, such as Edward Cathcart and Max Rubner – who came to view the lab, collaborate with Benedict and use or train on its specialist equipment. While learning about new apparatus and techniques remained a theme of the trip, Benedict also aimed to acquaint foreign scholars with CNL apparatus and innovations. He writes of this tour, "It has likewise been possible to introduce into European laboratories apparatus which has been devised in this laboratory by supplying sketches, blue prints, and occasionally sending a model for reproduction" (Benedict, *Report 1913*, 8). Interested in establishing a standard apparatus in metabolism research, Benedict promoted the Universal Respiration Apparatus developed by his lab, translating essays on its construction and principles into French and German.[15]

Benedict's new confidence in his expertise and that of his lab emerge clearly in this *Report*. He assumed an advisory role in specific research questions and in the use and set-up of apparatus and discussed with European scientists new research questions that the CNL was or should be pursuing, such as metabolism at high altitudes and in diabetes and the metabolism of alcohol. He also sought to advertise the work done in Boston and the importance of his and his lab's contributions to the field. CNL monograph publications were distributed freely to numerous European laboratories, CNL publications were translated or abstracted for foreign journals and handbooks, and on his travels Benedict observed library practices with an eye to improving the dissemination of his laboratory's results.[16] The 1913 tour aimed to situation the CNL within the international research landscape.

The post-war visits (1923, 1926, 1929, 1932/33)

Benedict reached the height of his international influence in the years immediately following the First World War. His direct political involvement during the war had been limited to an advisory position to the US government's Food Administration, which supplied food aid

15. F.G. Benedict, (1912), "Ein Universalrespirationsapparat", *Deutsches Archiv für Klinische Medizin* 107, 156-200; F.G. Benedict, (1918), "Effets physiologiques d'une réduction prolongée du régime alimentaire expérimentée sur vingt-cinq sujets", *Bulletin de Société Scientifique d'Hygiène Alimentaire* 6 : 422-30. From 1928 onwards Benedict contributed numerous articles on the apparatus and methodology of his laboratory to E. Abderhalden, [ed.], *Handbuch der biologischen Arbeitsmethoden,* Berlin/Vienna: Urban & Schwarzenberg 1920-1939.

16. Since its establishment, the CNL had staff translators for its own publications and to translate the linguistically less accessible Russian metabolism research into English. Benedict mentions CNL translation work in numerous annual reports in the *Carnegie Institution of Washington Year book*. For a discussion of libraries see FGB Papers, Box 7, F. G. Benedict, *Report of Visits to Foreign Laboratories 1913*, 35, 210, 324-326.

to allied nations, but as a committed internationalist, he increasingly viewed his role – and that of science – in political terms. Although on his first tours, Benedict had visited the laboratories privately, in the 1920s he began attending meetings of the International Congress of Physiologists, endeavouring to facilitate the re-establishment of international scientific relations. The CIW, along with the Rockefeller Foundation, had advanced to a significant international research funding institution that now sought to extend its benevolence to the European scientific community. As a representative of that organisation in his field, Benedict wielded considerable influence, advocating for particular labs and researchers with their national governments and organising research exchanges and donations of equipment and periodicals.

Benedict's previous visits had put him in a good position to act as an intermediary in post-war European science. As an American, he had been in a privileged position prior to the war, since he was simultaneously an insider in the research field and an outsider in regard to inner-European national and scientific rivalries. He was thus able to move freely between laboratories, discussing research questions by proxy with scientists who would not speak to one another, and collecting the physiological gossip and opinions of the day. Due to his cultivation of the "personal element", on his return to Europe, Benedict was able to reinsert himself into a still conflicted European scientific scene without difficulty.

Although he originally planned to tour European laboratories every three years, the First World War led to a longer interruption in his visits. Benedict kept in touch with his European colleagues as far as possible and spoke out strongly in defense of Germany until the evidence for German atrocities could no longer be doubted.[17] European travel was interrupted during the war and remained harrowing in the aftermath, especially in Germany, where political upheaval, rampant inflation and a continuing dispute with France made border crossings difficult and the issuing and acknowledgement of visas often arbitrary. In 1920 Benedict sent Miles on a scouting mission to Europe to evaluate whether a resumption of the tri-annual tours seemed advisable. In 1923 he returned himself. The travel conditions were not good, as his report of an unexpectedly short sojourn Munich illustrates:

> Although Professor Müller did everything he could to secure my entrance into Munich under as comfortable conditions as possible, we were subjected to a great deal of annoyance and difficulties before being allowed to cross the Bavarian frontier from Vienna, and had it not been for a letter from Professor Kossel, inviting me to lecture at Heidelberg, I probably would not have been allowed to enter. As it was I had to forego my expected stay in Munich and had to be out in six hours, going on to Heidelberg (Benedict, *Report 1923*, 73).

17. See his correspondence with Max Rubner, Archive of the Max Planck Society, Abt. III, Reps. 8, 41/4/5-7.

Aware through Miles' *Report* of 1920 and through his correspondence with European colleagues of the effect of the war on European physiological research, Benedict emphasised that the importance of this visit and the following ones lay in the resumption of contact with foreign researchers, both with the Boston laboratory and amongst one another.

Despite the difficulty of travel, Benedict visited thirty-two cities on this trip. Conspicuously absent was Russia, where the political situation had changed radically due to the Revolution. Although American laboratories had seen war-time cuts to their budgets,[18] the decade between 1913 and 1923 had been a devastating one for Europeans. The state of many European laboratories was depressing. Some had been commandeered as hospitals during the war, others stripped of useful metals, and most had pre-war equipment that by the 1920s was out-dated and often in need of repair. Especially in Germany in 1923, inflation was out of control. A German professor told Benedict "of an incident with regard to a certain foundation of which he is a member of the committee. The postage of a letter sending the income cost more than the entire income from the fund" (Benedict, *Report 1923*, 74). With food shortages and a highly instable currency, funding for nutrition research was not the most pressing problem confronting the population, or even the physiologists. Benedict's German colleagues had suffered personally during the war and its aftermath, many grown thin through the wartime food shortages, shabbily dressed and poorly nourished, while others had lost family members in battle or through diseases aided by malnutrition.

Benedict and his colleague Graham Lusk of Cornell University organized donations of money and instruments to the hardest-hit German labs, and the CIW donated instruments to laboratories in other countries as well.[19] By Benedict's next visit of 1926, there were some signs of recovery, especially in Germany, but this was by no means universal. Benedict described the situation in the Physical-Chemical Institute of the University of Budapest:

> His [Professor Hári's] laboratory is without doubt the dirtiest and shabbiest I have ever seen. I do not understand how it is possible for any one to do any work under such conditions […]. All the instruments were dirty. In the calorimetry connections there were half a dozen pieces of glass tube pieced out with rubber tube instead of one length. Hári said there is *always* a leak in the system; it is never completely tight, but they simply correct for the nitrogen leaking in (Benedict, *Report 1926*, 94).

On his return to Europe Benedict was impressed, and not positively, by the shift from metabolism to research on vitamins: "Perhaps the most important information that I got [in Aberdeen] was in the discussion with Orr of the vitamine research, which was sweeping through Europe. I found Orr to be an intense 'anti-vitamine' man, so it was rather good to

18. Archive of the Max Planck Society, Abt. III, Reps. 8, 41/8/2, Benedict to Max Rubner, 1 Nov 1922.

19. FGB Papers, Box 6, F. G. Benedict, *Report of Visits to Foreign Laboratories 1923*, 73, 10.

get a little leavening into the large mass of vitamine dough that had been rising for several months" (Benedict, *Report 1923*, 214). In the second half of the decade though, perhaps as a sign that better times had come, a new topic of metabolism research had begun to emerge. Since the late nineteenth century, physiologists had studied the effects of inanition, fasting and starvation on metabolism.[20] By 1926 they were pointing to the need for a study of the metabolism of the obese.[21]

Not surprisingly, the political situation dominated the post-war *Reports*. With tensions still running high between Germany and France, England and Belgium, Benedict began increasingly to describe his role as that of a go-between and scientific diplomat, re-establishing the broken ties between physiologists of different countries. His self-proclaimed role as an emissary of knowledge was now complemented by that of a messenger of international understanding, and, as the representative of a financially powerful American funding organization, Benedict did his best to wield his influence in political circles in support of his physiologist colleagues. By his final visit in 1932 he was referring to his "diplomatic missions," which involved not only advocating for specific laboratories and researchers with their governments, but also functioning, in his own words, as a "liaison officer" facilitating communication and clarifying misunderstandings between laboratories.[22] The painful actuality of the European political situation can be especially felt in the *Report* of the August 1932-February 1933 tour, when Benedict closed his descriptions of several German institutions with the information that in the *weeks* since his visit, the hosting researcher had "come under the ban" or left the country "on account of the Jewish situation": "One can not understand the thing at all" (Benedict, *Report 1932/33*, 200, 202, 205).

What stands out in these post-war years is a shift of research centres. Germany, and especially Berlin, had been the foremost site of physiological and metabolism research into the early twentieth century. Benedict's enthusiasm had also been fired by the research laboratory of Franz Tangl in Budapest and the St. Petersburg apparatus and programme. In the 1920s Benedict no longer visited Russia. The great Berlin metabolism tradition had also reached an end. Nathan Zuntz, who had done significant research on respiration and developed several apparatus for the study respiration under varying conditions, had passed away. The elderly Rubner was involved in other research and, Benedict confided, "I rather felt that he had 'shot his bolt' many years ago and had been

20. C. Lehmann, et al., "Untersuchungen an zwei hungernden Menschen", *Archiv für pathologische Anatomie und Physiologie und klinischen Medicin* 13. Folge – 131 Supp. (1893), 1-228; F.G. Benedict, *The Influence of Inanition on Metabolism*, Washington DC: Carnegie Institute of Washington 1907; F.G. Benedict, *A Study of Prolonged Fasting*, Washington DC: Carnegie Institute of Washington 1915.

21. For example, Professor Erich Graf of the University of Würzburg Medical Clinic, in FGB Papers, Box 6, F.G. Benedict, *Report of Visits to Foreign Laboratories 1926*, 167, 197, 382.

22. FGB Papers, Box 6, F. G. Benedict, *Report of Visits to Foreign Laboratories 1932/33*, 19.

more or less living upon that […]" (Benedict, *Report 1926*, 88). Benedict was impressed by the new facilities of the *Kaiser-Wilhelm-Institut für Arbeitsphysiologie*, which had completed its move from Berlin to Dortmund by his visit in 1929, describing with enthusiasm the care put into laboratory construction and underlining his admiration with numerous photographs of the facilities. At his return visit three years later, this state-of-the-art laboratory was largely closed or on stand-by, due to lack of sufficient funds to buy heating coal (Benedict, Report 1932/33, 184). Emerging as new centres of physiological research were the Scandinavian countries, especially Sweden and Denmark, and, to a lesser degree, Holland.

What also stands out is the altered status of the CNL. If Benedict had visited the European labs in 1907 and 1910 seeking to benefit from their established expertise and as an equal partner in 1913, by the 1920s the tables had turned, and American leadership in metabolism studies was apparent. Benedict had completed his birth-to-death metabolism project and, in collaboration with the statistician Arthur Harris of the Carnegie Laboratory for Experimental Evolution (Genetics), the results had been put on a firm biometric statistical foundation (Harris and Benedict, 1919). His lab had acquired an impressive degree of technical and experimental expertise, invited guests for training and exported apparatus and technical knowledge across Europe and the United States. The war had interrupted European metabolism research, while the CNL had continued its work, and Benedict now held lectures in numerous cities on his tour, informing the European institutions of the latest results of the CNL research and of innovations that had passed them by during the war and the following turbulent years. He was well aware of the grounds for this shift in research capacities and argued against American arrogance. The new American scientific leadership position was an accident of history, he claimed, not a sign of innate superiority: "I believe a spirit of humility should surround all our laboratory life. It is only as the result of a great cataclysm in which, by the grace of God, America was not too heavily involved, that we are financially and economically in a better situation than most of the European countries" (Benedict, *Report 1926*, 387). Nonetheless, he concluded in 1929,

> Many of the research workers are so handicapped by lack of material equipment and small means that one can expect very little in most places in the coming decade […]. Unfortunately it would appear that further immediate scientific surveys of the European situation are not needed […]. In any event, one of the deciding factors in taking up another tour to Europe would be not what the Nutrition Laboratory would receive but what the Nutrition Laboratory could give (Benedict, *Report 1929*, 306-7).

The final tour of 1932/33 only confirmed this assessment (Benedict, *Report 1932/33*, 355).

Thematic threads

Two recurrent themes of these volumes deserve particular attention. First, Benedict was, at least in the assessment of a contemporary, not a particularly gifted physiological theorist, but his technical skill and interest in technical questions were "of the highest order."[23] This interest and ability is reflected in the *Reports*, which contain extensive descriptions of instruments, apparatus and experimental set-ups, of successful constructions and blind alleys, but only briefly mention physiological theories. As such, they provide much detailed information for a history of the material culture of early twentieth-century physiology laboratories, the development of human and animal calorimeters and respiration apparatus and metabolism experimentation, but they also contain insights into instrumental practices that go beyond this special field. Second, Benedict was both an intensely social scientist, as his extended networking activities and "diplomatic missions" show, and he was the director of a large research laboratory with national and international connections and ambitions and affiliated with a financially powerful institution. Laboratory cultures, human interactions, gossip and communication play a prominent role in his *Reports*.

Instruments

A respiration calorimeter is conceptually a very simple piece of apparatus, consisting of an isolation chamber and a means for measuring energy input and output. Putting this concept into practice successfully, however, requires a high degree of skill, since isolation is difficult to maintain, when input and output are necessary (the experimental subject needs to breath), and output takes on a great number of forms, including solid and fluid waste, exhaled gases and water in breath and perspiration, heat and motion. Some of these can be measured directly, others indirectly, and many require a number of stages of chemical analysis. Physiologists wrote extensive descriptions of calorimeters and respiration apparatus, their calibration and stabilization, methods of measurement and of gas analysis, the effect of environmental variables and the means to correct for them, and the conduction of experiments with them under various conditions.[24] Use of the calorimeter and respiration apparatus, procedures for analyzing gaseous exchange and the demands of precision measure-

23. Graham Lusk to Max Rubner, 7 July 1931, Archive of the Max Planck Society, Abt. III, Rep. 8, Nr. 59/9/12-13.

24. See, for example, M. Rubner, "Calorimetrische Methodik. " In: Medicinische Facultät zu Marburg [ed.], *Zu der fünfzigjährigen Doctor-Jubelfeier des Herrn Carl Ludwig*, Marburg 1890, 33-68; W.O. Atwater and E.B. Rosa, *Description of a New Respiration Calorimeter and Experiments on the Conservation of Energy in the Human Body*, Washington D.C.: Government Printing Office 1899; W.O. Atwater and F.G. Benedict, *A Respiration Calorimeter with Appliances for the Direct Determination of Oxygen*, Washington DC.: Carnegie Institution of Washington 1905; F.G. Benedict and Th.M. Carpenter, *Respiration Calorimeter for Studying the Respiratory Exchange and Energy Transformations of Man*, Washington DC.: Carnegie Institution of Washington 1910.

ment required skill and training on the part of the experimenter and his assistants, and the apparatus and experiments often required that the experimental subjects also undergo special training or be tested for their experimental “aptitude”, thus raising the question of whether the results obtained using trained or particularly adaptable subjects could even be viewed as representative.

The difficulty of constructing and experimenting with the apparatus of metabolism research is shown clearly in Benedict’s *Reports*. His returning visits to the same laboratory chronicle in occasionally comical tones the stages of apparatus construction and stagnation. Many calorimeters took years to build and years to calibrate, if successful calibration was achieved at all, and many researchers developed their own apparatus, leading to great variety in calorimeter and respiration apparatus construction. Only few of these proved reliable and gave good experimental results, even when the constructing researcher had been able to observe and use calorimeters in other laboratories, that is, to acquire experiential knowledge. Few researchers, it seems, had the necessary skills and insights to build a functional respiration calorimeter or apparatus and use it productively.

In addition, apparatus that functioned well for a particular investigator could not always be translated into another laboratory setting or be used satisfactorily by another researcher. Sometimes it demanded an unusual degree of skill. Thus, while Benedict was full of admiration for the gas analysis apparatus demonstrated to him by August Krogh of Copenhagen, he “regretted that probably very few people can use it and secure such results as Krogh has secured with it,” in part because of Krogh’s rare ability to estimate to 1/20 of a subdivision (or to 0.0001 per cent oxygen) on his measurement scale (Benedict, *Report 1910*, 216-220). Occasionally the complexity or idiosyncrasy of the apparatus was tied too strongly to the experience of the researcher who developed it. Benedict observed with frustrated amusement the calorimeter-building activities at the Parisian *Société Scientifique d’Hygiene Alimentaire* over the course of a decade and a half, concluding in 1929, “I cannot image a more imposing display of machinery without any practical use. As I have so often remarked, if [Professor J.] Lefèvre should die tomorrow, no living man would or could go on with his equipment” (Benedict, *Report 1929*, 20).

Using a standard apparatus, equipment and materials did not always provide a solution. Small variations in the research question required modifications of an established apparatus and these were not always undertaken, as when Benedict criticized the experiments of another laboratory:

> The application of the Universal [Benedict] apparatus to the experiments with the dog showed again the apparent impossibility of people using a well worked out piece of apparatus and applying it to their own problems and at the same time giving too little attention to the various basic points necessary to have successful usage of such an apparatus (Benedict, *Report 1932/33*, 254).

There could be no one-size fits all apparatus, and even the modification of existing apparatus required a high degree of experimental and technical skill.

Further complicating the matter, not all instrument makers or suppliers were reliable. Many researchers did not have the skills to build and modify their own apparatus or make their own chemicals and instead relied on outside sources. Often they could not get their experiments to work and could not figure out why. Searching for the reason for the poor reputation of his own Universal Respiration Apparatus in France, for example, Benedict found that the instruments attributed to his design that were sold by a Parisian instrument-maker and the chemicals attributed to his name that the main French provider supplied were substandard.[25] The experiments could not have succeeded, no matter how closely the researchers had followed his procedures. The need for standard instruments and methods or for a means to make experiments on different apparatus and from different laboratories commensurable is a persistent theme in the *Reports*.

Laboratory Cultures

The study of laboratory administration was an explicit goal of Benedict's 1913 tour, and various aspects of laboratory culture and inter-laboratory or inter-researcher disputes are frequently mentioned throughout the *Reports*. Benedict could afford to be frank – his reports were confidential – and they bristle with physiological gossip. The atmosphere in the laboratory and the spatial arrangement of the workplaces, he found, had a considerable effect on research productivity. Laboratories could be set up so that projects took place in separate rooms, or so that all researchers worked together in one large room. The presence or absence of strong direction could make the difference between a successful and a stagnating research programme. In Oscar Hagemann's laboratory in Bonn, for example, he found,

> One striking reason for the lack of coordination is the fact that no one is in charge of an experiment. Each individual is given a certain part to do and does his or her part utterly independent of anyone else, and no one has entire charge or supervises. Even when the experiment is made at night, Professor Hagemann goes home and a girl with an assistant is left there with no trained man in charge" (Benedict, *Report 1910*, 23).

In some laboratories, researchers communicated freely with one another, while in others "there seemed to be a tendency for each man to work by himself and not tell any one else what he was doing" (Benedict, *Report 1913*, 206). In regard to Tangl's laboratory in Budapest, in contrast, Benedict commented,

25. FGB Papers, Box 6, F. G. Benedict, *Report of Visits to Foreign Laboratories 1929*, 31, 36, 48.

> In very few laboratories have I noted such complete harmony and such a charming atmosphere as in the laboratory at Budapest […]. The men all worked together, there were apparently no bitter rivalries, no secrets, and none of the little unpleasantness that one sees so frequently in foreign laboratories […]. Altogether there is quite a charming atmosphere about the laboratory and one can easily understand how so much work can be done (Benedict, *Report 1913*, 164).

The sense of community and loyalty that Benedict found in this laboratory may have affected its ability to survive the death of its director, regulate the question of succession, withstand the collapse of its budget and continue productive research under drastic material conditions.

Although the war and economic crises were clearly significant factors in the decline of many European laboratories, another can be found in the question of generational change and succession. Benedict's *Reports* reveal how vulnerable laboratory research programmes could be to changes in leadership personnel. Laboratory traditions, even those that had generated the most productive research programmes such as that of the Munich laboratory under Voit or that of Zuntz in Berlin, might continue only as long as that strong director remained active. In absence of an "heir apparent", the research programme might stagnate or undergo radical change under a new director, while the remaining, older personnel were left to stumble along on their own. In his 1907 *Report*, Benedict described the atmosphere in Munich as paralyzed, since Voit was quite elderly and his successor unclear (Benedict, *Report 1907*, 117). By 1910, the famous Pettenkofer-Voit respiration apparatus – the foundational apparatus of nutrition physiology – had been dismantled and removed, and by 1913 Benedict concluded that, with the exception of one of Voit's old assistants, "From the standpoint of technique and from experimental work one need look for very little in the line of metabolism in the Munich laboratory at the present time […]" (Benedict, *Report 1913*, 178). The laboratory that had founded a new research specialty, trained a generation of European and North America scholars and generated an internationally renowned research programme was no longer active in the field. Zuntz' laboratory suffered a similar fate in the 1920s.

Another thread that emerges from these reports is the increasing presence of women in European physiological laboratories. Benedict was an early supporter of women in science, as Toby Appel has shown, (1994: 46-47) and he wrote numerous collaborative papers with female researchers, including his scientifically-trained wife. Although European laboratories were slower to integrate women, the *Reports* contain numerous references to their presence as technicians, students and assistants. In 1910 Benedict found that Hagemann, plagued by a scarcity of capable male assistants and weary of hung-over German students, had begun hiring young middle-class women for calculations, experimental observations, technical assistance and basic chemical analysis (Benedict, *Report 1910*, 22-23). In the

1920s Zuntz' laboratory employed a qualified female experimenter, and Benedict was suitably impressed by Marie Krogh in Copenhagen, who collaborated with her husband, August and was a capable independent researcher in her own right. Physiology was often a family affair. In 1929 Benedict commented on one laboratory he visited, "Here again we found, as one finds so frequently now in European laboratories, a very intelligent, well-trained wife working assisting her husband, not infrequently in independent research and frequently without compensation" (Benedict, *Report 1929*, 37). Whether or not he compensated his own wife, who assisted at the CNL, is currently unknown.

Conclusion

Benedict's *Reports* offer insights for a number of different histories and studies. While acknowledging their partial and subjective nature, one can trace, for example, the shifting constellations of laboratory dominance, the emergence of new research centres, the collapse of established ones and the conditions that contributed to the continuation or decline of research programmes. The decades they encompass were crucial ones in the history of physiology, covering the transition of research leadership in physiology from France and Germany to the United States, with European research divided among multiple national centres. While the rising status and independence of American physiology began in the early twentieth century, Benedict's *Reports* document unambiguously the conclusions drawn by Gerald Geisen from quantitative data, that the emergence of the United States as a leader in the field was a direct result of the effect of the war on European, and especially German physiology (Geison, 1987).

The *Reports* also provide a thick description of the material culture of early twentieth-century laboratories and of laboratory culture. They describe in great detail construction materials, apparatus, techniques and experimental set-ups, track the increasing presence and changing status of women in European laboratories, compare laboratory organisation, note the role of national politics and academic rivalries, as well as differences between publicly and privately expressed opinions, and describe the difficulties of establishing and maintaining international scientific communities. In particular, the copious visual material, photographs of laboratories and apparatus in different constellations and detail provide a visual record of laboratory set-ups and instrumentation in the early twentieth century.

In addition, the *Reports* span an important generational and theoretical transition in nutrition physiology. In 1907, nutrition physiology in Europe and North America was dominated by researchers who had trained with the first generation of quantitatively-oriented metabolism and physiology researchers, and a significant number of them had spent time in the laboratories of Voit in Munich or Carl Ludwig in Leipzig. Rubner, who first fully experimentally articulated the thermodynamic approach to metabolism, was a product of this school, as was Atwater, with whom Benedict trained, and the heavy emphasis on calorimetry, respiratory exchange, and precision measurement was its defining characteristic. By the 1920s, however, many of these second-generation nutrition physiologists had left active research or found themselves increasingly marginalized by younger scholars and the newer research on vitamins. Neither Benedict nor the CNL were able to make this transition. The laboratory continued its focus on energy transformations and metabolism measurement after Benedict's retirement in 1937, but in the mid 1940s the CIW decided this was no longer a productive field for its support. The CNL was dissolved in 1946 and its inventory sold, donated or dispersed among other CIW laboratories.[26]

26. See the correspondence between Thorne M. Carpenter and Walter Gilbert, Archive of the Carnegie Institution of Washington, Nutrition Laboratory Files, Box 3, File 1.

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