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Park, Hyung Wook

2010

Park, H. W. (2010). Longevity, Aging, and Caloric Restriction: Clive Maine McCay and the Construction of a Multidisciplinary Research Program. *Historical Studies in the Natural Sciences*, 40(1), 79-124.

<https://hdl.handle.net/10356/96440>

<https://doi.org/10.1525/hsns.2010.40.1.79>

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HYUNG WOOK PARK*

Longevity, Aging, and Caloric Restriction: Clive Maine McCay and the Construction of a Multidisciplinary Research Program

ABSTRACT

Since the 1930s scientists from fields such as biochemistry, pathology, immunology, genetics, neuroscience, and nutrition have studied the relation of dietary caloric intake to longevity and aging. This paper discusses how Clive Maine McCay, a professor of animal husbandry at Cornell University, began his investigation of the topic and promoted it as a productive research program in the multidisciplinary science of gerontology. Initially, McCay observed the effect of reduced-calorie diets on life span and senescence while pursuing his nutrition research in the context of animal husbandry and agriculture. But when he received funding from the Rockefeller Foundation and started to participate in the establishment of gerontology during the 1930s, the scope of his research was considerably expanded beyond his original disciplinary domain. It became a multidisciplinary research program that attracted scholars from a variety of scientific and medical disciplines. This paper argues that through this expansion

*Department of Philosophy, Durham University, 50 Old Elvet, Durham DH1 3HN, United Kingdom; hyung.park@durham.ac.uk.

The following abbreviations are used: AC, Alexis Carrel Papers, Georgetown University Archive, Washington, DC; CMM, Clive Maine McCay Papers, Cornell University Archive, Ithaca, NY; EVC, Edmund Vincent Cowdry Papers, Washington University Medical School Archive, St. Louis, MO; GS, Gladys Sperling Papers, Cornell University Archive, Ithaca, NY; *HSPS*, *Historical Studies in the Physical and Biological Sciences*; *JBC*, *Journal of Biological Chemistry*; *JG*, *Journal of Gerontology*; *JHB*, *Journal of the History of Biology*; *JN*, *Journal of Nutrition*; NWS, Nathan W. Shock Papers, Bentley Historical Library, University of Michigan, Ann Arbor, MI; RF, Rockefeller Foundation Archive, Rockefeller Archive Center, Sleepy Hollow, NY; RGSS, Record Group 443, Records of the National Institutes of Health, Division of Research Grants, Records of the Gerontology Study Section, 1946–1950, National Archives and Records Administration, College Park, MD; *TAFS*, *Transactions of the American Fisheries Society*; WBC, Walter B. Cannon Papers, HMS c40, Countway Library of Medicine, Boston, MA; WDM, William de B. MacNider Papers, University of North Carolina Archive, Chapel Hill, NC.

Historical Studies in the Natural Sciences, Vol. 40, Number 1, pps. 79–124. ISSN 1939-1811, electronic ISSN 1939-182X. © 2010 by the Regents of the University of California. All rights reserved. Please direct all requests for permission to photocopy or reproduce article content through the University of California Press's Rights and Permissions website, <http://www.ucpressjournals.com/reprintinfo.asp>. DOI: 10.1525/hsns.2010.40.1.79.

McCay's research created a means of maintaining cooperation among the diverse and heterogeneous academic fields constituting gerontology.

KEY WORDS: caloric restriction, aging, longevity, Clive Maine McCay, nutrition, gerontology, multidisciplinary research

INTRODUCTION

The relationship between dietary caloric intake and longevity has been an important problem in gerontology, the science of aging. This paper discusses the life and work of Clive Maine McCay (1898–1967), an American scientist who substantially contributed to the study of this subject through an active research program.¹ While historians have not examined McCay's research extensively, scientists of aging and nutrition have described him as one of the first researchers who discovered that reduced caloric intake increased longevity and decreased the rate of aging.² As early as 1956 the British gerontologist Alex Comfort wrote that McCay's research was "very remarkable" and "represents the only successful assault which has ever been made on the problem of mammalian specific age, which is itself the key problem of medical gerontology."³ More recently, the renowned gerontologist Edward J. Masoro has described McCay's experiments as among the first investigations into the effects of caloric restriction.⁴ Nutrition scientists Patricia B. Swan and J. K. Loosli have also praised McCay's work as an important contribution to the science of nutrition and the study of dietary restriction.⁵ According to *Profiles in Gerontology*, a biographical dictionary of gerontologists,

1. In this essay, I use McCay's own expression, "caloric restriction," rather than "calorie restriction" or "dietary restriction." "Ageing" (instead of "aging") is also used in direct quotations in accordance with its usage among early gerontologists.

2. In addition to the remarks of the scientists cited below, British scientist Peter Medawar mentioned McCay's research in a positive way. See Peter Medawar, "Problems of Ageing. Ed. E. V. Cowdry. 2nd., undated, C. 26, the Peter Brian Medawar Papers, Wellcome Library, London, England. Also see an extensive biography of McCay written by his wife, Jeanette B. McCay, *Clive McCay, Nutrition Pioneer: Biographical Memoirs by His Wife* (Charlotte Harbor, FL: Tabby House, 1994).

3. Alex Comfort, *The Biology of Senescence* (New York: Rinehart, 1956), 148.

4. Edward J. Masoro, *Caloric Restriction: A Key to Understanding and Modulating Aging* (Amsterdam: Elsevier, 2002), 2–3.

5. Patricia B. Swan, "To Live Longer, Eat Less! (McCay, 1934–1939)," *JN* 127 (1997): 1039S–1941S; J. K. Loosli, "Clive Maine McCay (1898–1967)—A Biographical Sketch," *JN* 103 (1973): 3–10.

some researchers even believe that McCay's experiments "may be the *only* research on the biology of aging that represents a genuine, original contribution by a gerontologist."⁶

Yet these accounts of McCay in scientific writings are mostly straightforward descriptions of his life and work rather than thorough analyses of his research in its historical contexts. Certainly, if we take a close look at the circumstances surrounding his work, we may find that the significance of his contribution becomes less obvious than it first appears. As we will see, the meaning of *discovery* was ambiguous in the case of McCay's research, primarily due to the problems in defining normal nutritional states. Moreover, preceding McCay, there were several scientists who had observed that restricted diets increased the duration of life. Scientific literature on longer life span and reduced or inadequate food can be found as early as the 1910s, while it was only during the 1920s that McCay performed his initial experiments on the subject.⁷ The popular discourse on the effect of decreased food consumption on life span can be seen in earlier publications, such as the Italian nobleman Luigi Cornaro's *Discorsi della Vita Sobria* (1548). Why, then, should we pay attention to McCay?

One answer is that McCay, despite several earlier scholars who studied related issues, was the first scientist who showed the effect of caloric restriction on aging in a visually striking way using a relatively large number of rats. But a more important aspect of his career is seen from what he did following his initial finding. From the late 1930s on, he promoted the study of caloric restriction in relation to longevity and senescence as a multidisciplinary research program in the science of aging. His effort in this direction was important, because it established an exemplary research program that the early gerontologists had hoped to create. As the historian W. Andrew Achenbaum, the sociologist Stephen Katz, and I have described, gerontology was constructed during the 1930s and 1940s as a broad scientific field including scholars from a multitude of distinct disciplines, such as biology, medicine, psychology, and the social sciences.⁸ Gerontology

6. "Clive M. McCay," in *Profiles in Gerontology: A Biographical Dictionary*, ed. W. Andrew Achenbaum and Daniel M. Albert (Westport, CT: Greenwood, 1995), 232.

7. Thomas B. Osborne, Lafayette B. Mendel, and Edna L. Ferry, "The Effect of Retardation of Growth upon the Breeding Period and Duration of Life of Rats," *Science* 45 (1917): 294–95; John H. Northrop, "The Effect of Prolongation of the Period of Growth on the Total Duration of Life," *JBC* 32 (1917): 123–26, on 126.

8. W. Andrew Achenbaum, *Crossing Frontiers: Gerontology Emerges as a Science* (Cambridge: Cambridge University Press, 1995), 52–84; Stephen Katz, *Disciplining Old Age: The Formation of*

emerged as a multidisciplinary field, because its early participants conceptualized aging as a complex problem with many interrelated dimensions, including the elderly's health, employment, and psychological adaptation, as well as diverse aspects of biological senescence manifested in various forms of life, such as plants, microbes, insects, and cultured tissues. Each discipline constituting gerontology, while conducting its separate research, was also expected to contribute to tackling the problems of aging in collaboration with other disciplines. During gerontology's early years, however, it was not very clear to scientists how this multidisciplinary study could be pursued. I argue that in this context McCay's research provided a successful approach to the experimental manipulation of aging, which could be cooperatively used by many gerontologists from diverse disciplinary backgrounds.

This aspect of McCay's research has a broader implication regarding the unity or disunity of science, a topic which has been extensively studied by historians, philosophers, and sociologists. Currently, several scholars are investigating the disunified aspects of science and how it can nevertheless maintain its integrity through the partial cooperation and communication of various participants.⁹ Gerontology can be a relevant, if atypical, example that demonstrates such a collaboration despite science's disunified nature. In fact, as Nathan W. Shock, an early gerontologist at the National Institutes of Health (NIH), pointed out, gerontology was and has been a field of "multiple disciplines" to which diverse experts who have not abandoned their original professional identity have contributed.¹⁰ As a result, the degree of cooperation in gerontology has often been a matter of persistent questions. According to Katz, the science of aging has "developed into a loosely connected, instrumental web of institutional and research programs," although this disunified structure can be considered as much a strength as a weakness of this

Gerontological Knowledge (Charlottesville: University of Virginia Press, 1996); Hyung Wook Park, "Edmund Vincent Cowdry and the Making of Gerontology as a Multidisciplinary Scientific Field in the United States," *JHB* 41, no. 3 (2008): 529–72.

9. For example, see Peter L. Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997), 781–844; Susan Leigh Star and James R. Griesemer, "Institutional Ecology, 'Translations,' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39," *Social Studies of Science* 19, no. 3 (1989): 387–420; Ilana Löwy, "The Strength of Loose Concepts—Boundary Concepts, Federative Experimental Strategies, and Disciplinary Growth: The Case of Immunology," *History of Science* 30, no. 4 (1992): 371–96; Ilana Löwy, *Between Bench and Bedside: Science, Healing, and Interleukin-2 in a Cancer Ward* (Cambridge, MA: Harvard University Press, 1996), 247–53.

10. Shock to Fremont-Smith, undated but written in the 1940s, EVC, Box 42, Folder 8.

multidisciplinary field.¹¹ Several contemporary gerontologists have offered similar accounts. For them, gerontology is a disunified field with but a few paradigmatic theories and methodologies shared by gerontologists in different disciplines.¹² The numerous journals, academic societies, and annual meetings regarding the science of aging, however, indicate that the structural integrity of gerontology as a multidisciplinary science has been maintained despite questions on the nature and viability of the field. What, then, has made gerontology a disunified but relatively stable research field with significant cooperative efforts across disciplinary boundaries? In a separate paper, I have offered a historical answer to this question by analyzing several factors that contributed to the making of multidisciplinary in early gerontology, such as cytology textbooks' unique organization, early gerontologists' social concerns, and the discourses on and the form of biological research during the first half of the twentieth century.¹³ In this paper, I focus on a concrete and specific research program that was successful in garnering the cooperation of researchers who participated in building the field in its early years. I argue that McCay's research brought about a research program that became a focal point of multidisciplinary interaction in the disunified field.

This paper has two sections. The first describes how McCay initially designed his experiments on caloric restriction during his nutrition research in relation to animal husbandry and agriculture. The second analyzes McCay's research as a multidisciplinary program in gerontology. I will discuss the role of the Rockefeller Foundation, which through its program of funding cross-disciplinary projects in the 1930s provided McCay with the initial financial and social impetus for the expansion of the scope of his research. At the same time, McCay began to frame his work within the new field of gerontology. His contact with other members in this field led him to establish through his investigation a communicatory channel among the multitude of disciplines constituting the science of aging.

11. Katz, *Disciplining Old Age* (ref. 8), 110–12. Katz's statement regarding gerontology is similar to what Julie Thompson Klein has mentioned on the nature of multidisciplinary. See Julie Thompson Klein, *Interdisciplinarity: History, Theory, and Practice* (Detroit, MI: Wayne State University Press, 1990), 55–73.

12. David A. Peterson, *Career Paths in the Field of Aging* (Lexington, MA: Lexington Books, 1987); R. D. Bramwell, "Gerontology as a Discipline," *Educational Gerontology* 11 (1985): 201–10; Ira S. Hirschfield and David A. Peterson, "The Professionalization of Gerontology," *The Gerontologist* 22 (1982): 215–20.

13. Park, "Edmund Vincent Cowdry" (ref. 8).

GROWTH, LONGEVITY, AND ANIMAL HUSBANDRY IN THE SCIENCE OF NUTRITION

Clive Maine McCay was born in Winamac, Indiana in 1898. He finished his undergraduate education in chemistry at the University of Illinois in 1920 and received his master's degree in biochemistry at Iowa State College in 1923. He then went to the University of California, Berkeley to study biochemistry and nutrition under C. L. A. Schmidt. There he took two courses from the renowned nutrition scientist and discoverer of vitamin A, Elmer Verner McCollum, who was then temporarily at Berkeley.¹⁴ After earning his PhD in 1925, McCay was awarded a National Research Council Fellowship that enabled him to go to Yale to study nutrition with the renowned nutrition scientist Lafayette B. Mendel.

While at Yale, McCay was heavily influenced by Mendel and his colleague Thomas Osborne, who conducted an experiment that would lead McCay to perform his famous research on caloric restriction. Mendel and Osborne studied several nutritional problems, such as how the absence of specific amino acids in diets caused the failure of growth in rats.¹⁵ It was during this experiment that they observed an interesting phenomenon. In 1917 after a series of studies on how long the rats could remain in the state of growth retardation under subnormal dietary conditions (such as reduced amounts of food, diets without essential amino acids, or the use of artificial diets with deficient nutritional content) before resuming a normal diet, Mendel and Osborne discovered that these underfed rats lived longer than the control group.¹⁶ Along with John Northrop's finding that yeast-free diets increased the life span of flies, Mendel and Osborne's work was one of the earliest studies of underfeeding and life.¹⁷ Although it was not certain whether McCay was aware of Northrop's research, McCay knew his

14. "Programme of the Final Public Examination for the Degree of Doctor of Philosophy of Clive Maine McCay," University of California Graduate Division, 18 Apr 1925, CMM, Box 47, Folder Montana; McCay to William MacNider, 12 Mar 1942, NWS, Box 6, Folder McCay, Clive.

15. For example, see Thomas B. Osborne and Lafayette B. Mendel, "Amino-Acids in Nutrition and Growth," *JBC* 17 (1914): 325–49.

16. Osborne, Mendel, and Ferry, "Effect of Retardation" (ref. 7).

17. Northrop, "Effect of Prolongation" (ref. 7). For other related studies with different approaches and results, see James Rollin Slonaker, *The Effect of a Strictly Vegetable Diet on the Spontaneous Activity, the Rate of Growth, and the Longevity of the Albino Rat* (Palo Alto, CA: Stanford University Press, 1912); T. Brailsford Robertson and L. A. Ray, "Experimental Studies on Growth. XV: On the Growth of Relatively Long Lived Compared with that of Relatively Short Lived Animals," *JBC* 42 (1920): 71–107.

teachers' experiments very well, and according to a later comment by McCay's colleague, Mendel even encouraged McCay to study the subject further.¹⁸

McCay followed his teachers' footsteps in terms of his choice of research venue as well. Like Mendel and Osborne, who studied underfeeding while working at the Connecticut Agricultural Experimental Station, an institute for practical research, McCay pursued his new project in a place with a practical objective, the State Hatchery in Burlington, Connecticut. There he worked to devise an inexpensive artificial diet that nevertheless contained all the essential nutrients for brook trout reared in hatcheries but destined for eventual release into rivers to supplement their decreasing numbers in the wild.¹⁹ He was particularly interested in understanding the identity of factor H in raw meat, whose absence resulted in retarded growth even when all other essential nutrients were provided.²⁰ But growth was not the only problem. A good diet also had to support adult fish characteristics such as longevity, vigor, and reproductive power to improve the trout's chances for survival after release.²¹

McCay first noticed the effect of underfeeding on longevity while investigating how various dietary components, such as proteins, vitamins, and minerals, influenced these characteristics of trout. In particular, his team was trying to determine how the amount of protein in diets was related to growth and death by feeding young trout with low-, medium-, and high-protein diets. In this research, he and his team discovered that many of the trout fed the low-protein diet did not grow well yet survived after the twentieth week, while those on the medium- or high-protein diets had died in earlier weeks. These surviving trout resumed their normal growth when they were subsequently given an ordinary diet containing raw liver. Remarkably, many of these trout still survived by the twenty-ninth week, when all of the others, including those fed dried skim milk as the control diet, had completely perished. For McCay, this showed that the phenomenon observed by Mendel and Osborne in their rats could also be observed in trout.²²

18. Loosli, "Clive Maine McCay" (ref. 5), 4.

19. C. M. McCay, "Goals in Nutrition," *TAFS* 57 (1927): 261–65; C. M. McCay, F. C. Bing, and W. S. Dille, "The Effect of Variations in Vitamins, Protein, Fat and Mineral Matter in the Diet upon the Growth and Mortality of Eastern Brook Trout," *TAFS* 57 (1927): 240–49; F. C. Bing, "A Progress Report upon Feeding Experiments with Brook Trout Fingerlings at the Connecticut State Fish Hatchery, Burlington, Conn.," *TAFS* 57 (1927): 266–80.

20. C. M. McCay and W. E. Dille, "Factor H in the Nutrition of Trout," *TAFS* 57 (1927): 250–59.

21. McCay, "Goals in Nutrition" (ref. 19), 263.

22. McCay, Bing, and Dille, "Effect of Variations" (ref. 19), 241.

After this initial study, McCay sought to identify why the low-protein diet retarded the trout's growth rate. For this purpose, he kept another group of trout fasting along with the trout on varying levels of proteins, and found that these fasting trout constantly lost weight. While it seemed obvious that starvation caused weight loss, McCay arrived at an interesting conclusion by comparing this group of trout with others: "[from] this we may conclude that those trout fed the low protein rations do not fast but consume just about enough food to maintain their body weights without any increase." Therefore, "[i]t appears that trout eat for calories and not protein."²³ Although no further discussion followed this statement, its meaning was clear, in light of the times. As historians Margaret Lowe and Harvey Levenstein have shown, the relation of high-caloric content of food to weight increase was widely discussed in the 1920s by both professional scientists of nutrition and the general public.²⁴ As one of the former, McCay thought that the maintenance of constant weight was a consequence of the low-protein diet's low-energy content, which was just adequate for maintaining weight. The starving trout lost weight because they could not find even this minimal level of energy necessary for weight maintenance. While lacking detailed accounts, this idea shows that he was already considering the significance of dietary calories in relation to the rate of growth.

During the 1920s, however, McCay investigated neither longevity nor caloric intake as a major research subject. In papers published in 1927 and 1928, McCay and his team paid more attention to the factor H in raw liver, which enabled the trout on the low-protein diet to resume their growth, along with other significant dietary factors, such as vitamins and minerals.²⁵ Admittedly, in their 1929 article on the same topic, McCay et al. stressed that "trout stunted upon low protein diets live twice as long as those that are allowed to grow upon similar synthetic rations with a higher protein level." "This seems to indicate," the authors suggested, "that their bodies contain a store of some substance that is

23. John W. Titcomb, Eben W. Cobb, Mary F. Crowell, and C. M. McCay, "The Nutritional Requirements and Growth Rates of Brook Trout," *TAFS* 58 (1928): 205–31, on 217–18.

24. Margaret A. Lowe, "From Robust Appetites to Calorie Counting: The Emergence of Dieting among Smith College Students in the 1920s," *Journal of Women's History* 7, no. 4 (1995): 37–61; Harvey Levenstein, *Revolution at the Table: The Transformation of the American Diet* (Berkeley: University of California Press, 2003), 166.

25. McCay, Bing, and Dille, "Effect of Variations" (ref. 19), 246–47; C. M. McCay, F. C. Bing, and W. E. Dille, "Factor H in the Nutrition of Trout," *Science* 67 (1928): 249–50.

essential for life but is consumed in growth.”²⁶ But even this article, published after McCay moved to Cornell, did not focus on longevity or dietary calories. His new Cornell post, however, would soon present an opportunity to change the direction of his investigations.

In 1927 McCay was appointed as an assistant professor in the Department of Animal Husbandry at the State College of Agriculture at Cornell on the recommendation of Leonard Maynard, a senior Cornell professor who met McCay during his sabbatical leave at Yale.²⁷ This appointment led McCay to become involved in research guided by the State College’s larger goal, namely, the promotion of basic and practical research for farmers and breeders in the state.²⁸ He joined a variety of projects in the animal husbandry department on the metabolism and nutrition of various animals such as cows, goats, sheep, trout, and rats. Animal husbandry was a broad field, which included many issues related to feeding and breeding animals. Some subjects in this field were connected to agriculture, but others were not. For instance, his animal husbandry research at Yale was about fisheries, not agriculture, and he devoted some of his time at Cornell to continuing such work.²⁹ But his primary focus at Cornell was on the nutrition of terrestrial farm animals and their experimental models, such as the rat. For example, McCay’s team studied the impact of low-fat diets on the lipid in cow’s milk and blood.³⁰ They also investigated the toxicity of cod-liver oil for farm herbivores such as sheep and goats, showing that it had mild toxicity for them.³¹

In 1933 McCay published a short paper in *Science* on the relationship between longevity and optimum growth, which showed his research priority in

26. C. M. McCay, W. E. Dilley, and M. F. Crowell, “Growth Rates of Brook Trout Reared upon Purified Rations, upon Dry Skim Milk Diets, and upon Feed Combinations of Cereal Grains,” *JN* 1 (1929): 233–46, on 245.

27. Daphne A. Roe, “Leonard Amby Maynard,” *Biographical Memoir of the National Academy of Sciences*, vol. 3 (Washington DC: Government Printing Office, 1993), 299, 304.

28. *Cornell University Register for 1927–1928* (Ithaca: Cornell University Press, 1928), 79–80.

29. For example, see C. M. McCay, John. W. Titcomb, Eben W. Cobb, M. F. Crowell, and A. Tunison, “The Nutritional Requirements of Trout,” *TAFS* 60 (1930): 127–39. See Jeanette McCay, *Clive McCay* (ref. 2), 279–304.

30. L. A. Maynard and C. M. McCay, “The Influence of a Low-Fat Diet upon Fat Metabolism during Lactation,” *JN* 2 (1929): 67–81; C. M. McCay and L. A. Maynard, “The Interrelationship between the Dietary Fat and the Phosphorus Distribution in the Blood of Lactating Cows,” *JBC* 92 (1931): 273–80.

31. L. L. Madsen, C. M. McCay, and L. A. Maynard, “Synthetic Diets for Herbivora, with Special Reference to the Toxicity of Cod-Liver Oil,” *Cornell University Agricultural Experimental Station Memoir* (Ithaca: Cornell University, 1935).

this new institutional environment. In the paper's opening paragraph, he criticized the philosophy of modern nutrition that "a diet which produces optimum growth in the young animal is the ideal." According to McCay, this philosophy led to the assumption that "optimum growth means optimum health" and to the idea that optimum health acquired from optimum growth led to greater longevity. As an expert in animal nutrition, McCay noticed that this idea was accepted by many breeders, who raised animals that were "slaughtered for meat shortly after they [matured]." ³² Unfortunately, however, "the same philosophy dominates the practices of rearing dairy calves and horses to maturity as rapidly as possible although it is desirable that they have a long productive life span," during which they could serve humans by providing milk and labor. The problem was that "no one has ever found it possible . . . to have both rapid growth with early attainment of maturity, and longevity."³³ Several researchers' studies, including those of his teachers and his own, indicated that longer life was observed only among the organisms that grew slowly.

Around 1931 McCay and his student Mary Crowell started a more systematic experiment on growth and longevity using rats and low-calorie foods. After his trout research at Yale, he had suspected that the main factor responsible for slow growth in the low-protein diet was its low-calorie content. At Cornell, he designed an experiment based on this idea and published its remarkable result in 1934.³⁴ After dividing 106 weaned rats of similar weight into three groups, McCay and Crowell allowed the first group to eat as much as they wanted. The second group received a diet with insufficient calories immediately after weaning, and the third group was given food with adequate calories only for the first two weeks and then fed a low-calorie diet. While the animals in the underfed groups were occasionally given additional calories to allow them to grow by a small degree, they generally remained in a state of retarded development until the twenty-eighth month, after which they were permitted to eat as much as they wanted and grow rapidly. Strikingly, the mean life span of the males in the underfed groups was 792 and 883 days, respectively, whereas that of the males in the first group was only 509. What was more surprising was that when the paper was written many of the underfed rats were still alive and their mean duration of life was increasing. The only exception to this overall trend was

32. Clive M. McCay, "Is Longevity Compatible with Optimum Growth?" *Science* 77 (1933): 410–11, on 410.

33. *Ibid.*, 411.

34. C. M. McCay and Mary F. Crowell, "Prolonging the Life Span," *Scientific Monthly* 39 (1934): 405–14.

the mean life span of the second group of females, which at 755 days was slightly shorter than the 801 days of the first group of females. This anomaly could be explained, however, by the death of some of the second group of females during the hot summer of 1931. In fact, the median, rather than the mean, life span of the second group of females was 904 days, whereas that of the first group of females was just 820. After 1,200 days, no rats in the first group remained alive, while thirteen survived in the other two groups.

Although this experiment resembled the work of McCay's teachers, it was different in certain respects. Both McCay and his Yale advisors had shown that underfeeding led to longer life, but in work with Crowell he used many more rats than Mendel and Osborne had used, and succeeded in keeping thirteen alive beyond the 1,200th day, while all four of Mendel and Osborne's rats that had survived for two years died before becoming 1,000 days old.³⁵ Moreover, whereas Mendel and Osborne tried many different ways to underfeed their rats, McCay focused on providing a diet that was deficient in only one respect—namely, the number of calories.³⁶

But the most striking feature of McCay's experiment was its emphasis on the aging process. In Mendel and Osborne's paper, age was only briefly mentioned when they stated that the rats' ability to resume growth after underfeeding was not inevitably lost with age.³⁷ McCay not only remembered this brief statement, but also tried to demonstrate its implication by way of a visual comparison. If the rats on a low-calorie diet could retain their ability to grow during a long period of growth retardation, what would be the extent of the progress of their aging at the end of that period? McCay wrote that "it is customary to observe the hair, since its condition frequently reveals changes that are taking place within the animal body."³⁸

It was quite noticeable that "the hair of the animals retarded in growth remained fine and silky for many months after that of the rapidly growing animals had become coarse."³⁹ McCay supported this statement with three photos

35. Osborne, Mendel, and Ferry, "Effect of Retardation" (ref. 7), 295.

36. Northrop, "Effect of Prolongation" (ref. 7), 124; Thomas B. Osborne and Lafayette B. Mendel, "The Resumption of Growth after Long Continued Failure to Grow," *JBC* 23 (1915): 439–54, on 442; C. M. McCay, Mary F. Crowell, and L. A. Maynard, "The Effect of Retarded Growth upon the Length of Life Span and upon the Ultimate Body Size," *JN* 10 (1935): 63–79, on 65.

37. Thomas B. Osborne and Lafayette B. Mendel, "The Suppression of Growth and the Capacity to Grow," *JBC* 18 (1914): 95–103, on 103.

38. McCay and Crowell, "Prolonging the Life Span" (ref. 34), 414.

39. *Ibid.*

FIG. 1 "THESE TYPICAL RATS ARE BOTH 900 DAYS OLD." Source: McCay and Crowell, "Prolonging the Life Span" (ref. 34), 407. The original picture comes from CMM, Box 11. Reprinted with permissions from AAAS.

showing the two rats in a single camera frame. One of these photos had a legend, "THESE TYPICAL RATS ARE BOTH 900 DAYS OLD." (Fig. 1) The normally grown rat on the left looked more senile than the underfed rat on the right.

But the photo raises many questions: How typical were these two rats? Was the underfed rat on the right actually less senile than the control rat on the left, or did it just appear to be? After all, the rats in the photo were deliberately chosen by McCay, and their outward appearance was not enough to reveal the actual degree of senile change, which was still considered a highly complex phenomenon. In light of recent sociological and historical scholarship on visual representation, it can be said that McCay's photo was a construct created through his laboratory techniques and rhetorical strategies in order to deliver his argument effectively.⁴⁰

40. See, for example, Michael Lynch and Steve Woolgar, eds., *Representation in Scientific Practice* (Cambridge, MA: MIT Press, 1988); Alex Soojung-Kim Pang, "Visual Representation and Post-Constructivist History of Science," *HSPS* 28, no. 1 (1997): 139–71; Timothy Lenoir, ed., *Inscribing Science: Scientific Texts and the Materiality of Communication* (Palo Alto: Stanford University Press, 1998); Luc Pauwels, ed., *Visual Cultures of Science: Rethinking Representational Practices in Knowledge Building and Science Communication* (Hanover, NH: Dartmouth College Press, 2006).

In historical terms, this construct was the product of a tradition in the science of nutrition which McCay had inherited from his teachers. The comparison of the appearance of two rats—one on an experimental diet and the other on the control diet—was an effective visual technology used by several nutrition scientists. In his publications McCollum often contrasted two rats, one of which always showed the deleterious consequence of the lack of a certain dietary factor such as vitamin A.⁴¹ Mendel and Osborne also contrasted two rats in a photo to demonstrate the effect of restricted diets upon the rats' growth.⁴² McCay, as their student, used photos of the rats to persuade other scientists and the general public of the importance of caloric intake in the aging process, as I will show further in the next section.

But McCay's subsequent research revealed many additional features of the rats that could not be observed in this photo. Although the underfed rat in the photo looked healthy and young, it was found to have many structural and functional problems. For instance, McCay's underfed rats failed to reach the normal size of rats with sufficient caloric intake during growth phases.⁴³ Moreover, the bones of the underfed rats were less dense than those of normally grown ones, and some of the former were highly decalcified and fragile.⁴⁴ As for the reproductive system, the underfed females showed delayed opening of the vagina, no estrus cycle until they were put on normal diets, and an irregular estrus cycle thereafter.⁴⁵ Likewise, the underfed males had penis deformity, which sometimes resulted in sterility or diminished fertility. Although McCay hoped that he could use his findings in animal husbandry, these problems indicated that it might be difficult for him to do so.⁴⁶

McCay did observe, however, that the underfed rats fared better than the control animals in some respects. Besides looking much younger in terms of silky hair and general outward appearance, the underfed rats developed fewer

41. E. V. McCollum, *The Newer Knowledge of Nutrition: The Use of Food for the Preservation of Vitality and Health* (New York: MacMillan, 1919), esp. fig. 5.

42. Osborne and Mendel, "Resumption of Growth" (ref. 36), 447.

43. McCay, Crowell, and Maynard, "Effect of Retarded Growth" (ref. 36), 67–69. Indeed, the size of animals was very important for most commercial breeders.

44. Ibid., 75. Also see "Conference on Nutritional Requirements for the Ageing Population," 1–2 Nov 1941, GS, Box 1, Folder Nutritional Requirements Conference 1941, p. 7.

45. "The Influence of Diet upon the Physiological and Biochemical Changes which Accompany Aging in the Animal Body: Supplementary Study," p. 1, undated, but written in 1935, RF, Series 200D, Record Group 1.1, Box 136, Folder 1687. See also "Conference," GS (ref. 44), 1, 6.

46. C. M. McCay, "Some Old Beliefs about Long Life," 26 May 1934, Agricultural College Hour Radio Talk Manuscript, NWS, Box 6, Folder McCay, Clive, p. 8.

tumors and had lower rates of middle ear infection and lung disease, which often killed many old rats.⁴⁷ Furthermore, these underfed animals were “alert and active even after long periods of retardation.”⁴⁸

Yet McCay’s research had theoretical problems that could diminish the significance of these beneficial characteristics and even threaten the validity of his entire argument. One such problem concerned his rats’ genetic makeup. When McCay was developing his rat experiments, many life scientists were already using experimental animals with standardized genetic constitutions, influenced by the pioneering works of Thomas Hunt Morgan, Clarence Cook Little, and others.⁴⁹ These genetically homogeneous animals were thought to produce more reliable results, since the effect of an experimental manipulation could be clearly detected when compared to the controls of the same genetic constitution. However, most contemporary nutrition researchers, including McCollum, Mendel, and Osborn, did not use genetically homogeneous rats.⁵⁰ Indeed, there were few genetically standardized rats available to researchers until the 1960s, although the Wistar Institute of Anatomy and Biology in Philadelphia produced some inbred strains.⁵¹ When Warren Weaver of the Rockefeller Foundation inquired whether McCay’s team used genetically homogeneous rats, he was told that “there has been no program of inbreeding” and most of their rats originated from Mendel’s random-bred strains. Yet McCay’s team was certainly

47. C. M. McCay, “Nutrition, Ageing, and Longevity,” *Transactions & Studies of the College of Physicians of Philadelphia* 10 (1942): 1–10, on 7, 9; “Conference,” GS (ref. 44), 12–13.

48. McCay, “Nutrition” (ref. 47), 9.

49. Robert E. Kohler, *Lords of the Fly: Drosophila Genetics and the Experimental Life* (Chicago: University of Chicago Press, 1994); Karen A. Rader, *Making Mice: Standardizing Animals for American Biomedical Research, 1900–1955* (Princeton: Princeton University Press, 2004); Lee B. Kass, Christophe Bonneuil, and Edward H. Coe, Jr., “Cornfests, Cornfabs, and Cooperation: The Origins and Beginnings of the Maize Genetics Cooperation News Letter,” *Genetics* 169 (2005): 1787–97; Rachel Allyson Ankeny, “Wormy Logic: Model Organisms as Case-Based Reasoning,” in *Science without Laws: Model Systems, Cases, Exemplary Narratives*, ed. Angela N. H. Creager, Elizabeth Lunbeck, and M. Norton Wise (Durham, NC: Duke University Press, 2007), 46–58; Angela N. H. Creager, *The Life of a Virus: Tobacco Mosaic Virus as an Experimental Model, 1930–1965* (Chicago: University of Chicago Press, 2001).

50. See J. Russell Lindsey and Henry J. Baker, “Historical Foundations,” in *The Laboratory Rat*, 2nd ed., ed. Mark A. Suckow, Steven H. Weisbroth, and Craig L. Franklin (Amsterdam: Elsevier, 2006), 15–20.

51. Bonnie Tocher Clause, “The Wistar Rat as a Right Choice: Establishing Mammalian Standards and the Ideal of a Standardized Mammal,” *JHB* 26, no. 2 (1993): 329–49, on 332; Lindsey and Baker, “Historical Foundations” (ref. 50), 10. The authors of an article published in 1957 still say that they used non-inbred Wistar rats. See Arthur Everitt and Carolyn Webb, “The Relation between Body Weight Changes and Life Duration in Male Rats,” *JG* 12 (1957): 128–35, on 128.

troubled by Weaver's question; according to Weaver, a scientist in McCay's team said that they needed to examine the "possible genetic factors which may well underlie (and confuse or mask?) the results of dietary factors."⁵²

Another important issue was raised by Irving Fisher at Yale, a renowned economist, eugenicist, health advocate, and chairman of the Hygiene Reference Board of the Life Extension Institute.⁵³ After receiving McCay's letter on his recent experiments—which was sent to scholars who might be interested in his work—Fisher pointed out that the short life of McCay's normally fed rats might be a product of being overfed, while the longer life span of his underfed animals was more typical. In other words, it was possible that McCay had not found anything new, since his "normally fed" rats might be far from normal. According to Fisher, "allowing the rats to eat all they [wanted] while they [were] in captivity [did] them harm healthwise" and made them die early.⁵⁴ But McCay argued that his experiment proved the effect of restricted dietary calories on the extension of life span, rather than overfeeding's influence on life span, since his underfed rats' longevity was "so great that it exceeded the bounds of any normally fed group of animals."⁵⁵ This argument was based on his assumption that his well-fed laboratory rats were given the normal level of calories and would thus show the normal life span. Extrapolating from Fisher, however, such normal conditions needed to be found among wild rats rather than lab organisms, since an animal's condition in its natural habitat should be considered its "normal" state. Wild rats could not eat as much as their laboratory counterparts, and perhaps due to natural underfeeding, they could live as long as McCay's underfed rats.

Even if the natural habitat of wild rats were identified as the "normal" condition, however, it would be difficult to use it for further research on longevity and caloric intake. It was hardly possible to measure the effect of the wild rats' natural starvation on their life span, since they tended to die early due to predation, disease, or other accidents. Moreover, their energy demand significantly differed from that of lab animals, which cannot move much in their cages. As a scientist who spent most of his time in labs, farms, and hatcheries, McCay did not worry much about these problems, and simply regarded his well-fed

52. Warren Weaver Diary, 29 Jul 1936, RF, Series 200D, Record Group 1.1.

53. Fisher's participation in national health movements is briefly described in Victoria Harden, *Inventing the NIH: Federal Biomedical Research Policy, 1887–1937* (Baltimore: Johns Hopkins University Press, 1986), 57, 119.

54. Fisher to McCay, 18 Apr 1934, NWS, Box 6, Folder McCay, Clive.

55. McCay, "Nutrition" (ref. 47), 6.

laboratory rats as normal. As historian Robert Kohler has put it, such a view may show how an animal was differently configured and understood as it moved from the wild to the laboratory through scientists' use.⁵⁶ As a laboratory researcher, McCay redefined the rat's criteria of the normal, which was different from those of the rat in the wild.

While this issue continued to haunt later researchers, scientists in the lab and the field have recently begun to tackle the problem cooperatively.⁵⁷ It has been suggested that it is more feasible to estimate how many calories a wild animal consumes by measuring the amount of its caloric expenditure and comparing it with that of experimentally underfed organisms, since caloric expenditure of an animal can be thought to be almost equal to its consumption.⁵⁸ If the wild rats' caloric expenditure differs substantially from that of the underfed rats in the lab, an old problem in the science of aging and longevity can find an answer.

But cooperative research has a long tradition in the field of caloric restriction and longevity, which goes back to the 1930s. Interestingly, many of the theoretical and practical problems in McCay's works, rather than leading to the abandonment of the research, contributed to making a collaborative project involving diverse expertise in various scientific and medical fields as well as animal husbandry. Originally a small project at a state agricultural college, his research expanded beyond its initial domain into medicine, physiology, psychology, dentistry, and other disciplines. By highlighting a series of concurrent events during the 1930s and 1940s, the next section will discuss how some of the above problems of the underfed rats enabled, rather than hindered, this expansion, which in turn produced further research problems that would attract more investigators from various fields.

MAKING A MULTIDISCIPLINARY RESEARCH PROGRAM: THE ROCKEFELLER FOUNDATION AND THE SCIENCE OF AGING

The first step in the expansion of McCay's research was taken when Alan Gregg, director of the Medical Science Division of the Rockefeller Foundation, visited

56. See Kohler, *Lords of the Fly* (ref. 49), 71–79; Robert Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (Chicago: University of Chicago Press, 2002).

57. See Leonard Hayflick, *How and Why We Age* (New York: Ballantine, 1994), 277–95.

58. Steven N. Austad, "Does Caloric Restriction in the Laboratory Simply Prevent Overfeeding and Return House Mice to Their Natural Level of Food Intake?" *Science of Aging Knowledge Environment* 2001, no. 6 (2001): pe3.

McCay's laboratory on May 29, 1935. It is not known how Gregg initially came to know of McCay's research. Maynard probably contacted the foundation as a former recipient of a Rockefeller grant and discussed the promising work of a junior faculty member in his department. Gregg "much enjoyed [his] visit" and was very impressed by McCay's research.⁵⁹ Gregg reported to the foundation that McCay and his colleagues were "doing some interesting work on longevity in rats" which was worth supporting.⁶⁰ Yet Gregg found that the Natural Science Division would be a more appropriate financial sponsor of this research. Hence he handed over the project to the division officers, Warren Weaver and Frank Blair Hanson.⁶¹

The Natural Science Division was undergoing a major transformation under Weaver's directorship during the 1930s. According to Kohler, Weaver brought cross-disciplinary initiatives from the University of Wisconsin to the Natural Science Division after being appointed by Max Mason as its director.⁶² However, with the financial impact of the Great Depression forcing the foundation to abandon many of its prospective programs, he began to narrow the division's emphasis to projects in the life sciences rather than natural science in general.⁶³ Yet these projects in the life sciences had to be interdisciplinary studies, using tools borrowed from the physical sciences, rather than research in traditional biology. Weaver's broad cross-disciplinary initiative was transformed into a more focused study program on what he called the "vital processes" that should be studied using "mathematics, physics, and chemistry."⁶⁴

59. Gregg to Maynard, 3 Jun 1935, RF, Series 200D, Record Group 1.1, Box 136, Folder 1687.

60. "Cornell University—Nutrition," 31 Apr 1941–31 Dec 1941, RF, Series 200D, Record Group 1.1, Box 137, Folder 1689.

61. Gregg to Livingston Farrand, 3 Dec 1935, RF, Series 200D, Record Group 1.1, Box 136, Folder 1687.

62. Robert E. Kohler, *Partners in Science: Foundations and Natural Scientists, 1900–1945* (Chicago: University of Chicago Press, 1991), 268–73, 303–29.

63. *Ibid.*, 279–81. Other scholars have offered different interpretations. Daniel Kevles has argued that biological science received more attention since it could be an alternative to the physical sciences, which were thought to be the basis of new technology that was considered responsible for the economic crisis, at least partially. On the other hand, Lily Kay has argued that biological science was expected to reveal the basis of human behavior and might contribute to the proper solution of contemporary social problems concerning labor, heredity, and immigration. See Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (Cambridge, MA: Harvard University Press, 1971), 247–51; Lily E. Kay, *The Molecular Vision of Life: Caltech, the Rockefeller Foundation, and the Rise of the New Biology* (Oxford: Oxford University Press, 1993), 22–57. Also see A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities* (Baltimore: Johns Hopkins University Press, 1986), 344–68.

64. Weaver memo, 27 Jan 1933, RF, Series 915, Record Group 3.

As Kohler has shown, these studies were problem-solving rather than discipline-oriented, and they were expected to overcome “ancient limitations” in the traditional biological sciences.⁶⁵

Weaver’s funding policy fit well with McCay’s proposed research. While not giving up his hope of using caloric restriction in animal husbandry, McCay was trying to expand the scope of his research as a cross-disciplinary project, borrowing a variety of approaches used in biochemistry, biophysics, physiology, pathology, and psychology. This plan was probably related to his search for research money in the difficult time of the Depression.⁶⁶ Since he viewed the Rockefeller Foundation’s interest in his work as too good an opportunity to miss in the 1930s when the state college’s budgets were substantially cut, he tried to fit his research into the foundation’s new policy. But the structure of nutrition science was also important in guiding the direction of his investigation. As several historians have shown, nutrition was related to many disciplines and subdisciplines in the life sciences, such as biochemistry, genetics, clinical medicine, agriculture, and animal husbandry.⁶⁷ Certainly, nutrition research was often conducted by biochemists and geneticists who worked in agricultural institutions and sometimes produced results relevant to medicine and other fields. In this sense, McCay was attempting to broaden the potentiality of his discipline.

In the research statement submitted to the foundation, McCay detailed his project. He proposed to study changes in the biochemical, pathological, and physical properties of the aged animal’s body through long-term feeding of specific diets.⁶⁸ Mental alterations accompanying aging in rats on a particular diet would also be studied with the help of experimental psychologists.⁶⁹ Moreover, his research could extend to an investigation of diet’s effect on sex and

65. Kohler, *Partners in Science* (ref. 62), 276–77.

66. See Frank Blair Hanson Diary, 17–18 Dec 1935, RF, Record Group 12.1; Carl E. Ladd to Hanson, 27 Mar 1936, RF, Series 200D, Record Group 1.1, Box 136, Folder 1687.

67. For example, the discovery of vitamin A, which was made by biochemists in agricultural institutions, was important for medicine as well, and genetic research in agricultural institutions was related to nutrition. See Barbara Kimmelman, “Mr. Blakeslee Builds His Dream House: Agricultural Institutions, Genetics, and Careers, 1900–1915,” *JHB* 39, no. 2 (2006): 241–80, on 253–70; Charles E. Rosenberg, *No Other Gods: On Science and American Social Thought* (Baltimore: Johns Hopkins University Press, 1976), esp. 153–72, 200–24.

68. “The Influence of Diet upon the Physiological and Biochemical Changes which Accompany Aging in the Animal Body: General Statement of Project,” undated, but written in 1935, RF, Series 200D, Record Group 1.1, Box 136, Folder 1687, pp. 4–5.

69. *Ibid.*, 6.

reproduction, which the foundation actively supported at the time.⁷⁰ McCay's observation of underfed rats' reproductive problems became a starting point for further studies of the interrelationship of age, diet, and reproduction, which had broader implications.⁷¹

McCay's research was designated as the science of nutrition, a major area supported by Weaver's division.⁷² McCay could have chosen "aging" to describe his project, but had he done so, the foundation might not have funded him. Aging research was not a field the foundation was promoting at that time.

Another significant issue related to the direction of McCay's research was how the Rockefeller money could be supplemented by other sources of funding, including the state and federal budgets appropriated for the state college's agricultural research. According to the foundation's position, the responsibility for supporting a scientific program within an institution should be shared among other patrons, and above all by the institution itself, up to the amount it could pay. To resolve this issue and discuss other topics, Hanson visited Ithaca in December 1935. He suggested that Cornell's Agricultural College should fund McCay from its annual budgets, particularly those appropriated according to the Bankhead-Jones Act which was created in 1935 to support land-grant colleges. Yet McCay, along with Maynard, asserted that Cornell would receive only \$15,000 for the year from the act, and there were some "[difficulties] of getting State or Federal money for work with rats" that were thought to be appropriate for basic, rather than agricultural, investigations.⁷³ According to Hanson, McCay and Maynard said that "if they are to do pure research they must continue on the small funds available or get outside help." Strangely, however, they also claimed that their research would be useful for agriculture and animal husbandry. They stated that "at present farmers are

70. "The Influence of Diet upon the Physiological and Biochemical Changes Which Accompany Aging in the Animal Body: Supplementary Study," undated, but written in 1935, RF, Series 200D, Record Group 1.1, Box 136, Folder 1687. On the National Research Council's Committee for Research in Problems of Sex supported by the Rockefeller Foundation, see Adele E. Clarke, *Disciplining Reproduction: Modernity, American Life Sciences, and the Problems of Sex* (Berkeley: University of California Press, 1998), 90–120; Philip J. Pauly, *Biologists and the Promise of American Life: From Meriwether Lewis to Alfred Kinsey* (Princeton: Princeton University Press, 2000), 227–38.

71. "Influence of Diet," RF (ref. 70), 1.

72. Minutes of the Executive Committee of the Rockefeller Foundation, 26 Mar 1936, RF, Record Group 16; Maynard to Gregg, 31 May 1935, RF, Series 200D, Record Group 1.1, Box 136, Folder 1687; "Influence of Diet," RF (ref. 70), 1; "Committee Paper No. I," RF, Series 915, Record Group 3.1, Box 2, Folder 9, p. 3.

73. Frank Blair Hanson Diary, 17–18 Dec 1935, RF, Record Group 12.1.

interested in how early the hens begin to lay [eggs] and how early the heifers give milk, but with no account taken as to the length of time the hens lay [eggs] or the cows give milk.” Hence, “it might be a better economics to have eggs and milk given over a longer period,” and thus to eliminate the “present wasteful methods” which were to “get all the milk and eggs possible from the young animals and then discard.” To which direction, then, were McCay and Maynard planning to steer their future research? Since the problems of his underfed rats were not yet thoroughly observed, it is possible that McCay was still quite serious about his research’s usefulness for animal husbandry, while considering its expansion as a basic research project at the same time. It is also possible that the above claims were just rhetorical statements coming from McCay and Maynard, who wanted to emphasize the broad relevance of the research. In any case, Carl E. Ladd, dean of the Agricultural College, seemed to accept McCay’s claim about the agricultural applicability of his finding. Ladd wrote that “the projects . . . are of great interest to all of us” and suggested to Hanson that the college could provide not more than \$3,500 per year from the Bankhead-Jones Act to supplement the Rockefeller Foundation’s grant for McCay.⁷⁴

Yet Ladd was not completely confident about the usefulness of McCay’s research for local farmers’ immediate problems. He later wrote to Hanson that “we are under very great pressure from practical farmers to undertake certain investigations that mean much to them financially and that would undoubtedly have been supported by the State before this if we had not had the depression.”⁷⁵ Ladd suggested that if “it is going to be impossible for the Foundation” to support McCay he would “immediately relocate these [public] funds in such a way as to start work on some of the more pressing problems with the beginning of the crop year this spring.” For Ladd, who was more concerned about farmers during the Great Depression, McCay’s investigation was too close to basic research to be supported by the state college’s public funds.

But Ladd did not need to worry about relocating the research money. Since McCay’s project fit well within the category of cross-disciplinary research that the foundation was promoting at the time, and the peer evaluations of the project were also highly positive,⁷⁶ the executive committee of the foundation

74. Ladd to Hanson, 2 Jan 1936, RF, Series 200D, Record Group 1.1, Box 136, Folder 1687.

75. Ladd to Hanson, 27 Mar 1936, RF (ibid.).

76. All of his scientific colleagues—including McCay’s doctoral advisor C. L. A. Smith, renowned nutrition researcher Henry Sherman, and dean of the Agricultural College Carl Ladd—recommended his project for funding. See Frank Blair Hanson Diary, 17–18 Dec 1935, RF, Record Group 12.1.

decided to award \$42,500 to McCay and Maynard for five and a half years.⁷⁷ Maynard was named as the principal investigator, because McCay, who actually implemented the project, was still a junior faculty member. The amount of money awarded was quite large by 1930s standards. Only ten of fifty-two scientists funded by the Natural Science Division from 1933 to 1936 received more money than McCay did.⁷⁸

The Rockefeller grant gave McCay and his coworkers both material and social supports. They increased the number of the rats in the rat colony from 300 to 1,000, and bought new equipment such as X-ray apparatus, microtomes, galvanometers, and electrocardiographs.⁷⁹ Moreover, the prestigious award demonstrated to their contemporaries that their research was an important scientific work worthy of long-term support. An article in *Time*, published soon after the foundation's decision, reported that McCay and his colleagues were "learned, industrious biochemists [who] hope to validate the theory that the characteristics of youth can be retained . . . by special diets."⁸⁰

The grant also enabled McCay to hire new scientific personnel who could pursue novel lines of research, including physicist LeRoy Barnes, chemist Gordon Ellis, histologist Katherine Hummel, and microbiologist and laboratory assistant Gladys Sperling.⁸¹ These scholars studied the rats' senile changes by analyzing the bones' physico-chemical properties, such as the degree of calcification, recalcifying ability, breaking strength, and density.⁸² In this research, they used the X-ray apparatus to visualize the growth and senescence of the

77. Minutes of the Executive Committee of the Rockefeller Foundation, 26 Mar 1936, RF, Record Group 16.

78. "Appropriations Made in New Program, 1933, 1934, 1935, 1936," RF, Series 915, Record Group 3.1, Box 1, Folder 2. Of course, a comparison of absolute amounts of grants might not reveal how well funded a scientist was overall; other factors, such as the length of the term of funding, should also be considered.

79. Diet and Longevity: Excerpt from Trustee's Confidential Monthly Report, Jun 1937, RF, Series 200D, Record Group 1.1, Box 136, Folder 1688; "Rockefeller Foundation Research in Longevity, Outstanding Orders, Dec. 31 1936, Revised Statement March 19, 1937," RF, Series 200D, Record Group 1.1, Box 136, Folder 1688; "Expenditure from the Rockefeller Foundation Grant for Research in Longevity: January 1, 1937 to January 1, 1938," RF, Series 200D, Record Group 1.1, Box 137, Folder 1689.

80. "Diet for Age," *Time*, 20 Apr 1936.

81. "Rockefeller Foundation Research in Longevity, Outstanding Orders, Dec. 31 1936, Revised Statement March 19, 1937," RF, Series 200D, Record Group 1.1, Box 136, Folder 1688. Sperling finished her master's degree in microbiology at Cornell.

82. LeRoy Barnes and Gordon Ellis, "Studies of the Skeletons of Animals: A Progress Report," 1 May 1940, RF, Series 200D, Record Group 1.1, Box 137, Folder 1689.

rats' bones over time. McCay's team also investigated the effects of low-calcium diets on the bones' decalcification and fragility by adding sodium metaphosphate to the rats' diet, which made calcium ions in the food unavailable to the animals.

For McCay and his colleagues, dietary calcium was important because they believed that its deposition in various parts of the rat's body was related to the degree of aging. This belief stemmed from the common medical observation that aged bones tended to have less calcium than younger ones. Hence, the underfed rats' severely decalcified bones indicated that they constantly underwent aging during the extended life span, despite the relatively youthful appearance of their coats.⁸³ But the calcification of arteries accompanying arteriosclerosis showed that the relationship between the amount of calcium and the state of aging could be different in other organs. Unlike aging bones, aging arteries appeared to have more calcium deposits, which would often lead to arteriosclerosis. To McCay and his colleagues, this meant that the deposition of calcium was associated with the senile process in complex ways, which needed to be studied further. McCay's team thus systematically examined the amount of calcium in various organs of the underfed rats, such as their aorta, kidneys, eyes, and costal cartilages. According to this research, the costal cartilages of the underfed rats were less calcified than the controls, whereas the eyes, aorta, and kidneys of the same animals revealed more advanced calcification.⁸⁴ The result implied that each organ of the body was distinct in terms of its rate and mode of senile changes. As we will see, this finding would become important in the development of McCay's study as a gerontological project.

Scientists in other labs also became involved in McCay's research using his underfed rats that they could not yet produce by themselves. An important factor that made this possible was the increased number of rats in his colony, which enabled him to offer some of them to scientists in other institutions belonging to different disciplines. It was also significant that McCay became

83. C. M. McCay, "Chemical Aspects of Ageing," in *Problems of Ageing: Biological and Medical Aspects*, ed. E. V. Cowdry (Baltimore: Williams and Wilkins, 1939), 574. See also C. M. McCay, "The Conservative Attack upon Problems of Aging," *Geriatrics* 13 (1958): 709–17, on 712; Frank Pope, Wanda Lunsford, and C. M. McCay, "Experimental Prolongation of the Life Span," *Journal of Chronic Disease* 4 (1956): 153–58, on 156.

84. C. M. McCay, G. H. Ellis, LeRoy L. Barnes, C. A. H. Smith, and Gladys Sperling, "Chemical and Pathological Changes in Aging and After Retarded Growth," *JN* 18 (1939): 15–25.

more renowned among scientists through his prestigious Rockefeller grant, media exposure, and public presentations.⁸⁵ His participation in gerontology enhanced his reputation further in scientific communities and made his rats known to other researchers of aging. Probably for these reasons, Hanson wrote, “there are, from time to time, requests for materials from research workers in various institutions, and these materials are gladly furnished.”⁸⁶ Notably, “[out] of this type of co-operation some valuable contributions [were] made,” which appeared in the form of research papers coauthored by these investigators and McCay. For example, pharmacologist William MacNider at the University of North Carolina employed the tissue of McCay’s rats in his investigation into how senile changes affect susceptibility to certain chemicals.⁸⁷ J. R. Murlin at the University of Rochester acquired McCay’s animals to study their metabolism, while Clifton Smith, a dental researcher in Manhattan, employed them to investigate their teeth and jaw bones.⁸⁸ McCay’s rats were used by scientists affiliated with medical schools as well. For instance, A. Baird Hastings and his colleagues at Harvard Medical School studied the histochemical changes of the underfed rats’ skeletal muscle, observing that its chemical composition was close to that of younger rats.⁸⁹ Through the Josiah Macy Jr. Foundation’s funding, John Saxton, a pathologist at Cornell Medical College, also studied caloric restriction’s impact on McCay’s rats, especially their process of pathogenesis.⁹⁰ Remarkably, Saxton claimed that the frequency of lymphosarcoma, leukemia,

85. For McCay’s public presentation, see “Notes on A. M. A. Meetings, June 6–12, 1942,” GS, Box 1, Folder Notes on AMA meeting 1942. For the media exposure, see “Longer Life-Span in Biologists’ Aim,” *New York Times*, 31 Mar 1938; J. D. Ratcliff, “Let’s Live a Little Longer,” *Collier’s*, 13 Mar 1943; Edwin Teale, “Stay Hungry and Live Longer,” *Popular Science*, Oct 1941; James Rorty, “The Thin Rats Bury the Fat Rats,” *Harper’s Magazine*, May 1949.

86. Frank Blair Hanson Diary, 17 Jan 1939, RF, Record Group 12.1.

87. See, for example, MacNider to McCay, 13 May 1941, GS, Box 1, Folder Correspondence 1940–1941.

88. Frank Blair Hanson Diary, 21 Oct 1940, RF, Record Group 12.1; C. A. H. Smith, R. F. Light, and C. M. McCay, “Advanced Age in Relation to Dental Caries in White Rats,” *Journal of the American Dental Association* 26 (1939): 1700–03; C. A. H. Smith and C. M. McCay, “Advanced Age in Relation to Dental Caries in White Rats. II,” *Journal of the American Dental Association* 34 (1947): 340–44.

89. O. H. Lowry, C. M. McCay, A. B. Hastings, and A. N. Brown, “Histochemical Changes Associated with Aging. III. The Effects of Retardation of Growth on Skeletal Muscle,” *JBC* 143 (1942): 281–84.

90. Lawrence Frank to McCay, 14 Oct 1937; and McCay to Frank, 15 Oct 1937; both in NWS, Box 6, Folder Clive, McCay; Maynard to Weaver, 2 Dec 1937, RF, Series 200D, Record Group 1.1, Box 136, Folder 1688.

and chronic nephrosis was considerably decreased by caloric restriction.⁹¹ To Sexton and his colleagues, these results indicated that controlling caloric intake could become a means to study chronic diseases affecting many middle-aged and elderly patients.

There were also scientists who used McCay's rats but did not study caloric restriction or longevity. For example, John Nelson of the Rockefeller Institute requested some of McCay's aged rats to obtain a bacterium that he thought could be found in aged animal bodies.⁹² Likewise, Ernst Gellhorn of the University of Minnesota investigated the reaction time of the autonomic nervous system using McCay's very old rats.⁹³ Herbert Evans at the University of California also asked McCay to send him his old rats to conduct research on epiphysis, while William F. Windle at the University of Pennsylvania proposed to use the rats to study the senile changes of the central nervous system.⁹⁴

Several historians of science, such as Robert Kohler, Karen Rader, Rachel Ankeny, and Angela Creager, have analyzed an issue that is relevant to this facet of McCay's work. By tracing the uses of "model organisms"—such as fruit flies, mice, nematodes, and viruses—they have studied how scientists created networks of exchanging and disseminating experimental organisms that transformed and enlarged their scientific communities, the hierarchy within them, and the scope and character of scientific knowledge produced by them.⁹⁵ But I think that the case of McCay's rats was slightly different. Unlike Morgan's fruit flies or Little's mice, McCay's rats were not genetically standardized and could hardly be used for further breeding due to their old age and the reproductive problems incurred by caloric restriction. Nevertheless, in line with Creager's definition, McCay's rats were a model in the sense that they were prototypes through which several research questions on aging and energy intake were "defined and resolved" and were "useful precisely because they have already been so well studied."⁹⁶ Since the rat had already been widely used as a

91. John A. Saxton, "Nutrition and Growth and Their Influence on Longevity in Rats," in *Biological Symposia*, vol. 11, ed. Jaques Cattell (Lancaster, PA: Jaques Cattell, 1945), 177–96.

92. Sperling to Nelson, 25 Mar 1941, GS, Box 1, Folder Correspondence 1940–1941.

93. Gellhorn to McCay, 22 Jan 1945, GS, Box 1, Folder Correspondence 1944–1945.

94. Evans to McCay, 21 Feb 1944, GS, Box 1, Folder Correspondence 1944–1945; Windle to Gladys Sperling, 26 Apr 1949, GS, Box 1, Folder Correspondence and Christmas and Easter Newsletter 1949.

95. Kohler, *Lords of the Fly* (ref. 49), 133–70; Rader, *Making Mice* (ref. 49); Ankeny, "Wormy Logic" (ref. 49); Kass, Bonneuil, and Coe, "Cornfests, Cornfabs, and Cooperation" (ref. 49); Creager, *Life of a Virus* (ref. 49).

96. Creager, *Life of a Virus* (ref. 49), 5.

research organism by nutrition scientists, it could be employed by McCay to address the questions on caloric intake and longevity. The dissemination of McCay's rats to other scientists further enhanced their characterization as a model organism, since the researchers, through their various specialties, diversified the kinds of questions asked about McCay's rats. In this process, the fact that the rats could not breed further was probably not so much detrimental as beneficial to their increased use as model organisms, because it could make other scientists depend on McCay's supply of rats at least during the early years of research on caloric restriction. As McCay became known among other scientists as a chief supplier of old animals, his rats crossed disciplinary boundaries and spread to other labs as an experimental model useful for dealing with various questions on aging, longevity, diets, and other subjects.⁹⁷

Another aspect of model organisms which Creager articulated can also be found in the way McCay's rats influenced other scientists.⁹⁸ For them, the rats were exemplary animals showing a process that could be observed and studied in other organisms and under different conditions. Indeed, McCay's publications on rats were read by many scientists who learned about longevity and caloric restriction and began their own projects using different organisms. Admittedly, as I have stated, McCay was not the earliest scientist who investigated the effect of dietary restriction. Hence, it might not be historically correct to say that he and his rats were wholly responsible for prompting other researchers to start their research on various organisms. Yet many of them clearly acknowledged the significance of McCay's papers in the initiation of their experiments. For instance, W. H. Riesen's team at the University of Wisconsin studied the relation of dietary calories to longevity, cancer formation, and respiratory infection with Sprague-Dawley rats. Riesen and his colleagues wrote that "[the] present study was undertaken to determine whether this beneficial effect upon the length of the life span of rats would be as pronounced on the synthetic diet used in this laboratory as on the diet used by McCay *et al.*"⁹⁹ Anton Carlson and Frederick Hoelzel at the University of Chicago also examined how the life span of the rats obtained from the Wistar Institute was influenced by intermittent

97. For McCay's reputation as a supplier of old animals, see, Willard Roth to McCay, 10 Jan 1956, GS, Box 1, Folder Correspondence 1956–57; V. W. Steward to McCay, 19 May 1958, GS, Box 1, Folder Correspondence 1958–59.

98. Creager, *Life of a Virus* (ref. 49), 5–6.

99. W. H. Riesen, E. J. Herbst, Catherine Walliker, and C. A. Elvehjem, "The Effect of Restricted Caloric Intake on the Longevity of Rats," *American Journal of Physiology* 148 (1947): 614–17, on 614.

fasting and omnivorous/vegetarian diets. It is quite notable that in the opening paragraph of their article they cited McCay's "repeated findings" as a critical basis of their own research.¹⁰⁰ Scientists using water fleas, mice, and protozoa also read McCay's articles and became involved in the research to which he substantially contributed.¹⁰¹ For example, Lester Ingle, H. Howard Dunham, and other scientists at Brown University investigated how the longevity and heartbeat of water fleas were influenced by underfeeding.¹⁰² McCay's influence on these investigators was obvious, especially on Ingle, who began his article with the statement that "[in] line with a recent article in *Science* by Dr. C. M. McCay, some of the writer's experiments . . . may be of interest."¹⁰³

Many of these researchers began to study caloric restriction's effect using organisms with standardized genetic backgrounds. As early as 1938 Howard Dunham employed the clones of a single water flea in his research on longevity and dietary restriction.¹⁰⁴ The investigators using mice also adopted inbred strains, particularly those supplied by the Jackson Memorial Laboratory. For example, Maurice Visscher and other scientists at the University of Minnesota employed the C3H mouse strain for their investigation of caloric restriction and cancer incidence, and Martin and Ruth Silberberg at Washington University used the C57 strain in their study of high fat diets and the joints of aging mice.¹⁰⁵

While McCay and other scientists using rats did not then employ inbred animals, they certainly were concerned about the significance of genetic factors.

100. Anton J. Carlson and Frederick Hoelzel, "Apparent Prolongation of the Life Span of Rats by Intermittent Fasting," *JN* 31 (1946): 363–75, on 363. See also Anton J. Carlson and Frederick Hoelzel, "Growth and Longevity of Rats Fed Omnivorous and Vegetarian Diets," *JN* 34 (1947): 81–96.

101. On early experiments on mice, see H. P. Rusch, B. E. Kline, and C. A. Baumann, "The Influence of Caloric Restriction and of Dietary Fat on Tumor Formation with Ultraviolet Radiation," *Cancer Research* 5 (1945): 431–35. For a research project using protozoa, see Maria Rudzinska, "Overfeeding and Life Span in *Tokophrya Infusum*," *JG* 7 (1952): 544–48.

102. Lester Ingle, Thelma R. Wood, and A. M. Banta, "A Study of Longevity, Growth, Reproduction and Heart Rate in *Daphnia Longispina* as Influenced by Limitations in Quantity of Food," *Journal of Experimental Zoology* 76 (1937): 325–52; H. Howard Dunham, "Abundant Feeding Followed by Restricted Feeding and Longevity in *Daphnia*," *Physiological Zoology* 11 (1938): 399–407.

103. Lester Ingle, "Effects of Environmental Conditions on Longevity," *Science* 78 (1933): 511–13, on 511.

104. Dunham, "Abundant Feeding" (ref. 102), 399.

105. Maurice B. Visscher, Zelda B. Ball, Richard H. Barnes, and Ivar Sivertsen, "The Influence of Caloric Restriction upon the Incidence of Spontaneous Mammary Carcinoma in Mice," *Surgery* 11 (1942): 48–55; Martin Silberberg and Ruth Silberberg, "Effects of a High Fat Diet on the Joints of Aging Mice," *Archives of Pathology* 50 (1950): 828–46.

But there is no evidence that they ever used inbred strains as late as the early 1960s when McCay retired.¹⁰⁶ They probably thought that the use of genetically standardized animals was not a highly urgent matter. It is also noticeable that their research using random-bred strains was not considered particularly unreliable or untrustworthy. As far as the records show, Warren Weaver was the only person who raised this issue, and even he did not think that the absence of inbred rats in McCay's colony was a serious problem which might lead to the termination of McCay's Rockefeller grant. Nonetheless, McCay did have some worries on this issue and conducted an experiment in 1946 to examine the influence of heredity on longevity. This experiment showed that a rat's litter of origin was related to its life span, indicating that genetically close individuals tended to have comparable life spans. Indeed, after the early 1930s, he had tried to minimize the hereditary influence on longevity "by the assignment of individuals from the same litter to different groups" that were subsequently reared on distinct diets.¹⁰⁷ Although this procedure was certainly not enough to make the rats' genetic background homogeneous, McCay thought that it decreased the degree of hereditary influence on their life span.

In his later publications, McCay stated that he became more serious about the genetic factors involved in life span and even argued that the study of genes' role in longevity should become a part of cooperative research in gerontology. In 1948 he claimed that "inheritance plays a vital part in predetermining the life span" and that genetic approaches should be adopted for research on longevity, along with pathological, psychological, and nutritional approaches.¹⁰⁸ Although McCay himself felt that he was "not familiar with experimental evidence" in genetics and never employed the methodologies in the discipline in his subsequent works, he hoped that geneticists would join the multidisciplinary efforts to investigate the influence of caloric restriction on longevity and aging.¹⁰⁹

106. C. E. Brown, L. L. Barnes, G. Sperling, and C. M. McCay, "Radioactive Calcium Osteosarcomas and Squamous Carcinomas: Influence of Dietary Restriction and Retarded Growth on Incidence," *Cancer Research* 20 (1960): 329–34, on 330.

107. Gladys Sperling, J. K. Loosli, L. L. Barnes, and C. M. McCay, "The Effect of Coffee, Human Diets, and Inheritance upon the Life Span of Rats," *JG* 1 (1946): 426–32, on 431.

108. C. M. McCay, "Gerontology and Nutrition," in *Biological Foundations of Health Education: Proceedings of the Eastern States Health Education Conference, April 1–2, 1948* (New York: Columbia University Press, 1950), 84–85.

109. McCay to E. V. Cowdry, 28 Oct 1946, EVC, Box 41, Folder 10. Later researchers did begin to study how the genes were involved in restricted diets' impact on the duration of life and senescence. For example, see David B. Allison, Richard A. Miller, Stephen N. Austad, Claude

An important factor responsible for the renewal of McCay's Rockefeller grant in 1941 was that he had encouraged these multiple lines of research on senescence and life span. When Hanson requested an evaluation of McCay, pathologist Eugene Opie of Cornell emphasized that McCay's works contributed to the medical understanding of cancer formation by showing the reduced occurrence of tumors in underfed rats.¹¹⁰ William Ladd, dean of Cornell Medical College, pointed out that McCay's research raised an important issue concerning public health and nutrition, asking "whether it is a wise thing to feed one's children so that they grow rapidly to large stature and are kept well nourished all along through childhood and adolescence, or whether it might possibly be wiser for the sake of health and longevity to not so force them."¹¹¹ Robert Coker, ex-chairman of the Division of Biology and Agriculture of the National Research Council (NRC), commented that "McCay's animals could serve not only for him and his staff but also be sources of authentic materials for research by others in different institutions."¹¹² Similar to Coker, Anton Carlson wrote that McCay distributed "valuable materials to other workers in this field, such as MacNider of the University of North Carolina."¹¹³ MacNider himself wrote a very enthusiastic letter showing his firm belief that "[McCay's] work . . . has been of the greatest value in obtaining information concerning the influence of fundamental factors on the process of ageing."¹¹⁴ Such statements brought about highly positive comments on McCay's project during the executive meeting of the foundation. It was emphasized that "a valuable by-product of these researches is co-operation with a number of investigators in other institutions" who had various distinct specialties.¹¹⁵ The executive committee thus decided to award \$60,000 to McCay's research on aging and longevity beginning in 1942.

It is noteworthy that Maynard's name disappeared in the project description, and McCay's research was designated as a study of aging and longevity rather

Bouchard, Rudolph Leibel, Simon Klebanov, Thomas Johnson, and David E. Harrison, "Genetic Variability in Responses to Caloric Restriction in Animals and in Regulation of Metabolism and Obesity in Humans," *Journals of Gerontology: Series A* 56A (2001): 55–65.

110. Hanson to Opie, 31 Jan 1941, and Opie to Hanson, 1 Feb 1941, both in RF, Series 200D, Record Group 1.1, Box 137, Folder 1690.

111. Ladd to Hanson, 6 Feb 1941, RF (ibid.).

112. Coker to Hanson, 5 Feb 1941, RF (ibid.).

113. Carlson to Hanson, 5 Feb 1941, RF (ibid.).

114. MacNider to Hanson, 4 Feb 1941, RF (ibid.).

115. Minutes of the Executive Committee of the Rockefeller Foundation, 2 Apr 1941, RF, Record Group 16.

than nutrition. These changes, significant to McCay's later career, were related to the emergence of "this field" mentioned by Carlson in the above comment, to which McCay, MacNider, Coker, and Carlson himself belonged. What, then, is "this field"?

This question can be answered by examining the formation of gerontology in the United States, whose origins can be traced to at least two historical factors. As I have argued elsewhere, the first factor is the Great Depression.¹¹⁶ While the actual social and economic condition of the elderly at that time is a subject of debate, many Americans perceived that the elderly were suffering from the problems of the Depression more severely than those in other age groups.¹¹⁷ In particular, it was pointed out that many elderly and even middle-aged people were experiencing difficulties due to worsening age discrimination in the shrinking job market and the collapse of private pension plans. While the federal government passed the Social Security Act to amend these problems, a group of scientists responded to it in their own way by taking a step toward the making of gerontology as the science of old age. But the social problems of aging in the 1930s were not the same as the "problems of aging" defined by gerontologists. The latter were broader than the former, because gerontologists' problems included issues defined by their research as well as the social problems of old age and the elderly.

The second factor that contributed to the creation of gerontology can be found in the nature of the research, especially that by several leading scientists such as Alexis Carrel, C. M. Child, and Raymond Pearl, who brought forth the new practices and conceptions regarding senescence.¹¹⁸ In at least three aspects, their perspectives and approaches were different from those of earlier doctors and naturalists, such as Galen, Roger Bacon, Christopher Hufeland, and Xavier Bichat. First, as renowned experimental scientists, they actively attempted manipulation of the mode and rate of aging, which had seldom been

116. Park, "Edmund Vincent Cowdry" (ref. 8), 544–64.

117. W. Andrew Achenbaum, *Social Security: Visions and Revisions, A Twentieth Century Fund Study* (Cambridge: Cambridge University Press, 1986), 13–37; Carole Haber and Brian Gratton, *Old Age and the Search for Security: An American Social History* (Bloomington: Indiana University Press, 1994), 139–42; 181–85; John Macnicol, *Age Discrimination: An Historical and Contemporary Analysis* (Cambridge: Cambridge University Press, 2006), 211–23; William Graebner, *A History of Retirement: The Meaning and Function of an American Institution, 1885–1978* (New Haven: Yale University Press, 1980), 181–214.

118. For various reasons, Carrel, Pearl, and Child did not participate in the creation of gerontology despite their substantial contributions to it.

tried before the late nineteenth century.¹¹⁹ Second, through the development of cytology, histology, and other disciplines that focused on life's minute details, they began to find different modes and rates of senescence in many distinct localities of the body.¹²⁰ This was a departure from the ideas and practices of earlier scholars, who thought that senile changes of the whole body proceeded through the decline of a single mysterious factor such as "innate heat."¹²¹ Third, the new scientists believed that senile changes were contingent on environmental, evolutionary, and developmental processes in many forms of life, including microbes, plants, and some types of animal tissues.¹²² This conception was different

119. See, for example, Alexis Carrel, "Rejuvenation of Cultures of Tissues," *Journal of the American Medical Association* 57 (1911): 1611; C. M. Child, *Senescence and Rejuvenescence* (Chicago: University of Chicago Press, 1915), 58–59, 186; Edwin G. Conklin, "The Size of Organisms and of Their Constituent Parts in Relation to Longevity, Senescence and Rejuvenescence," in *The Harvey Lectures*, series 8 (Philadelphia: Lippincott, 1913).

120. See Charles S. Minot, *The Problem of Age, Growth, and Death: A Study of Cytomorphosis* (New York: Putnam, 1908), 214–16; Alfred E. Cohn and Henry A. Murray, Jr., "Physiological Ontogeny I. The Present Status of the Problem," *Quarterly Review of Biology* 2 (1927): 469–93, on 482, 490; Raymond Pearl, *The Biology of Death* (Philadelphia: Lippincott, 1922), 138–49, 225; Alexis Carrel, "Tissue Culture and Cell Physiology," *Physiological Reviews* 4 (1924): 1–20; E. V. Cowdry, "Ageing of Tissue Fluids," in *Problems of Ageing: Biological and Medical Aspects*, ed. E. V. Cowdry (Baltimore: Williams and Wilkins, 1939), 643, 685, 689. See also Nathan W. Shock, "Ageing of Homeostatic Mechanism," in *Cowdry's Problems of Ageing*, 3rd edn., ed. Albert I. Lansing (Baltimore: Williams and Wilkins, 1952), 421, 429–31, 436, 438; A. J. Carlson to Cowdry, 28 Jun 1937, WDM, Box 10, Folder 397. For a brief summary of this issue, see Park, "Edmund Vincent Cowdry" (ref. 8), 546.

121. Among numerous books and papers, see Hippocrates, "Aphorisms," in *The Genuine Works of Hippocrates*, trans. Francis Adams (Baltimore: Williams and Wilkins, 1939), 294; Galen, "The Nature and Sources of Growth and of Disease," in *A Translation of Galen's Hygiene*, trans. Robert Montraville Green (Springfield, IL: Charles C. Thomas, 1951), 6–8; Roger Bacon, *The Cure of Old Age and Preservation of Youth* (London: Tho. Flesher and Edward Evets, 1683), 2; Francis Bacon, preface to *History Natural and Experimental of Life and Death or the Prolongation of Life* (London: William Lee and Humphrey Moseley, 1658); Christopher William Hufeland, *The Art of Prolonging Life* (London: J. Bell, 1797), 35, 63–64; Marie François Xavier Bichat, *Physiological Researches upon Life and Death*, trans. Tobias Watkins (Philadelphia: Smith and Maxwell, 1809), 1–2; Homer Bostwick, *An Inquiry into the Cause of Natural Death or Death from Old Age* (New York: Stringer and Townsend, 1851), 7.

122. Botanists were probably the first group of scientists who observed the contingency of aging. See Friedrich Hildebrand, "Die Lebensdauer und Vegetationsweise der Pflanzen, ihre Ursache und ihre Entwicklung," *Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie* 1 (1881): 51–135; William Crocker, "Ageing in Plants," in Cowdry, ed., *Problems of Ageing* (ref. 120), 27. The control of the protozoa's aging was also attempted and investigated. See Herbert Spencer Jennings, "Genetics of the Protozoa," *Bibliographia Genetica* 5 (1929): 213–26; "Senescence and Death in Protozoa and Invertebrates," in Cowdry, ed., *Problems of Ageing* (ref. 120), 40. For a good historical analysis of Alexis Carrel's argument for the contingency of

from that of earlier scholars and doctors who, based only on their observation of humans' aging, thought that senescence occurred in an inevitable and unidirectional way, at invariant rates.¹²³ Early American gerontologists—such as Edmund Vincent Cowdry, William deB. MacNider, Nathan Shock, and Alfred Cohn—were well aware of these new developments and made their own contributions through their research. Their simultaneous efforts to establish the science of aging were heavily indebted to these new biomedical and biological possibilities, approaches, and practices.

While these early progenitors were mostly biologists and biomedical scientists, gerontology subsequently developed as a broader, multidisciplinary field. Although this resulted from many factors, an important cause was the gerontologists' view of senile changes, which, for them, were complex phenomena with biological, social, medical, and psychological aspects. The early scientists of aging were deeply interested in how their research was relevant to their contemporary society and the elderly person's place in it. This broader view of aging was particularly true for Cowdry, a leading cytologist and gerontologist at Washington University, who had absorbed the discourses on the interrelatedness of biological knowledge and social structures from the senior scholars he came to know well during his training, such as John Dewey, Walter Cannon, and C. J. Herrick.¹²⁴ According to Cowdry, while "all living things age . . . at the human level . . . the study of aging becomes more complicated because of the entry of social and economic factors."¹²⁵ These factors should be "added to the hereditary, environmental, chemical, and physical factors that operate in a

senescence and immortality, see Hannah Landecker, *Culturing Life: How Cells Became Technologies* (Cambridge, MA: Harvard University Press, 2007), 68–106.

123. In addition to the primary sources cited in ref. 121, see Thomas R. Cole and Mary G. Winkler, "Aging in Western Medicine and Iconography: History and the Ages of Man," *Medical Heritage* 1 (1985): 336–47; M. D. Grmek, "On Ageing and Old Age: Basic Problems and Historic Aspects of Gerontology and Geriatrics," in *Monographiae Biologicae*, vol. 5, no. 2, ed. F. S. Bodenheimer and W. W. Weisbach (Den Haag, The Netherlands: Junk, 1958), 8–22; Richard L. Grant, "Concepts of Aging: An Historical Review," in *Roots of Modern Gerontology and Geriatrics*, ed. Gerald J. Gruman (New York: Arno, 1979), 443–78.

124. Park, "Edmund Vincent Cowdry" (ref. 8), 533–36. On the discourse on biology and society among American biologists in the early twentieth century, see Sharon Kingsland, "Toward a Natural History of Human Psyche: Charles Manning Child, Charles Judson Herrick, and the Dynamic View of the Individual at the University of Chicago," in *The Expansion of American Biology*, ed. Keith R. Benson, Jane Maienschein, and Ronald Rainger (New Brunswick, NJ: Rutgers University Press, 1991).

125. Minutes of the Business Meeting, Fifteenth Conference on Problems of Aging, 22 Jan 1953, NWS, Box 30, Folder Macy Conference on Aging 1953 [final], p. 2.

great many levels of animals and plants,” and for this reason, “the appraisal and the approach must . . . be multidisciplinary.”¹²⁶ As I have analyzed elsewhere, this argument, along with his other similar statements on multidisciplinary, can be understood in terms of the broader contemporary social issues concerning old age, such as pension, retirement, and age discrimination, as well as the developments in the biological and biomedical study of aging during the early twentieth century.¹²⁷

There were other factors that contributed to the multidisciplinary of gerontology. As many historians have described, the early twentieth century was a time of increasing attempts to cross disciplinary boundaries in the natural and medical sciences, which often resulted in the creation of specific, problem-oriented projects, such as the reproduction research sponsored by the NRC and the spectroscopy project at Caltech.¹²⁸ The transformation of the Rockefeller Foundation is such a case, and similar movements took place in several universities, research institutions, and philanthropies, such as Caltech, the University of Wisconsin, Stanford University, the University of Chicago, the NRC, the Marine Biological Laboratory at Woods Hole, and the Josiah Macy Jr. Foundation. The reasons for promoting such cross-disciplinary efforts were diverse, including a number of scientists’ increasing awareness of broader societal implications of natural science, their reaction against rigid disciplinary boundaries, and their hopes for scientific innovation through interdisciplinary cross-fertilization. Amid these various endeavors, gerontology was created, as we can see from Cowdry’s career. He brought the ideal of cooperative and

126. Ibid.

127. Hyung Wook Park, “Refiguring Old Age: Shaping Scientific Research on Senescence, 1900–1960” (PhD dissertation, University of Minnesota, 2009), 2, 31, 40–2, 49, 63, 307–11.

128. Robert H. Kargon, “Temple to Science: Cooperative Research and the Birth of the California Institute of Technology,” *HSPS* 8 (1977): 3–31; Stuart W. Leslie, “Playing the Education Game to Win: The Military and Interdisciplinary Research at Stanford,” *HSPS* 18, no. 1 (1987): 55–88, on 57–61; Glenn E. Bugos, “Managing Cooperative Research and Borderland Science in the National Research Council, 1922–1942,” *HSPS* 20, no. 1 (1989): 1–32; Kohler, *Partners in Science* (ref. 62), 268–83, 303–29. On the cooperative environment at the University of Chicago and Woods Hole, see Jane Maienschein, “Cytology in 1924: Expansion and Collaboration,” in Bensen, Maienschein, Rainger, *Expansion* (ref. 124); Jane Maienschein, “Whitman at Chicago: Establishing a Chicago Style of Biology?” in *The American Development of Biology*, ed. Ronald Rainger, Keith Benson, and Jane Maienschein (Philadelphia: University of Pennsylvania Press, 1988); W. E. Garrey and E. V. Cowdry, “Marine Biological Laboratory Increases Activities,” *The Nation’s Health* 7 (1925): 805–08. The Macy Foundation’s cross-disciplinary programs have not been well studied. But see “Extract from a Letter November 21, 1947 from Dr. Frank Fremont-Smith to Dr. E. V. Cowdry,” EVC, Box 41, Folder 8.

interdisciplinary research from the University of Chicago and the Marine Biological Laboratory, where he was trained, to the science of aging, which was supported by the Macy and Rockefeller Foundations.¹²⁹ When he started creating gerontology as a new research field, a well-established organizational model had already existed in major research institutions and sponsors with which he was interacting.

The Rockefeller Foundation's renewal of McCay's grant with the different designation and the changed principal investigator reflected the creation of this new scientific field. After joining the group of researchers who were then constructing gerontology, McCay continuously stressed the relevance of his research to the aging process in his progress reports to the foundation, and often called his work "the Aging project" rather than research on nutrition.¹³⁰ His promotion to full professor in 1936 qualified him to be the principal investigator of this renamed project. It is also important that Weaver and Hanson were aware of the NRC's Committee on Biological Processes of Ageing, which was formed in 1938 by gerontologists and tried to seek research funds from the foundation. Although the committee's effort was not successful at that time, it informed the foundation officers of the creation of gerontology as a scientific field and of its major organizers.¹³¹ Indeed, after the 1940s, the foundation began to spend more money supporting aging research projects, including Robert Havighurst's social gerontology program at the University of Chicago and Franz J. Kallmann's genetic study of mental illness in old age at Columbia University.¹³²

But the changes in the details of the terms of McCay's Rockefeller grant did not mean that he gave up his nutrition research to become a gerontologist. In the 1940s and 1950s, he continued his study of nutrition for humans and animals. In 1943, for instance, he published *Nutrition of the Dog*, later to become

129. Park, "Edmund Vincent Cowdry" (ref. 8), 533–44.

130. "C. M. McCay and John A. Saxton (cont'd.)," 21 Oct 1940; and C. M. McCay, "The Influence of Diet upon the Physiological and Biochemical Changes which Accompany Ageing in the Animal Body: A Progress Report," 17 Apr 1940, both in RF, Series 200D, Record Group 1.1, Box 137, Folder 1689.

131. Frank Blair Hanson Diary, 12–13 Oct 1943, RF, Series 200, Record Group 2, Box 243, Folder 1680. Its failure in fundraising was partially due to the administrative obstacles of the borderland committees within the NRC. See Bugos, "Managing Cooperative Research" (ref. 128), 29–32.

132. Minutes of Meeting of the Executive Committee of the Rockefeller Foundation, 19 Jan 1945; and 13 Jun 1947; both in RF, Record Group 16; Leland DeVinyne to Norman Buchanan, 5 Oct 1955, RF, Series 910, Record Group 3.1, Box 3, Folder 22.

a classic monograph summarizing the current knowledge on feeding dogs. During World War II he also became involved in the investigation of the nutritional adequacy of military rations as the head of the Mobile Nutrition Unit of the National Naval Medical Research Institute.¹³³ After the war he continued participating in various nutrition projects, such as research on the problems of irradiated food and the effect of soft drinks on teeth.¹³⁴

McCay's work indicates not so much his hesitation in changing his major research fields as the typical path toward becoming a gerontologist. He remained loyal to the science of nutrition in which he was originally trained, while trying to contribute to gerontology as an expert in his discipline in cooperation with those from different disciplines. Other gerontologists followed similar paths. Cowdry never ceased to be a cytologist during his attempts to establish gerontology, and Walter Miles continued to work as both a psychologist and gerontologist. Likewise, MacNider continued to pursue his research in pharmacology while becoming a scientist of aging, whereas Havighurst maintained his dual professional identity as a social scientist and gerontologist. Thus the science of aging was created as a multidisciplinary field by scholars who kept their original disciplinary affiliation and applied their expertise to the study of aging.¹³⁵

As Achenbaum asserts, the first step in the field's development was taken when Cowdry edited *Problems of Ageing* (1939).¹³⁶ Indeed, Cowdry was already highly renowned as the editor of several cytology textbooks and medical handbooks, such as *General Cytology* (1924), *Special Cytology* (1928), *Human Biology and Racial Welfare* (1930), and *Arteriosclerosis* (1933). These books were written by many authors with different specialties and research backgrounds, reflecting the current biomedical and biological understanding of cells, humans, and chronic illnesses, which, for them, were complex subjects demanding

133. See, for example, "Food Experts Here for Study," *Norfolk Seabag: U. S. Naval Training Station*, 13 May 1944.

134. C. M. McCay and G. L. Rumsey, "Final Report—Part I: Effect of Ionized Radiation on the Nutritive Value of Food (Beef) as Determined by Growth, Reproduction, and Lactation Studies with Dogs," 15 Mar 1960, CMM, Box 8; J. S. Restarski, R. A. Gortner, Jr., and C. M. McCay, "Effect of Acid Beverage Containing Fluorides upon the Teeth of Rats and Puppies," *Journal of the American Dental Association* 32 (1945): 668–75.

135. In this sense, gerontology is similar to materials science, because both fields benefit from contributions by scholars who maintain their own disciplinary affiliation. See Bernadette Bensaude-Vincent, "The Construction of a Discipline: Materials Science in the United States," *HSPS* 31, no. 2 (2001): 223–48.

136. Achenbaum, *Crossing Frontiers* (ref. 8), 52–84.

multidimensional approaches.¹³⁷ But maintaining coherence and consistency within these books was a problem, and Cowdry not only had to devise ways to recruit the best contributors from many different research fields, but also to master the art of eliminating or reducing contradictions and inconsistencies among the books. *Problems of Ageing*, a product of such efforts, helped him to become a proficient editor who could organize a book out of the distinct initiatives, perspectives, and norms of various authors. During this work, his roles as president of the Union of American Biological Societies and chairman of the Division of Medical Research within the NRC were also important. In these positions he came to know many prominent natural and medical scientists in the United States, among whom he found contributors to his edited volumes. To edit *Problems of Ageing*, which he hoped to publish as a comprehensive multidisciplinary survey like his former textbooks and handbooks, he also invited articles by a number of eminent scientists: cardiologist Alfred Cohn, psychologist Walter Miles, and physiologists Walter Cannon and Anton Carlson. Significantly, they were among the scholars who helped establish gerontology as a multidisciplinary field and formed its core research group during the early years.

McCay's participation in gerontology also began when Cowdry asked him to contribute to *Problems of Ageing*. It is not known why Cowdry invited McCay. He was the youngest and perhaps the least experienced scientist among the contributors. But McCay had already published several articles on longevity and nutrition. As a renowned textbook editor and the leader of the two scientific organizations, it is likely that Cowdry knew of his work. McCay gladly accepted Cowdry's invitation and replied that aging was a significant problem "in both human life and in animal husbandry."¹³⁸ In particular, he believed that the relation of nutrition to aging was very complex and should be investigated through the cooperation of several distinct fields. Unfortunately, McCay added, aging had not been studied extensively, due to "the extreme slowness with which one gets results and also the difficulty of securing appropriations to cover periods of five years, which are about the smallest time units to consider." Yet he was fortunate to acquire such appropriations from the Rockefeller Foundation, which enabled him to cooperate with a number of scholars trained in a variety of disciplines on a long-term basis. Cowdry was very

137. See Maienschein, "Cytology in 1924" (ref. 128); Clarke, *Disciplining Reproduction* (ref. 70); Christopher Lawrence and George Weisz, eds., *Greater than the Parts: Holism in Biomedicine, 1920–1950* (Oxford: Oxford University Press, 1998).

138. McCay to Cowdry, 30 Nov 1936, EVC, Box 32, Folder 21.

pleased with this reply, since he, as a former editor of cytology textbooks, also aimed at publishing a book that would deal with aging through interdisciplinary collaboration.¹³⁹ Cowdry asked McCay to write the chapter on the chemical aspects of aging, which included McCay's own research on caloric restriction.

This seemingly smooth and pleasant exchange of correspondence between Cowdry and McCay belies the different aspirations and objectives of the two scientists. Cowdry aimed at publishing a handbook based on the collaboration of contributors with distinctive specialties. What was important for him was not yet to create gerontology, but to edit a multi-authored but relatively coherent book with submissions by the best investigators in each field. As a young scientist of nutrition, McCay's goal was different. He developed his research as a multi-disciplinary project in response to the situations surrounding him, including the transformation of the Natural Science Division of the Rockefeller Foundation. Therefore, Cowdry's invitation was a good opportunity for McCay; by writing a chapter in *Problems of Ageing*, he could disseminate the results of his research and its significance in the company of many senior and prestigious coauthors who might help him promote his research. Hence, it appears that Cowdry's contact with McCay was an accidental encounter of two professionals with distinct goals, who arrived at the same point in quite a coincidental way. But this encounter led to a closer relationship during the editorial process managed by Cowdry.

While the creation of gerontology was not still anticipated, Cowdry's editorial policy of promoting interaction among the contributors encouraged them to become more seriously interested in aging and to be acquainted with other investigators studying similar subjects. In fact, he had circulated every chapter's abstract or its partially completed version among the contributors while editing his earlier textbooks and handbooks. In a similar manner, Cowdry sent each chapter to the authors who were writing about related topics, and asked them to comment on it. This practice led the contributors to become more aware of the other authors' subjects and approaches that belonged to different disciplines.¹⁴⁰ Eventually, through the process of reading and commenting, the contributors came to communicate with one another independently, and began to feel they were part of a group that studied aging cooperatively.¹⁴¹

139. Cowdry to McCay, 12 Dec 1936, EVC (ibid.).

140. Park, "Edmund Vincent Cowdry" (ref. 8), 554–64.

141. For example, see Walter Miles to William MacNider, 8 Dec 1937, WDM, Box 11, Folder 47; Alfred Cohn to Walter Cannon, 29 Oct 1937, Alfred E. Cohn Papers, Rockefeller Archive Center, Sleepy Hollow, NY, Box 5, Folder 5; Anton Carlson to Cowdry, 20 Jul 1938, EVC, Box 25, Folder 23.

The first scientific conference on aging at Woods Hole, Massachusetts, in 1937 deepened the contributors' feeling of collegiality and helped to make their research programs, including those of McCay, a part of this nascent field. While Cowdry, with the sponsorship of the Macy Foundation, held the conference to facilitate discussions among the contributors to *Problems of Ageing*, it also strengthened their sense of community and gave them an opportunity to present their research projects to other participants.¹⁴² McCay attended this conference and enjoyed meeting with the other authors. According to him, the importance of his research was "stressed sufficiently at the meeting," although he wanted to hold another conference at Ithaca "in order that members may see the living animals" directly.¹⁴³ Indeed, some of the participants—particularly Carlson, MacNider, Hastings, and Henry Simms—began to study longevity and caloric restriction after this conference.¹⁴⁴ Furthermore, MacNider, Carlson, and Coker wrote strong letters of recommendation for McCay when he applied for a renewal of his Rockefeller grant in 1940.

Along with the above participants, McCay contributed to the establishment of the early professional organizations in gerontology. In fact, as Achenbaum and I have shown, the Woods Hole conference played a key role in the beginning of the science of aging in the United States by prompting Cowdry, McCay, and other participants to create the earliest communities devoted to the study of aging.¹⁴⁵ Initially, McCay and his colleagues formed the Committee on the Biological Processes of Ageing in 1938 and the Club for Research on Ageing in 1940.¹⁴⁶ While the committee's efforts were unsuccessful, the club continued until 1953 as a small elite organization of prominent researchers interested in aging. With the Macy Foundation's sponsorship, the club members held annual meetings during which they intensively discussed aging. They also established the Gerontological Society in 1945 as a national professional organization, and in 1946 launched the first academic journal devoted to the study of aging, the

142. E. V. Cowdry, "Woods Hole Conference on the Problems of Aging," *Scientific Monthly* 45 (1937): 189–91. See also Park, "Edmund Vincent Cowdry" (ref. 8), 562–64.

143. McCay to Cowdry, 1 Mar 1938, EVC, Box 32, Folder 21.

144. For Simms's work on this topic, see Benjamin N. Berg and Henry S. Simms, "Nutrition and Longevity in the Rat: Longevity and Onset of Disease with Different Levels of Food Intake," *JN* 71 (1960): 255–63.

145. Achenbaum, *Crossing Frontiers* (ref. 8), 64, 76–78, 98; Park, "Edmund Vincent Cowdry" (ref. 8), 562–63.

146. The club was formed by the encouragement of the Russian-British scientist, Vladimir Korenchevsky. See MacNider to Cowdry, 21 Mar 1938; and Cowdry to MacNider, 25 Mar 1938; both in EVC, Box 31, Folder 8; Cowdry to E. F. Williams, 18 Aug 1938, EVC, Box 42, Folder 22.

Journal of Gerontology. McCay published many articles in the early volumes of the journal, while serving the society as its fifth president in 1949. Moreover, he worked from 1946 to 1949 as a panel member of the NIH's Gerontology Study Section, which was the first peer-review-based extramural grant committee for researchers of aging. At the NIH, together with his gerontologist colleagues, he reviewed and selected applications, particularly those aimed at studying aging in relation to nutrition. When necessary, he visited applicants' laboratories before giving his advice on the desirability of funding.¹⁴⁷ In reviewing McCay's own grant application, other members of the section stated that "his research in the same field has been so extensive and has been carried on so long that there was little question as to the merit of this request."¹⁴⁸ His 1947–48 grant was \$29,109, and the NIH kept supporting his research thereafter.¹⁴⁹

One apparent reason for such a successful integration of McCay and his work into the new science of gerontology was the prospect of experimental manipulation of aging, visualized nicely in his publications. His papers appeared to represent a possible way to control the rate of senescence, which excited many investigators and led them to participate in gerontology. For instance, in his chapter in *Problems of Ageing*, McCay included a photo of the two rats of the same chronological age, whose differences were more striking than those between the two rats in his 1934 article. (Compare figures 1 and 2) The rat on the left, which looked quite senile and was dying, was normally fed, while the young rat on the right, which seemed to be healthy, active, and even appeared smiling, was raised with reduced dietary calories. Like the photo in his 1934 article, it was still unclear how this one was taken and how these two rats were chosen among the rats in his experiments. What was clear was that the striking difference between the two rats highlighted in the dark background was a culmination of nutrition researchers' visual technology, which McCay masterfully used. This photo argued that the aging process could be controlled by experimental means.

147. Gerontology Study Section Minutes of Meeting, 20 Nov 1946, p. 5; and 21 Feb 1947, p. 4; both in RGSS, Box 1, Folder Minutes of Meetings.

148. Gerontology Study Section Minutes of Meeting, 21 Feb 1947, RGSS, *ibid.*, p. 5.

149. Ernest M. Allen to McCay, 7 Jul 1947; David Price to McCay, 24 Feb 1949; Price to McCay, 1 Mar 1950; Allen to McCay, 24 Feb 1951, all in CMM, Box 21, Folder USPH 584 Prints 1952. After the Gerontology Study Section was disbanded in 1949, the National Heart Institute, to which Nathan Shock's Gerontology Research Center belonged, supported McCay's research. See "NIH Research and Training Grants Active on January 31, 1958," NWS, Box 12, Folder Annual Reports 1957, p. 17.

FIG. 2 Two rats of the same chronological age. Source: McCay, "Chemical Aspects" (ref. 83), 578. The original picture comes from CMM, Box 15, Folder Food-Nutrition Photo. The author has tried to find the copyright holder of this photo without success and assumes full legal responsibility for the republication of this material.

As McCay himself knew well, this photo "always [interested] people," including many prestigious scientists involved in aging research.¹⁵⁰ For instance, McCay sent a letter with this photo to Alexis Carrel—a Nobel Laureate in 1912 and an initiator of tissue culture techniques who surprised the world with his claim that cells could live indefinitely in certain culture conditions without undergoing senescence.¹⁵¹ McCay was well aware of Carrel's claim and expected that his photo would please him.¹⁵² In fact, Carrel exerted a substantial influence on many early American gerontologists including McCay, who regarded his "immortal" tissue culture as a proof that senescence could be postponed and manipulated.¹⁵³ McCay's rats could thus be considered another proof of the possibility of experimental manipulation of the aging process. Interestingly, Carrel replied that he already knew of McCay's research and had even delivered a lecture on it in 1935. Yet the difference between the two rats shown in the photo was still "quite striking" to Carrel.¹⁵⁴

150. McCay to Cowdry, 12 Feb 1937, EVC, Box 32, Folder 21.

151. Whereas Carrel's "immortal" tissue culture was often denounced after the 1960s as a fraud, its historical meaning has recently been reevaluated. See Landecker, *Culturing Life* (ref. 122); Melinda Cooper, "Resuscitations: Stem Cells and the Crisis of Old Age," *Body and Society* 12 (2006): 1–23.

152. McCay to Carrel, 18 Dec 1937, AC, Box 64, Folder 9.

153. On Carrel's influence upon early gerontologists, see E. V. Cowdry, "Ageing of Tissue Fluids," in Cowdry, ed., *Problems of Ageing* (ref. 120), 643; Edward J. Stieglitz to Carrel, 26 Jun 1940, AC, Box 69, Folder 27; Alfred Cohn to Carrel, 15 Oct 1935, AC, Box 41, Folder 22; Lawrence Frank to Carrel, 24 Oct 1935, AC, Box 61, Folder 41; T. Wingate Todd to Carrel, 9 Nov 1937, AC, Box 65, Folder 29.

154. Carrel to McCay, 21 Dec 1937, AC, Box 64, Folder 9; "Carrel Sees Lives Extended for Ages," *New York Times*, 13 Dec 1935.

When McCay's chapter in *Problems of Ageing*, including the above photo, was published, some scientists thought the photo revealed more about the rats than simply the changes in their outward appearance. The photo, impressive on its own, seemed to imply, if not definitely reveal, that a multitude of changes were occurring in the aging body. Indeed, McCay and colleagues' research on calcium deposition indicated that each portion of the rat's body underwent aging at a distinct rate and in a different mode. This research corresponded to the views of other major scientists of aging, who began to depart from the traditional view that the whole body's aging occurred at uniform rates through the decline of a single factor. McCay's research supported the new idea that senescence proceeded at different rates in distinct organs and tissues of the body.

But many of the senile changes in McCay's underfed animals still remained relatively unknown, and a number of scientists of aging became interested in studying these features more deeply and systematically. Indeed, six leading members of the Club for Research on Ageing—Cowdry, McCay, Hastings, Cannon, E. J. Stieglitz, and Jean Oliver—declared in 1941 that the study of caloric intake and longevity was a project in need of “immediate attention” and “greatly extended study.”¹⁵⁵ Vladimir Korenchevsky, the founder of the British Society for Research on Ageing, also praised McCay's “excellent experiments” in his letter to William MacNider and stated that a similar research project was being pursued at the University of Cambridge.¹⁵⁶ To these gerontologists, McCay created what they eagerly wanted—a doable, problem-oriented, and specific research project that could garner the cooperative involvement of scholars across established academic disciplines.

This current state and future prospects of research on caloric restriction as a multidisciplinary program was intensively discussed during the Conference on Nutritional Requirements for the Ageing Population, which was held in November 1941, at Cornell's Ithaca campus. The attendance of many of the founding members of the Club for Research on Ageing indicated their strong interest in the potential significance of McCay's research and its broader implication for the aging population.¹⁵⁷ Moreover, the wide spectrum of these conference attendees' expertise, which included physiology, pathology, physics, social

155. Report of the Committee upon the Importance of Future Research into the Biology of Senescence, 15 Sep 1941, WBC, Box 82, Folder 1113.

156. Korenchevsky to MacNider, 24 Apr 1941, WBC (ibid.).

157. In fact, the conference itself was very unusual; during the 1940s and 1950s, there was no other similar meeting held by gerontologists to talk about a particular project of one scholar.

science, clinical medicine, and animal husbandry, revealed that the study of caloric restriction transcended its origin and became a focus of gerontology's multidisciplinary investigation.¹⁵⁸

Many of the problems found in McCay's underfed rats, which made them less useful than expected for animal husbandry or agriculture, greatly interested these multidisciplinary participants and motivated them to suggest new problems and issues. For instance, they discussed the underfed rats' severely decalcified bones, which were then actively studied in McCay's lab. Frank Fremont-Smith of the Macy Foundation recommended that to get a more reliable result on this problem McCay should control an important variable—the degree of the rats' exercise—which influenced the deposition of calcium in their bones. Baird Hastings, with regard to the underfed rats' calcium metabolism, argued that the underfed and the control rats' ability to use and maintain calcium in blood should be tested using calcium citrate or radioactive strontium, with an aim to determine a reason for the decalcification of the underfed rats' bones. Ephraim Shorr of Cornell Medical College, agreeing with Hastings, proposed that the factors influencing decalcification, such as vitamin D and estrogen, also needed to be studied.

The reproductive problem of underfed rats also became the focus of an intense discussion. McCay reported that the underfed male rats, due to problems in sexual organ development, might show diminished fertility, although none of his rats had yet been allowed to breed. Earl Engle of Columbia University contended that these rats' actual breeding ability should be examined to arrive at a more definite conclusion. The absence of estrus cycle of the female underfed rats and its partial recovery after returning to normal diets was another topic of discussion. Shorr cited an analogous case through his clinical experience with humans. Just as the amenorrhea of the underfed rats was treated through sufficient dietary calories, the amenorrhea of human females could be treated with estrogen therapy.¹⁵⁹ This statement was followed by comments on the need for studying the endocrine functions of the underfed animals. It was also suggested that the effect of extra hormones upon longevity and aging should be investigated.

158. The conference attendees included LeRoy Barnes (physics), Lawrence Frank (BA in social science), John Saxton (pathology), A. V. Moore (clinical medicine), Anton Carlson (physiology), and Clive McCay and his colleagues in the animal husbandry department. See "Conference," GS (ref. 44), 1.

159. *Ibid.*, 6.

Although these physiological problems were considered so severe that caloric restriction was regarded as a “too drastic treatment to be used on humans,” gerontologists thought that McCay’s research was relevant to human aging.¹⁶⁰ For them, his experiments supported the widely held wisdom that to enjoy healthy and long life, one ought to avoid high-calorie diets that might lead to obesity. For this reason, his work was considered relevant to the changes in the condition of elderly Americans after the establishment of the Social Security Act, which, during and after the Great Depression, institutionalized the mass retirement of people over sixty-five. This led many people to ask whether it was natural for workers to retire at that age and whether there were other ways to enable them to keep working and adapt themselves better to the job market and workplaces. In this sense, clinician A. V. Moore pointed out that there were “few obese persons above the age of seventy” and L. S. Cottrell suggested that the relation of body weight to aging should be accurately recorded.¹⁶¹ Lawrence Frank of the Macy Foundation also asked whether it was possible to design an experiment to test the effect of better diets and proper exercise on an aged person’s body and mind “with the idea that retirement would not be demanded at sixty-five if significant improvement in physical and mental conditions occurred” through such measures. In agreement with Frank, Carlson commented that “absolute retirement” should be avoided by all means and “some way” had to be found to promote the elderly’s continuous active life “in line with their capacities.” Thus, a “new physiological criteria of ageing” should be developed, which might differ from chronological age.¹⁶² Other participants, such as Nathan Shock at the NIH, discussed the parameters that could be measured to determine the physiological age, such as reaction time, basal pulse rate, and responses to lowered oxygen. Many of these parameters would eventually be measured by Shock in his longitudinal study of aging at the NIH which began in 1958.¹⁶³ Fremont-Smith suggested that these tests could benefit large manufacturing corporations which might hope to “adjust jobs to capacities of [the] aged.”¹⁶⁴

Psychological issues concerning nutrition and longevity were also raised during the conference. Frank commented that “nutrition is not purely a

160. Sperling to Forest J. Sur, 6 Dec 1944, GS, Box 1, Folder Correspondence 1943–1944.

161. “Conference,” GS (ref. 44), 10.

162. *Ibid.*, 11.

163. See Nathan Shock, Richard Greulich, Paul Costa, Jr., Reubin Andres, Edward Lakatta, David Arenberg, and Jordan Tobin, *Normal Human Aging: The Baltimore Longitudinal Study of Aging* (Baltimore: National Institutes of Health, 1984), 63–94.

164. “Conference,” GS (ref. 44), 11.

biological problem” since “there are psychological, sociological, and cultural aspects of the problem as well.” While these multidimensional issues were not discussed further during the conference, McCay succeeded in beginning a study of the influence of caloric restriction upon mental capacities in later years. During the 1940s he investigated underfed dogs’ behavior in cooperation with W. T. James at the University of Colorado.¹⁶⁵ In fact, McCay had already recognized the importance of psychological approaches when he had applied for a grant from the Rockefeller Foundation during the mid-1930s. Although the foundation refused to support his cooperative work with a psychologist at that time, McCay and Cornell’s department of psychology eventually succeeded in beginning a project on the learning capacity of underfed and normal rats with a grant from the NIH during the early 1950s.¹⁶⁶

CONCLUSION

McCay’s investigations and experimental animals became a rallying point and common reference for the emerging network of a number of investigators engaged in aging research during the 1930s and 1940s, including those from physiology, pathology, dentistry, psychology, histology, physics, and nutritional science.¹⁶⁷ The circulation of McCay’s experimental rats further consolidated these scientific links. This cooperative research effort did not automatically result from his observation of the increased life span of his rats on reduced-calorie diets. Rather, it was a consequence of the concurrence of several social, personal, and institutional factors, including the new funding policy of a major philanthropy, McCay’s appropriation of the opportunity within his academic and financial context, and the formation of a multidisciplinary research field.

165. W. T. James and C. M. McCay, “An Analysis of the Effect of Retarded Growth on Behavior in Dogs,” *Journal of Comparative Psychology* 37 (1944): 173–85.

166. The reason why the foundation did not approve the project is not known. See Warren Weaver to Madison Bentley, 27 Apr 1937, RF, Series 200D, Record Group 1.1, Box 136, Folder 1688. On the cooperative work with the psychology department during the 1950s, see “Progress from Research upon Aging during the Year 1951”; and “Progress from Research upon Aging during the Year 1953,” both in CMM, Box 21, Folder USPH 584 Prints 1952. The psychological and neurological dimensions of the problem of caloric restriction continued to be studied by later researchers. See Masoro, *Caloric Restriction* (ref. 4), 55–60.

167. The following scholarly works are relevant to this situation: Galison, *Image and Logic* (ref. 9), 781–844; Star and Griesemer, “Institutional Ecology” (ref. 9); Löwy, “Loose Concepts” (ref. 9); Löwy, *Between Bench and Bedside* (ref. 9), 247–53.

Through this process, a viable research program attracting a large number of investigators from various disciplines was created within the science of aging.

According to a later gerontologist, caloric restriction provided researchers with “a handle for looking at the mechanisms of aging.”¹⁶⁸ Gerontologists observed that diets with reduced calories increased the longevity of many kinds of living organisms, including mice, dogs, hamsters, fish, and even yeasts. But why restricted caloric intake can increase longevity and retard aging remains a matter of debate. While McCay initially attributed the longer life of underfed animals to their delayed development, that also postponed the onset of aging, his subsequent research showed that caloric restriction’s impact on longevity and senescence was more complex, especially in terms of its different effects on distinct parts of the body. Later studies also revealed that caloric restriction could increase life span even without lowering the rate of growth in early phases of life. In fact, a large number of factors seem to be involved in senescence, and caloric restriction in diets has been known to be related to many of them in multiple ways. For contemporary scientists of aging, these findings point to the necessity of a broader research scope and the cooperation of a larger number of experts from various fields, including “epidemiology, clinical trials, nutrition, metabolism, endocrinology, neuroendocrinology, genetics, pharmacology, and behavioral medicine.”¹⁶⁹

This current state of caloric restriction research is deeply associated with the construction of gerontology as a disunified field. Although the Russian zoologist Elie Metchnikoff, who coined the term “grontologie” in 1903, implied that it should develop as a part of medicine, the researchers who created the science of aging in later decades made their new field a multidisciplinary science in which McCay’s research found a certain place.¹⁷⁰ Admittedly, gerontologists sometimes questioned the viability of their disunified organization. For example, facing the financial crisis of the *Journal of Gerontology* in 1947, the Gerontological Society had to decide whether the “present editorial policy

168. Laura Beil, “Lean Living,” *Science News* 134 (1988): 142–43, on 143.

169. Evan C. Hadley, Chhanda Dutta, Judith Finkelstein, Tamara B. Harris, Mark A. Lane, George S. Roth, Sherry S. Sherman, and Pamela E. Starke-Reed, “Human Implications of Caloric Restriction’s Effects on Aging in Laboratory Animals: An Overview of Opportunities for Research,” *Journals of Gerontology: Series A* 56A (2001): 5–6, on 5.

170. Elie Metchnikoff, *tudes sur la nature humaine: Essai de philosophie optimiste* (Paris: Masson, 1903), 386. In the book’s conclusion, in which he mentioned “grontologie,” Metchnikoff argued that medical science could help people age in a more physiological, rather than pathological, way.

of a multidiscipline Journal [should] be pursued,"¹⁷¹ since it was thought that the multidisciplinary nature of the journal might be the main reason for its small number of subscriptions. But subsequent voting on the issue led the society to maintain the multidisciplinary policy of the journal, and early gerontologists' commitment to their organizational ideal was reconfirmed. Amid such situations, McCay's experiments offered a research subject that could be appropriated by a number of scientists with diverse expertise, who, even while participating in building gerontology, did not want to abandon their original disciplinary affiliation. These scientists, with distinct training and perspectives, cooperated at multiple levels, including actual collaboration in a single laboratory, coauthoring a scientific paper based on shared animals, and discussing data, implications, and future prospects of their current research at scientific meetings.

In its disunified respect, gerontology is similar to other fields that have often been deemed multi- or interdisciplinary, such as materials science, gender studies, operations research, and cognitive science. Perhaps they, along with gerontology, are different from more coherent fields like physics and biology that have developed as formal academic disciplines with relatively standardized textbooks, curricula, and technical vocabulary. Yet it has often been pointed out that even these disciplines can be considered disunified due to the distinct traditions, institutional norms, and approaches within them.¹⁷² It seems that disunity is a normal feature of most forms of scientific activity.

Gerontology and the study of caloric restriction show how this scientific activity, which does not have unity, can maintain its strength and structural integrity through certain instruments of cooperation and communication. Although norms, practices, and training procedures within a field or discipline can hardly be completely unified, scientists can still communicate at least partially using various institutional, conceptual, and discursive media. Gerontology has developed and maintained these media through its multidisciplinary journals, academic meetings, and research programs. The significance of McCay's investigation within this disunified structure of gerontology can be found in its role as a research program that has supported the multidisciplinary of the science of aging.

171. "Minutes of the Second Annual Meeting of the Council of the Gerontological Society, Inc.," *JG* 2 (1947): 163–66, on 166.

172. Galison, *Image and Logic* (ref. 9), 781–844; Toby A. Appel, "Organizing Biology: The American Society of Naturalists and Its 'Affiliated Societies,' 1883–1923," in Rainger, Benson, Maienschein, *American Development* (ref. 128), 87–120.

ACKNOWLEDGMENTS

I wish to express my gratitude toward Sally Kohlstedt, John Eyler, Mark Borrello, Susan Jones, Jennifer Gunn, and Dominique Tobbell, who carefully read and commented upon this paper. I would also like to thank the two referees who provided valuable comments on this article. In addition, I deeply appreciate the members of the Nathan Reingold Prize Committee of the History of Science Society who decided to award the Prize to an earlier version of this work. My project was funded by the National Science Foundation Dissertation Enrichment Grant (History and Philosophy of Science of SET #0620408), the University of Minnesota Dissertation Fellowship, and the Rockefeller Archive Center Grants-in-Aid. Preliminary versions of this paper were presented at Columbia History of Science Group Annual Meeting and Mephistos Conference in 2007.