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Inbreeding, eugenics, and Helen Dean King (1869–1955)

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Abstract. Helen Dean King's scientific work focused on inbreeding using experimental data collected from standardized laboratory rats to elucidate problems in human heredity. The meticulous care with which she carried on her inbreeding experiments assured that her results were dependable and her theoretical explanations credible. By using her nearly homozygous rats as desired commodities, she also was granted access to venues and people otherwise unavailable to her as a woman. King's scientific career was made possible through her life experiences. She earned a doctorate from Bryn Mawr College under Thomas Hunt Morgan and spent a productive career at the Wistar Institute of Anatomy and Biology in Philadelphia where she had access to the experimental subjects which made her career possible. In this paper I examine King's work on inbreeding, her participation in the debates over eugenics, her position at the Wistar Institute, her status as a woman working with mostly male scientists, and her involvement with popular science.

Keywords: Eugenics, Helen Dean King, Inbreeding, Wistar Institute

Introduction

''Women Afraid of Rats? Here's One Who Raises 'Em'' reported a headline in the January 4, 1922, Philadelphia *Evening Public Ledger*. The article, complete with a picture of Helen Dean King holding an albino rat in her gloved hand, stated that she had ''upset a lot of traditions'' including that age-old one that ''women are afraid of rats and mice'' and, significantly for this study, ''exploded the theory that intermarriage caused the race to deteriorate.'' Claiming that ''some rats are positively handsome,'' the picture of this pleasant-looking middle-aged woman ''holding a rat in the palm of her hand'' belies the stereotype of the immiscibility between women and rodents. The author

Figure 1. Helen Dean King and Wistar Rats. Courtesy of the Wistar Institute, Wistar Archive Collections, Philadelphia, Pennsylvania.

of the article found it difficult to believe "that one of the greatest authorities on rats in the country is a very human and thoroughly feminine woman." As "the only woman in this country to hold a research professorship" her ideas on inbreeding shocked some and fit right into the ideas of many who were exploring the implications of genetics to human heredity (Figure 1).[1]

On October 1, 1921, the geneticist/eugenicist Charles B. Davenport wrote to Helen Dean King at the Wistar Institute of Anatomy and Biology in Philadelphia praising her for her part in making the Second International Congress of Eugenics held at the American Museum of Natural History on September 22–28, 1921, a success. "We all felt that the success of the Congress depended very much upon getting the support of the geneticists of the country and this we were able to do thru your work."[2]

King replied that she was delighted with the success of the Congress and modestly reported that "I didn't feel that I had much to do with the

[1] Philadelphia *Evening Public Ledger*, 1922.

[2] C. B. Davenport to H.D. King, October 1, 1921. Charles B. Davenport Papers, American Philosophical Society, BD27. Hereafter cited as CBD papers.

outcome. All of the credit belongs to you.'' She predicted that ''great good will come from it in the future''[3] This interest in eugenics lasted throughout her life and was supported by her experimental data.

King spent her entire professional career at the Wistar Institute of Anatomy and Biology in Philadelphia, published many scientific papers (82 by one count and 85 by another),[4] belonged to many scientific societies, and corresponded extensively with leading geneticists of the time, including Charles B. Davenport (1866–1944), Leslie C. Dunn (1893–1974), Raymond Pearl (1879–1940), and William E. Castle (1867–1954). Bonnie Tocher Clause began the effort to revive interest in King through her meticulous examination of materials in the Wistar archives culminating in a 1993 publication in the *Journal of the History of* Biology.[5] As Clause remarked in another publication, ''King remains one of the unsung heroes of 20th century American biology.''[6] King's importance was also recognized by biologist and historian of biology Jane M. Oppenheimer who stated that her work on inbreeding was ''perhaps a contribution of almost the same level of importance in its sequel as Morgan's demonstration of the usefulness of *Drosophila* as experimental material.''[7] In 1932, King was honored with the coveted Ellen Swallow Richards Research Prize which she shared with the Astronomer Annie Jump Cannon (1863–1941).[8] In this paper I will extend the work of Clause and Oppenheimer by noting the relationship of her inbreeding experiments to the eugenics movement, analyzing the ways in which King fit into her contemporary community through her research, exploring her production and use of a standardized rat as a commodity, uncovering her local reputation in Philadelphia as a science popularizer, investigating the gender issues that she encountered, and surveying the economic and political issues that had an impact on her research at the Wistar.

Early Life

Helen Dean King was born in Owego, New York, on September 27, 1869, to George A. and Leonora Dean King. Like her father before her, she attended the Owego Free Academy; she graduated as one of 23

[3] Ibid.

[4] Clark, 1955, pp. 650–651.

[5] Clause, 1993, pp. 329–349.

[6] Clause, 1998, p. 6.

[7] Oppenheimer,1983, p. 853.

[8] Philadelphia *Evening Bulletin*, 1932; Philadelphia *Public Ledger*, 1932.

students on June 25, 1886. In the fall of 1887, she entered the Vassar preparatory program and graduated in 1892 with an A.B. Degree.[9] After two years she returned to Vassar to pursue graduate work in biology and serve as assistant demonstrator (1894–1895). In the fall of 1895, King received a scholarship from Bryn Mawr College to do post-graduate work in biology and paleontology and pursue a Ph.D. degree with T. H. Morgan and the geologist Florence Bascom. At the end of the second semester1897, Morgan (1866–1945) appended a handwritten note to her list of courses. After "grad. Morphology" he wrote, "has taken the graduate work of the department and has carried on a long and laborious piece of investigation that promises to give results."[10] Geology professor Florence Bascom (1862–1945) was also pleased with King's performance, noting that "her work has been done faithfully."[11]

King continued to take classes during both semesters (1898–1899), passed her Ph.D. examinations and finished her Morgan-supervised dissertation ("The Fertilization and Maturation of the Egg of Bufo-Lentigenosus.").[12] King's preparatory studies with Morgan prepared her to think independently on many scientific questions. When she was a student most of Morgan's work was in embryology, and he was known for investigating the development of widely diverse organisms. As an influential teacher, Morgan encouraged his female students to engage in independent research. Oppenheimer illustrated his influence on the young women of Bryn Mawr by a survey of papers from 1898 through 1904 either independently authored or coauthored with him. Forty-eight articles were published independently and eight papers included students as co-authors with Morgan.[13] King was one of the students who benefited from Morgan's policies. Although she did not publish with Morgan, her early work reflected his current interests in embryonic development and in regeneration.[14]

Probably unable to secure a satisfactory professional position, King spent the first years after she received her doctorate (1899–1907) teaching at the two preparatory schools in Bryn Mawr, the Shipley and Baldwin Schools, while continuing to take classes. Jobs were scarce for all biologists at that time, but were particularly difficult for a woman to

[9] King, "Life," 1899, Sketch appended to her Ph.D. dissertation.

[10] "Studies Pursued in the College, Bryn Mawr College hand-written book.

[11] Ibid.

[12] Ibid.

[13] Oppenheimer, 1983, p. 852.

[14] King, 1901; For an example of her work on regeneration see King, 1898, pp. 361–363.

Figure 2. Wistar Institute. Courtesy of the Wistar Institute, Wistar Archive Collections, Philadelphia, Pennsylvania.

secure, as is demonstrated by the career of the geneticist Nettie Maria Stevens (1861–1912) known for her work on the role of chromosomes in sex determination demonstrated.[15] In 1908 what proved to be a serendipitous opportunity opened for King. She obtained a position without pay at the Wistar Institute as a "volunteer assistant to pursue her own researches and to aid us with our technical work."[16] Obviously the Institute was happy with her work, for the next year she was given a staff position. Volunteering was a strategy that women sometimes used to work their way into paid positions. For example, a contemporary of King, Anna Wessel Williams (1863–1954), first volunteered in the diagnostic laboratory of the New York City Department of Health. Her volunteer position evolved into a full-time job at this institution where she spent her entire career (Figure 2).[17]

King was originally hired as a technician with the title of Assistant in Anatomy on February 1, 1909 to aid in "the preparation of sections and the elaboration of new technical methods which will be most helpful in our neurological work." It was also clear that King was not

[15] Ogilvie and Choquette, 1981, pp. 292–311.

[16] Wistar Institute, Report of the Director, 1908.

[17] Ogilvie and Harvey, "Williams, Anna Wessels," 2, p. 1381.

just content to help others but also "conducted her own researches in sex determination."[18]

Research and the Evolution of King's Ideas on Eugenics

By 1910, King's potential was recognized, as the Director praised her "interesting and important" results "soon to appear under the title 'The effect of changing the water content of the egg at or before the time of fertilization on the sex ratio, etc.'"[19]

This particular study, although on amphibians, presages her life-long interest in sex ratios and sex determination as well as her awareness of the effect of the environment in determining these characteristics. It also is clear from the Director's report that although she came to the Institute "as a technician with the privilege of devoting a portion of her time to research," she was now recognized as an important scientist and "the character of her research has been such as to warrant the expenditure of her full energies in this line of work."[20]

In 1912, the structure of the Institute was changed to allow for the creation of assistant professorships and instructorships. At a meeting on December 19th, "an assistant professorship of embryology was created and King was nominated for this position." The Report of the Director praised the decision of the Board to elevate King, noting that "your decision to promote to an Assistant Professorship, Dr. Helen Dean King will be met with earnest approval by men working in the biological field of science, and it seems to me for the present a very fortunate outcome of our efforts to secure a Professor of Embryology.[21] This promotion demonstrated that King was popular with her colleagues in the Institute and at the same time was making connections in the broader scientific community.

Inbreeding Experiments

Because of the Wistar's commitment to experiments with rats, it was not surprising that King left behind her amphibians and replaced them with

[18] Wistar Institute, Report of the Director, 1909.

[19] Wistar Institute, Report of the Director, 1910.

[20] Ibid., 1911.

[21] Wistar Institute, Report of the Director, 1912. She was actually appointed assistant Professor in 1913. Wistar Institute, Report of the Director, 1913. She was promoted to full professor in 1927. *American Men of Science*, 1938.

rats. However, the reason that she chose inbreeding for her rat studies was at least partially related to the political and scientific dialogue that emerged during the nineteenth and continued into the twentieth century regarding the consequences of consanguineous marriages in humans. Although often considered the culprit today, concerns about the deleterious effects of consanguineous marriages on the offspring have not been historically the major reason for marriage prohibitions between blood relatives. Social, cultural, religious, and dynastic factors were more important than biological factors in determining acceptable spouses. For example, some cultures accepted the marriage of cousins but forbade the marriage of a man to his sister-in-law (Figure 3).[22]

During the latter part of the 19th century, an attempt to study the biological consequences of inbreeding surfaced. Although many societies historically had prohibitions against incest, King and others credited Charles Darwin with giving the idea a scientific basis.[23] Darwin, himself a product of cousin marriages, continued the trend by marrying his Wedgwood cousin, Emma. Darwin was concerned about the possibility that he had inflicted hereditary illness on his children. After a devastating year of family illness, Darwin wrote to Gray, "we are a wretched family & ought to be exterminated."[24] Darwin not only collected the data available in the literature regarding inbreeding, he also carried on a series of inbreeding experiments on plants for 11 years.[25] Whereas Darwin consistently insisted that inbreeding plants over a long period of time was harmful, his views on consanguineous marriages seem to have changed over time. In the first edition of his book *On the Various Contrivances by which British and Foreign Orchids are Fertilised by Insects*, he extrapolated to humans, concluding that "marriage between near relations is ... in some way injurious – that some unknown great good is derived from the union

[22] Ottenheimer, 1996, pp. 1–17.

[23] An excellent description of Darwin, Wallace, and Galton's views on eugenics issues may be found in Paul, 1995, pp. 22–39.

[24] Charles and Emma Darwin had 10 children. Three of the children died young: Anne Elizabeth, died of tuberculosis at age 10 and Mary Eleanor died as an infant. Their last child, Charles Waring, was apparently retarded and also died as a baby. Of his surviving daughters Elizabeth was possibly mildly retarded or mildly autistic and lived at home all of her life. Henrietta had been sickly as a child and young adult but married at thirty and had no children. Two of his married sons, William and Leonard also were childless although Leonard married twice. Francis, George, and Horace all married and had healthy children. Browne, 2002. For quote, see Correspondence of Charles Darwin, Darwin to Asa Gray, 21 August [1862], p. 373.

[25] Darwin,1876.

Figure 3. Wistar Rat. Courtesy of the Wistar Institute, Wistar Archive Collections, Philadelphia, Pennsylvania.

of individuals which have been kept distinct for many generations?''[26] However, by the second edition of this book (1877) he kept to plants and removed the statement about near relatives while still insisting that ''nature tells us, in the most emphatic manner, that she abhors perpetual self-fertilisation.''[27] In 1875 he also discussed the dangers over time of inbreeding plants in *The Effects of Cross and Self Fertilization in the Vegetable Kingdom*. He wrote that ''the consequences of close

[26] Darwin, 1862, p. 360.

[27] Darwin, 1877, p. 293.

interbreeding carried on for too long a time, are, as is generally believed, loss of size, constitutional vigor and fertility, sometimes accompanied by a tendency to malformation.''[28] His modified views about human inbreeding may have resulted from the research of his geophysicist son, George Darwin.

In 1875 George published the results of his research on the offspring of cousin marriages in the *Journal of the Statistical Society of London* in response to a study by Arthur Mitchell in Scotland. Mitchell sought evidence that consanguineal marriage was dangerous. When his studies did not support his hypothesis, he nevertheless maintained that although cousin marriage was harmful ''proper living'' could mitigate its effects.[29] George Darwin's studies refuted Mitchell's conclusions, but they were widely accepted in the United States.

Many late 19th century experimenters, including H. Crampe (1883),[30] and J. Ritzema-Bos (1893–1894)[31] agreed with Charles Darwin that inbreeding experiments demonstrated harmful effects on the offspring,[32] but others such as Alfred H. Huth (1887) were less certain. Huth noted that the ''sole reason'' for prohibiting consanguineous marriages is ''that our fathers did so, and their fathers did so before them.''[33] Marriage, he concluded, should be prohibited in ''the direct ascending and descending line, between brother and sister, and uncle and niece; or those degrees which as a rule imply an unsuitable difference of age between the parties,''[34] but that the marriage of cousins was not a problem. He agreed that although an ''idiosyncrasy was more likely to occur in families where marriages of blood relations was common, it practically does not occur oftener than in other marriages, or it would be more easily demonstrated.''[35]

Experimentation with maize added another dimension to the problem of inbreeding. Charles Darwin's research on plants demonstrated, as had both his predecessors and successors, that hybrids were superior to inbred plants. George Harrison Shull reported in a paper

[28] Darwin, 1875, v. 2, p. 93.

[29] Darwin, G., 1875, 172–177. Ottenheimer, 1996, pp. 84–85 presents a good discussion of George Darwin's role; Yearsley, 1914.

[30] Crampe, 1883.

[31] Ritzema-Bos 1894.

[32] Ibid., p. 1.

[33] Huth 1887, p. 3.

[34] Ibid., p. 342.

[35] Ibid., p. 343.

of 1908 that inbred lines of maize were, indeed, less hardy and more prone to defects than their predecessors, noting "that self-fertilization, or even inbreeding ... results in deterioration." However, he noted, that hybrids between two inbred lines often produced a higher yield than the original varieties.[36] Edward M. East agreed with Shull's conclusions, although they argued about the practical use of the results because the inbred lines produced a paucity of seeds and, according to East, would cancel any increase in yield by the hybrids.[37] The cause of "hybrid vigor," (christened heterosis by Shull in 1914)[38] was debated and various theories were advanced to explain it. East and Donald F. Jones summarized and interpreted data on inbreeding and, more important to King's work, discussed the sociological implications.[39]

By the late 19th and early 20th centuries both scientists and lay persons became obsessed by the Darwinism-induced fear that the quality of human stock was deteriorating. As the geneticist E.G. Conklin wrote anonymously in *Harper's Magazine*, "We cannot avoid the conclusion that although our human stock includes some of the most intellectual, moral, and progressive people in the world, it includes also a disproportionately large number of the worst human types."[40] The many reasons for this decline included the immigration of "undesirable" people into the United States and the uncontrolled breeding of defectives such as the "feeble minded," the insane, criminals, and the physically handicapped. The tendency, they complained, was for the dregs of society who were a drain on the economy to reproduce more rapidly than the superior types. If this trend continued, American society would be unable to sustain itself. Scientists and laypersons alike were intrigued by ideas of human degeneracy,[41] and searched for a way to reverse the tendency. The solution might be found in the Progressive movement in the United States.

King's early scientific career coincided with the apex of Progressive ideas in the United States. Progressivism, although it has many faces,

[36] Shull, 1908.

[37] Crowe, 1998, p. 923. Crow and Oliver Nelson, 1993, provide a good discussion of the relationship between the works of the early maize geneticists.

[38] Shull, 1914.

[39] East and Jones, 1919; Shull, 1948.

[40] Conklin (anonymous), *Harper's Magazine*, 1928, p. 532.

[41] See the following sources for discussions of degeneracy. Rosenberg, 1976, pp. 43–46; Talbot, 1901; Fink, 1938. Paul, 1995 in chapter 1 describes the late 19th century belief that humans were degenerating and that the worst types of humans were reproducing at a higher rate than more "fit" humans. Also see Paul, 1998.

usually includes the idea of scientific management of social processes by "experts." Social scientists insisted that by adopting the methodologies of the "hard" sciences efficiency in the workplace, control of the environment, and even control of human behavior could be achieved. Recently reformulated Mendelian genetics offered a Progressive solution for resurrecting a declining society. Rather than attacking the problem by altering the environment as earlier social reformers had attempted to do, the new reformers resolved to assault the problem by striking at the cause – inferior heredity. This plan to control society could either be achieved through negative eugenics (sterilization of the defective) or positive eugenics (encouraging superior stock to breed), an activity that many biologists found compatible with progressive ideas of scientific management. King's inbreeding experiments fit tidily into this social and scientific context.

When King moved to the Wistar Institute she met people who were involved in mammalian genetics and interested in eugenics. This Institute was known for its success in breeding a genetically homogeneous laboratory animal, the Wistar Rat. The Wistar claimed that these rats were the first animals to be "standardized" for laboratory use.[42] Two scientists at the Wistar were especially important to King in her future research trajectory, Milton J. Greenman (1866–1938) and Herbert Henry Donaldson (1857–1939). Greenman, the Director of the Wistar, was the scientific administrator who was closely involved in the work of his scientific staff. Donaldson was a neuroanatomist whose research goals included establishing rats as models for human growth and development by collecting an all-inclusive set of data. King[43]

King began her inbreeding experiments in 1909 with two male and two female albino rats taken from a stock colony maintained for research purposes at the Wistar. She developed two lines of inbred animals from the original ancestors by mating brother and sister from the same litter, "the closest form of inbreeding that is possible in mammals."[44] These two lines were kept under the same environmental and nutritional conditions. By rigidly selecting for the largest and most vigorous animals to continue the inbred lines, "small, weak, defective individuals have been eliminated, either at birth or before reaching

[42] Clause, 1998, p. 3. Although C. C. Little's mouse laboratories were also involved in inbreeding studies, the Wistar projects preceded them and were used for different purposes. Rader, 2004, pp. 1–23.

[43] King, 1910. King's first paper using the rat as her experimental subject.

[44] Ibid., 1912; King, 1936, p. 271.

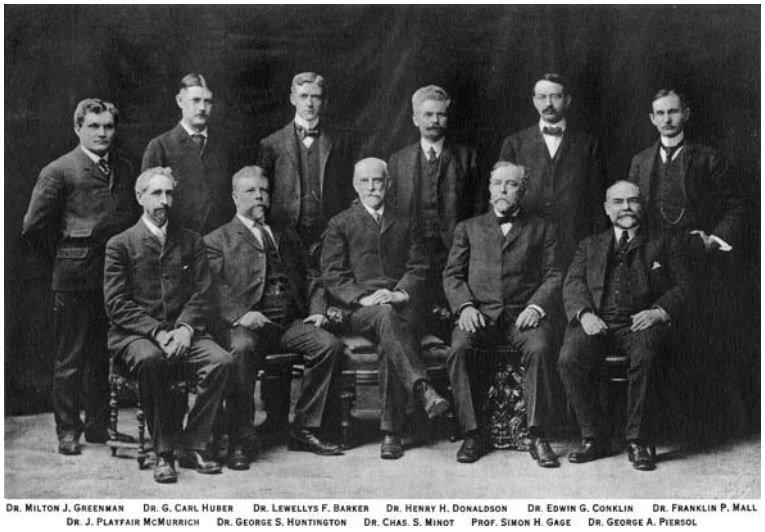

Figure 4. Genetics contemporary with Helen Dean King. Courtesy of the Wistar Institute, Wistar Archive Collections, Philadelphia, Pennsylvania.

sexual maturity.''[45] However, from the results of the first six generations, it looked as if the supporters of ''incest taboos'' were correct. ''There was a steady decline in the vigor of the animals in succeeding generations; many females were sterile, and those that did breed produced small litters that contained many stillborn young; most of the animals were undersized; and a number showed malformations, particularly deformed teeth.'' However, further observations indicated that the control ''stock'' albinos suffered from the same defects. When the food was changed there was a marked increase in fertility, size, weight, and general vigor in both the inbred rats and the stock colony. The malformations disappeared.[46]

In the Director's Report for 1915 King described her progress on the inbreeding project, reporting that she had inbred 22 generations of rats. For the first time she noted that ''there is yet no evidence that this form of breeding is injurious in any way.'' By this time she had accumulated records for approximately 12,000 individuals on growth in body weight and for the sex ratio in the first 15 generations.[47](Figure 4).

Although King planned to publish the results of her inbreeding studies in 1916 and promised that one of the papers was already in

[45] Report of the Director, 1912.

[46] Ibid.; King, 1918a.

[47] Report of the Director, 1915.

manuscript form,[48] she did not actually publish the first three until two years later (1918) and the fourth the following year (1919).[49] The delay may have been caused partially by disasters in the rat colony. The demand for the Wistar Rat had increased greatly and researchers from all over the country purchased these animals, providing the Institute with a modest, but constant form of income.[50] However, if they were to continue to supply their constituents, problems in husbandry had to be solved. Matters were brought to a head during the summer of 1918 when the usual supply of table scraps from nearby restaurants used for rat food became unavailable. Since little research had been done on the optimal diet for rats, the keepers purchased and combined foods that they assumed were suitable for the animals. Their best guesses were unfortunate, for the cotton-seed-meal mixed with grains that they substituted for table scraps killed many rats. To compensate, they introduced new rats to the colony with disastrous results, bringing in diseases and parasites.[51] Although all of the researchers suffered from the situation, by the close of the year with improved diet and care the situation improved.[52] In searching for the proper diet, they "developed a great diversity of recipes, including 'wheat and peas with milk, ... barley, salmon, and eggs, ... hominy grits, vegetables, and eggs,' and many others." Homemade diets were continued until the 1940s when dry commercial dog and fox diets supplanted them.[53] King later realized that some of her anomalous results could be explained by the disasters in the rat population.

King's first paper on inbreeding[54] was concerned with the effect of inbreeding on the growth and variability of the laboratory rat. The questions that King elucidated in this first paper were the same ones that fascinated her throughout her research career, "Does close inbreeding, if carried on for a long period of time, ever lead to degeneration if only the best animals, from sound stock are used for breeding?" If "degeneration does follow from this kind of mating, does it affect merely the body size, vigor, and fertility, or does it also influence body form and modify the structure and action of the central nervous system?" Finally,

[48] Ibid., 1916.

[49] Ibid., 1917; 1918; 1919.

[50] Rader, 2004, pp. 97–134 discusses the situation with mice at the Jackson Laboratory.

[51] Baker, Henry J., J. Russell Lindsey, and Steven H. Weisbroth, eds. 1979. 1, p. 6.

[52] Wistar Institute, Report of the Director, 1918.

[53] Baker, Lindsey, and Weisbroth. 1979. 1, p. 6.

[54] Ibid.; King, 1918a.

she was curious as to whether inbreeding could change the normal sex ratio, "as others have maintained."[55]

King's results confirmed that after "twenty-eight generations of continued brother and sister matings the inbred animals have not deteriorated in any way, and they are still superior in body size to stock animals reared under similar conditions."[56] She found that the variability in the body weights of the inbred rats decreased, indicating that the individuals were becoming more homozygous with respect to the factors that determine body size. Although she recognized that environmental factors had some effect on the results, she was careful to provide homogeneous conditions.[57]

The second paper in King's inbreeding series focused on the effects of inbreeding on fertility and constitutional vigor.[58] For the purpose of her paper, King defined fertility as "the total actual reproductive capacity of pairs of organisms, male and female, as expressed by their ability when mated together to produce ... offspring." In order to determine the normal fertility of any race (and King was considering the albino rat to be a race), normal fertility was estimated from the total number of offspring produced by many females during the entire period of their reproductive activity. Since the females of the inbred strain were discarded after four litters, the data could not be completely accurate. However, records for the inbred series covered the most productive period in the life of the females, and King was convinced that "if the fertility of the strain was impaired to any extent by inbreeding it is probable that all of the litters cast would have been smaller than normal."[59]

Since the earlier inbreeding experiments by Crampe, Ritzema-Bos, and von Guiata stressed the dire effects of inbreeding on rodents, King was determined to show that their unfortunate results could be traced to factors other than inbreeding. She was convinced that Crampe's results were caused by inadequate nutrition and the deterioration in Ritzema-Bos' stock by overcrowding, and that von Guaita's experiment with mice showing a 30% reduction in fertility was explained by a strong recessive tendency toward sterility in each of the strains crossed. "If such were the case, continued inbreeding, apparently without selection, would bring out this latent character and intensify it."[60]

[55] Ibid., p. 2.

[56] Ibid., pp. 48–49.

[57] Ibid.

[58] King, 1918b.

[59] Ibid., p. 336.

[60] Ibid., p. 371; von Guiata, G., 1898.

Edward East and Donald Jones stressed another characteristic that King also mentioned – the fact that these experimenters began with hybrid stocks. Downplaying King's environmental explanation, they stressed her belief that the original hybrid stock was the problem. East and Jones concluded that the major reason that both Bos and von Guaita's experiments should be disregarded was because "*each was started with hybrid stock, and such experiments with hybrid stock bring in an additional complication, Mendelian recombination.*"[61] King also had been gently, but persuasively critical of the experimental design of Crampe, Ritzema-Bos, and von Guaita and found it "rather remarkable" that of these experiments and the many geneticists who cited them "not one, to my knowledge, has emphasized the fact that all of these experiments were made with hybrids and not with a pure strain."[62] She noted that although some hybrids are equal or even superior to their parent stock in fertility, others are completely sterile. All gradations of productivity are found. Although Crampe, Ritzema-Bos, and von Guaita "show unquestionably that fertility in hybrid rats is diminished by random inbreeding, ... their results cannot legitimately be used to give evidence regarding the effects of inbreeding on the fertility of a pure race."[63]

East and Jones and King agreed that "the only type of investigation on bisexual animals calculated to offer critical evidence on the effect of inbreeding *per se* must be carried on with stock which has already been inbred long enough to reduce the genetic constitution of the animals to an approximately homozygous condition." Praising King's successful experiments, East and Jones credited her achievement largely to the fact that "the experiments were started with stock rats which already must have been very closely inbred and therefore in an approximately homozygous condition.[64]

Once adequate husbandry for King's rats was established, there was little variation in the fertility or in the longevity of the animals up to the 25th generation, "but, under the conditions of the experiment, they did not increase vigor beyond the stage which was reached at the 10th generation." In her experiments she found that rats of the A series, descended from the original prolific A female, were somewhat more productive than the rats of the B series. The A descendents also matured earlier and lived longer. Differing environmental conditions were discounted, because both A and B lines were kept under the same

[61] East and Jones, 1919, p. 103.

[62] King, 1918b, p. 371.

[63] Ibid., p. 372.

[64] East and Jones, 1919, p. 106.

conditions of light, temperature, and nutrition. She concluded that although they were descended from the same ancestral stock, there was a difference in the genetic constitution of the two original pairs of rats. This difference persisted from generation to generation and produced the observed effects.[65]

Although this second paper demonstrated that the inbred strain of rats seemed to be superior to the stock albinos in body size, fertility, and in longevity, King did not attribute this superiority "solely to the fact that the animals were inbred." Neither did she claim that "inbreeding is better than outbreeding for building up and maintaining the general vigor of a race." She did conclude, however, that inbreeding and outbreeding are not mutually exclusive and "the one should supplement the other to bring out the best in any stock."[66] Her experiments demonstrated that in mammals "even in the closest form of inbreeding possible" (brother–sister matings), inbreeding does not necessarily cause a lack of constitutional vigor or lack of fertility." The important factor is "the character of the stock that is inbred, on the manner in which the breeding animals are selected, and on the environmental conditions under which the animals are reared."[67] There is no evidence at all, she averred, that continued inbreeding will result in weakened animals through its own influence.

King's third paper on inbreeding concerned its effects on the sex ratio of the albino rat.[68] In an extensive literature survey, she noted that several studies on inbred mammals (rabbits and mice) showed a predominance of male offspring, whereas other studies concluded that inbreeding did not produce an excess of male young. None of these studies answered the question as to whether inbreeding influenced the sex ratio to King's satisfaction.[69]

In this paper King sought to determine whether inbreeding had an effect on sex ratios. Because the "normal" sex ratio for the albino rat was not known, King obtained the complete breeding history of a number of stock females for the previous four years and then noted the number of males to females. Since the stock individuals were reared under the same environmental conditions, the sex ratio among their young would serve as a control against which the sex ratios of the inbred animals could be compared. King selected breeding stock based on the

[65] King, 1918b, pp. 375–376.

[66] Ibid., p. 376.

[67] Ibid.

[68] King, 1918c.

[69] Ibid., pp. 1–2.

tendency of their parents to produce young of a certain sex.[70] She found a relatively large excess of males to females in the first litters cast by the stock females with the ratios modifying in subsequent litters. However, the results in the inbred stock defied explanation. In the inbred stock when there was no selection of animals for breeding, the inbreeding of brother and sister did not appreciably increase the number of males. However, beginning with the seventh generation, all breeding females in the A series were taken from litters that contained an excess of males. The females in this series produced an excess of male young whether they were paired with a litter brother or with an unrelated stock male. The opposite results occurred in the B series (also from the seventh generation on) when breeding females were selected from litters containing excess of females. When she combined the data for the two inbred series it appeared that through selection the inbred strain was separated into two lines, the A line with a high male to female ratio and the B line with a low male to female ratio. The same pattern continued as far as she had carried on the experiment; the variation from the norm had ''been in the same direction in each generation of each series.'' King concluded ''that in the rat the sex ratio is to a certain extent at least, a character that is amenable to selection.''[71]

King's presumption that it was not inbreeding itself but selection that caused a skewed ratio between males and females, contradicted the accepted assumption. According to King, the idea that inbreeding affected the ratio stemmed from Karl Düsing's work with humans. Düsing collected statistics on several isolated human communities in which there were many consanguineous marriages. He was especially interested in the supposed preponderance of male offspring born to Jewish families whom, he claimed, tended to intermarry frequently. However, Pearl and Salaman (1913) showed that Düsing's study was invalid, and that the reported anomalous sex ratio was because of faulty registration; the normal sex ratio among Jews was the same as in other humans.[72] King demonstrated that similar studies in other mammals that seemed to indicate that inbreeding caused a preponderance of one sex or the other were equally invalid.[73]

King's last paper in this inbreeding series was an update on her first paper. In this work she extended the data on growth and variability from the 16th to the 25th generation. The environmental conditions

[70] Ibid., pp. 5–6.

[71] Ibid., p. 29.

[72] Düsing, Karl, 1883; Pearl and Redcliffe N. Salaman, 1913.

[73] King, 1918c, p. 27.

under which the rats from these generations were reared were inferior to those of the earlier generations. The result was that these rats were not as heavy at any age as were the animals in the earlier experiments. Nevertheless, they were far superior in body weight to stock albinos reared under similar environmental conditions. The variability in the body weights of these animals followed the same general pattern as did the earlier ones. An increase in variability in the body weights of the later generations of both the inbred and the stock rats occurred; consequently, it seemed "that the increased variability in the body weights of the animals in the later generations of the inbred strain was due to the action of environment and of nutrition, not to the effect of continued inbreeding."[74] King continued to maintain her inbred colony through 150 generations[75], and her general results were similar to those of her first three papers.[76]

Implications for Eugenics

In spite of Huth's conclusions King reported that the question of the deleterious effects of inbreeding generally had been considered "proved." However, experiments by N. W. Gentry (1905),[77] Castle et al. 1906,[78] Moenkhaus (1911),[79] and various horse and cattle breeders (Chapeaurouge, 1909 [80] and Anderson, 1911)[81] reopened it and, as King reported, "have shown conclusively that there is no general physiological law forbidding inbreeding and that the results obtained depend very largely on the character of the stock that is inbred."[82]

The eugenic implications are clear in King's working assumption, "If no evil results appear, can inbreeding be used to improve a race by combining the best of the dominant characters with any desirable recessive ones that may appear?"[83] As early as 1915 the popular press became interested in King's research. The Philadelphia *Evening Ledger*

[74] King, 1919.
[75] *New York Times*, 1955.
[76] King, 1919, p. 100.
[77] Gentry, 1905.
[78] Castle et al., 1906.
[79] Moenkhaus, 1911.
[80] de Chapeaurouge, 1909.
[81] Anderson, 1911.
[82] King, 1918a, pp. 1–2.
[83] Ibid., p. 2.

stated that ''Dr. Helen D. King Declares Her Experiments with Rats Have Bearing on Human Problem.'' The article stated that although King preferred not to draw analogies between rats and humans, ''if you press the point'' she will admit that she saw no reason why the theories applicable to rodents would not be applicable to people. If inbreeding produced a rat from 20% to 25% larger than the average rat ''there is reason to suppose that the same sort of mating of the human race would result in a higher type of offspring.'' King recognized that a cry of ''heresy'' would arise ''on all sides as a result of the publicity of my research....I feel as the result of my experiments that if a brother and a sister of good stock were to marry, the children would be of a higher type than the ordinary, because the good points would all be accentuated.'' She contended that ''our repugnance to marriage with close blood relatives is only a matter of tradition and training'' and that ''we have been taught by man that this is immoral, but there is nothing in Nature to teach us so, or in science, either.''[84] In another article that same year in the *Asbury Park, New Jersey Press* she explained again that ''if close relatives carefully selected and of a higher type were to marry the result of the union would be a higher type of offspring than from the inter-marriage of two other people.'' However, if a ''person who is insane marries one who is related to him or her there is much more danger to their descendants.''[85]

Greenman, as director of the Wistar, agreed with King's interpretation of the experimental results and in an interview with the *Asbury, N.J. Press* in 1915, wrote that ''There seems to be no reasons why first cousins should not marry, nor even brothers and sisters.'' He continued, saying ''if our experiments are a guide, such unions, if selectively arranged, should produce offspring larger and more efficient physically than those of the marriages now recognized.''[86] However, Philadelphia pastors and prominent divines ''questioned whether or not the mating of close relatives would result in a stronger race, as in the case of the white rats,'' but most refused to take issue with King since this ''was a matter for medical and scientific experts to pass judgment upon.''[87] One Presbyterian clergyman, the Rev. Dr. William H. Roberts, took issue with King, using the royal families of Europe as examples, and he stated that ''the intermarriage of close relatives would bring about a deterioration of the race.''[88]

[84] *Philadelphia Evening Ledger*, 1915.

[85] *Asbury Park, NJ. Press*, 1915a.

[86] *Asbury Park, NJ. Press*, 1915b.

[87] *Philadelphia Evening Ledger*, 1915.

[88] Ibid.

King had not changed her ideas when the *Philadelphia Bulletin* of November 2, 1919, reported that "a woman at the Wistar Institute of Anatomy at the University of Pennsylvania is dealing hard blows to the traditional theory of Charles Darwin that interbreeding of related plants or animals results in weak offspring after a few generations."[89] King's experiments, this article reiterated, showed that the closest form of inbreeding possible in mammals is not necessarily destructive either to growth or constitutional vigor if only the best animals are selected. No doubt referring to the nutritional and disease problems in the rat colony, the article quoted King as saying that adverse environmental conditions produced far more detrimental effects on the growth of a particular rat than does inbreeding.[90] King again noted the similarity between rats and humans, noting that "the growth of the body and of the nerve structure of the white rat has been found in most respects to correspond to that of man."[91]

Not all of the public tranquilly accepted the implications of King's work. In an article of January 13, 1922, the Philadelphia newspaper, *The North American* headlined an article, "Dr. King Quizzed on Kin Marriage Theory," with a subheading "Home Folk Shocked by Advocacy of Human Inbreeding." The paper reported that King had been inundated with "all sorts and varieties of letters" in response to her statement that "consanguineous marriages under proper laws and conditions would improve the race." Not everyone was outraged by this statement. One of the more positive responses came from a 39-year-old unmarried woman in California who asked King to find her a husband, noting that she owned oil lands and "is passing fair to look upon." The man she was searching for should be "six feet tall and slender." To assure a prompt reply she enclosed a stamped, self-addressed envelope.[92] Others were clearly outraged at the goals of positive eugenics to select superior mates. "A Christian and a student" at Clark University wrote that he hoped someone would kill her and if they failed to do it he would do the deed himself. Another demanded complete data to support King's views on consanguineous marriages. King commented humorously that he did not even enclose a "2-cent stamp for a reply."[93]

King's statements on consanguineous marriages even had repercussions on her relations with her family in Owego, New York. "These

[89] *Philadelphia Bulletin*, 1919.

[90] Ibid.

[91] Ibid.

[92] Philadelphia *North American*, 1922.

[93] Ibid.

most proper and conventional individuals, most of them pillars of the church, refuse to have anything more to do with her.'' They were convinced that her immortal soul was utterly lost. ''Some of them whose custom it has been to send Christmas remembrances, even balked at a Christmas card this year.'' Although she found most of the comments of the ''uninitiated'' amusing, ''she admits that it is a little inconvenient to have the 'home folk' so chilly.''[94]

Davenport, Eugenics, and King

King sent her ''Studies on Inbreeding'' to Charles B. Davenport in 1919. Davenport, a staunch apologist for the eugenics movement, had been able to actualize his passionate dream of founding a continuously supported research laboratory devoted to the study of experimental evolution. Davenport resigned his position at the University of Chicago where he was an associate professor, moved permanently to Cold Spring Harbor, equipped a laboratory, planned buildings, and acquired a staff.[95] However, Davenport's interests moved more toward human heredity which clearly did not lend itself to direct experimentation. As it was both unworkable and unacceptable to perform direct experiments in genetics on humans, Davenport sought additional funding for a new institution, the Eugenics Record Office at Cold Spring Harbor.[96]

Although the exact time when Davenport and King became acquainted is unclear, we know that he soon became a ''customer'' for King's inbred rats. Davenport requested ''some of your inbred rats for an experiment that Dr. Govaerts wishes to undertake here.''[97] King quickly replied that she would be happy to supply him with rats ''if you can use animals of the 40th generation that are between two and three months old,'' for ''these are the only ones I can spare at the moment.''[98]

King also sought Davenport's input on her inbreeding experiments. In 1919, he wrote to King thanking her for copies of ''Studies on Inbreeding,'' noting that her studies brought ''out most clearly the conclusion that not inbreeding, per se, but only the inbreeding of

[94] Ibid.

[95] Allen, 1986, pp. 229–230.

[96] Allen, 1986, provides an excellent account of the ERO.

[97] CBD, Davenport to King, 1921, October 1.

[98] CBD, King to Davenport, 1921, October 5.

individuals from a common defective stock, containing recessive traits is dangerous to offspring.''[99]

King's sympathy for Davenport's eugenic research is evident. For example, in January 1921, Davenport mentioned a pleasant visit with King, and said that he was sending her two of the Records of Family Traits as promised.[100] The Records of Family Traits that Davenport mentioned referred to the results that he collected from field workers who accumulated family histories. These field records were analyzed and entered on cards that ''served as the source of bulletins, memoirs, and books, on such topics as sterilization, the exclusion from the United States of inferior germ plasm, and the inheritance of pellagra, multiple sclerosis, tuberculosis, goiter, nomadism, athletic ability, and temperament.''[101]

The Records of Family Traits that King received in these early years from Davenport appeared to be a part of her project designed to compare humans and rats involving the age of the mother and the sex of the child. Even before she collected the data from Davenport's records, King was interested in comparing human traits with those of other animals. In 1921 she had published a paper comparing birth mortality in the albino rat to that of humans.[102] She also engaged in a series of breeding experiments with stock albinos to ascertain the effects of the age of the parents on the fertility of their young. These experiments related directly to the data that she later acquired on humans from Davenport's Records of Family Traits.[103]

Eugenics: Virtues and Vices

Although the Second International Congress of Eugenics claimed the support of many geneticists, others began to be concerned that the American Eugenics movement was being co-opted by non-professionals. While claiming to admire the scientific basis of eugenics, many lacked understanding of the basic science. ''Of the more than 100 individuals who served on the Advisory Council of the American Eugenics Society in the 1920's [sic], only about ten per cent were trained geneticists.''[104]

[99] CBD, Davenport to King, 1919, October 18.

[100] CBD, Davenport to King, 1921, January 24.

[101] Kevles, 1995, p. 56. For a description of the Records of Family Traits, see Allen, 1986, especially pp. 240–245.

[102] Wistar Institute, Report of the Director, 1920; 1921.

[103] King, 1921.

[104] Ludmerer, 1972, p. 14.

Henry Fairfield Osborn, the respected director of the American Museum of Natural History, supplied the welcoming address for the conference. As a well-known scientist and administrator but not a geneticist, Osborn assumed credentials to speak to an area that interested a wide variety of people. As sometimes happens, a respected scientist in one field becomes a popularizer in another. Because of his expertise in paleontology and geology, Osborn's ideas about genetics and eugenics were acceptable to conference members. Osborn wrote that "as a paleontologist and geologist, as well as something of a biologist, I find no form of matter so stable in nature as that on which heredity depends – consequently the selection, preservation and multiplication of the best heredity is a patriotic duty of first importance."[105] Speaking of the situation in the United States, Osborn explained that

> we are slowly waking to the consciousness that education and environment do not fundamentally alter racial values. We are engaged in a serious struggle to maintain our historic republican institutions through barring the entrance of those who are unfit to share the duties and responsibilities of our well-founded government. The true spirit of American democracy that *all men are born with equal rights and duties* has been confused with the political sophistry that *all men are born with equal character and ability to govern themselves and others*, and with the educational sophistry that education and environment will offset the handicap of heredity.[106]

After stating that each race had its own strengths he continued by noting that the mixing of races indicates that "there is little promise in the 'melting pot' theory," for if you put "three races together, you are as likely to unite the vices of all three as the virtues,"[107] Osborn concluded by saying "to know the worst as well as the best in heredity; to preserve and to select the best – these are the most essential forces in the future evolution of human society."[108]

One of the strongest proponents of "pure races" was the Norwegian, Alfred Mjöen. A eugenicist who was not a very good geneticist, Mjöen, nevertheless, was one of the more effective foreign founders of the American Eugenics Society. Probably more highly regarded in the

[105] Osborn, 1923, p. 2.
[106] Ibid.
[107] Ibid.
[108] Ibid., p. 4.

United States than in his Native Norway, he advocated immigration restriction and antimiscegenation legislation.

Other geneticists with whom King was involved, including Conklin and William E. Castle, were also members of the American Eugenics Society.[109] Conklin was a Director and Castle was on the Advisory Council. King herself was on the Advisory Council from 1923–1935, a member of the General Committee of the Second International Congress of Eugenics and the Third International Congress of Eugenics, and a member of the Eugenics Research Association (1938). As much as Conklin feared that the "best elements are dying out or are losing control,"[110] he was concerned that racial prejudice and restrictive immigration issues were dominating the movement. He wrote that "biology shows that we are all cousins if not brothers" and "as a result of this common descent human resemblances are vastly more numerous and important than differences."[111] However, in spite of the fact that he opposed the illegitimate ways in which eugenics was being used, he remained active in the movement.

Other King correspondents, Raymond Pearl and L.C. Dunn, became increasingly more skeptical about the ability of eugenics to improve the human race. Although he remained a supporter of eugenics for many years, Pearl became skeptical about its practicality as a solution to social problems. Part of his skepticism came from his own experience at the University of Maine Agricultural Station. His goal was to increase the egg-laying capacity of hens, but he found that the opposite had occurred – his selected hens laid fewer eggs. He concluded that while selection might eliminate the unfit it could not produce lasting changes in an organism. Although it could weed out the unfit or produce homogeneous populations from an initial heterogeneous one, it could not produce anything new.[112]

Pearl expressed his disillusionment with eugenics in a paper in the *American Mercury* in 1927, a work which earned him the opprobrium of his eugenicist colleagues.[113] At the fifth meeting of the Board of Directors of the American Eugenics Society in 1928 the Directors voiced

[109] Since 1973 the American Eugenics Society has changed its name to The Society for the Study of Social Biology.

[110] Conklin, 1921, p. viii.

[111] Conklin, 1919, p. 408.

[112] See Allen, 1991, pp. 236–237, for a discussion of Pearl's disillusionment with eugenics.

[113] Raymond Pearl Papers, American Philosophical Society. BP 312. Hereafter cited as RPP.

their dismay in the minutes noting that "Professor Conklin asked if anything is being done by our Society to counteract the bad influence that has gone out from a few scientists who have been knocking eugenics, particularly Pearl and Jennings." Although Conklin himself had doubts about the practicality of eugenics, he still wanted the American Eugenics Society to counter Pearl's assertions and agreed to prepare a reply with another member.[114]

King's correspondence with Pearl was not extensive and essentially involved requests for rats in 1926. But the friendly tone of the letters gives some idea of the comfortable relationship between the two. Pearl asked, "How are things going with you? I should like very much to see you. It has been a long time since I have, but everybody works so hard that they never go anywhere."[115]

In replying to Pearl, King implied that many daily assigned tasks at the Wistar interfered with her research interests. She reported that "things are going about as usual at the Institute. I keep on piling up records but have no chance to write up the results of my work as I am kept busy with 'Bibliographic Service' which was turned over to me a couple of years ago." This mild complaint may have reflected a deeper dismay. The essentially non-creative work with the bibliographic service may have been given to King because there were still remnants of what was "woman's work" even at the Wistar. She noted that busy work, "making an index for the third volume of the extracts," kept her from progressing on her monograph "dealing with the effects of the age of the mother on the young."[116] The first reference to the bibliographic service appeared in the Annual Report of the Director in 1923, in which King's report indicated that she spent much time on this work.[117]

Rats and Relationships

King's relationships with other scientists were closely connected to the Wistar rat colony. Other workers wanted the homogeneous strains that she was breeding. As mutations appeared in the stock, she continued to maintain colonies of the mutants. Currently, there has been a considerable amount of literature produced on choosing the

[114] American Eugenics Society Records, American Philosophical Society.

[115] RPP. Pearl to King, 1926, March 19.

[116] RPP. King to Pearl, 1926, March 21.

[117] Wistar Institute, Report of the Director 1923.

"right" organism.[118] Clause noted that, although many programs in rat breeding and husbandry were found throughout the United States, it was at the Wistar Institute "that the concept of the rat as an instrument for scientific research was most clearly articulated and that the engineering of a superior animal was most vigorously promoted as an objective of the institution's scientific program."[119] The idea of the standardized rat with the trademarked name WISTARAT was the making of the Wistar Institute and perhaps King as well. As noted previously, the availability of the rats made it possible for King to move from her earlier studies on the embryology of marine invertebrates and amphibians to mammalian genetics. King and the Wistar then had a product that other geneticists needed. King was accepted into the largely male world of genetics at first because she had a desirable product and then because they recognized her scientific abilities.

Broadening the Scope – Domestication

Another problem that occupied King's attention for much of her career was the inheritance of domestication. The Norway rat, then *Mus norvegicus* and later *Rattus norvegicus*, was difficult to keep in captivity. King successfully worked with these animals from about 1922. As H. H. Donaldson noted in the Annual Report, King's attention to the domestication of the wild Norway rat was "a unique endeavor in the sense that the successive generations are not only closely studied for behavior, but are also anatomized and the progressive change in the organ constitution is thus determined."[120] The next year's report praised her work as "the first instance in which the effects of domestication have been scientifically followed." By the 11th generation reached in 1924, these rats had become so tame that they could be handled easily and gradually approached the albino type in "rate of growth, time of puberty, and in the sex ratio among the young at birth."[121]

In early 1924, King initiated an experiment to study fertility in hybrids between the Norway and Albino rats. The eugenic implications of this study were important as far as miscegenation laws were concerned.

[118] See, for example, Zallen, 1993; Kohler, 1993; and Kohler, 1994.

[119] Clause, 1993, p. 332. Karen Rader's fine study describes the standardization of the inbred mouse with significant parallels as well as significant differences in the purposes and uses. Rader, 2004.

[120] Wistar Institute, Report of the Director, 1922.

[121] Wistar Institute, Report of the Director, 1924.

If a decrease occurred in the fertility of hybrids in successive generations eventually leading to sterility, then there would be support for Mjöen, who predicted that such would be the fate of the American people because of continuous intermingling of different racial stocks.[122]

King recognized that the wild ancestors of the laboratory rat differed from their pampered domesticated brothers and sisters both in their anatomy and physiology. The *Philadelphia Record* described how she became involved with the gray Norway rat. According to the newspaper, these new rats were "savage" animals living in deserted stables on the outskirts of the city. They were trapped, brought to the Institute, and put into sterilized cages. King's collaborator on the project was Dr. Henry H. Donaldson who "studied the effects of the easy, cloistered life on the internal organs of the rat" while King studied life processes such as "weight increase, fertility, sex, behavior."[123] The new rats were indeed wild and would become agitated if a strange rat was put in their cage. "They'd smell a rat, so to speak; and they'd promptly slaughter him." Mothers would even slaughter their young if they were removed from the home cage and then reintroduced, having "lost the good, familiar cage smell. In order to save the lives of these small creatures, King gave them to foster-mothers, the "gentle albino rats." After several generations of domestication, the Norway rats increased in size and became much calmer.[124]

Donaldson and King were intrigued by the causes of physiological and anatomical changes resulting from domestication. After determining that the brain of the domestic rat weighed less than its wild ancestor's, Donaldson hypothesized three possible causative factions: the absence of the struggle for existence, interbreeding, and lack of exercise. Shinkishi Hatai joined the study to determine "whether central nervous system weight was inherited and related to albinism as a physiological condition, or acquired as the result of external conditions associated with domestication."[125] In order to ascertain the influence of exercise on the growth of the nervous system, Hatai developed a technique used by King to weigh and measure the changes that took place in the Norway rat under the influence of domestication. They exercised many generations of these rats in "revolving cages," weighed and measured their brains, and compared them to the original Norway stock as well as to albino rats. The result was a 5% loss of brain weight. King and

[122] Ibid.

[123] Philadelphia *Record*, 1939; Henry Donaldson, 1915.

[124] Philadelphia Record, 1939.

[125] Clause, 1993, 340.

Donaldson were fascinated by the conditions that caused the brain to grow to a greater size in the wild Norway rat and to a lesser size in the albino rat and by the implications for humans. "Do similar conditions produce like results in men?"[126]

King found many other differences in the physical structure of the wild Norway rat when subjected to domestication over a long period of time (15 generations by 1926). In addition to smaller brains, the animals of the later generations grew more rapidly, attained a much larger size, bred at an earlier age, and produced larger litters than those of earlier generations. Originally, the ratio of males to females was 88 males to 100 females, but in the later generations it was 104 males to 100 females. Similar observations had been noted in other domesticated animals, but the anatomical differences: "changes in brain weight, changes in the thyroid, thymus, suprarenals, hypophysis, spleen, pituitary body, and changes in the skeleton" had not been studied previously, and these changes formed the basis of numerous papers in succeeding years.[127]

One of the most interesting outcomes resulting from the domestication of the wild rat was an increasing number of mutations. For example, King reported that "early in 1926, a female of the thirteenth generation gave birth to a litter of black young" which bred true. Although "such black forms have been found in the wild state," they never before appeared in a laboratory strain of Norway rats. Another mutation occurred in the 14th generation, where the female gave birth to an animal with a much lighter coat color with red eyes instead of black eyes like its parents. And finally, at the end of 1926, a female gave birth to a litter containing several coat colors including one albino. Thus, she wrote, "for the first time an albino rat has been derived directly from the wild gray Norway rat under observations."[128]

The new albino was a new strain, apparently unrelated to the domesticated laboratory rat. "After 17 generations bred in captivity, nine pure albinos were obtained in 1927 directly from gray parents." King reared these albinos, recorded their growth and fertility, and hoped to develop a new strain of albino rats "of known pedigree." She then planned to "make a detailed study of the changes that undoubtedly have occurred in characters other than coat color."[129] The Director's report for 1927 was filled with praise for King and for the eugenic

[126] Wistar Institute, Report of the Director, 1926.

[127] Ibid.

[128] Ibid.

[129] Wistar Institute, Report of the Director, 1927.

implications of her studies. He wrote that "the work that Doctor King has done is unique and deserves better facilities and greater opportunities for development than are at our command at present. Much of this work has a direct bearing upon race betterment and an agricultural economic importance in connection with domestic animals."[130]

More Mutations

As King continued with her breeding studies, additional mutations appeared in both the albino and the Norway rats. The production of true-breeding mutant rats appealed to many geneticists who wanted to purchase these mutant strains. Scientists, including Harvard geneticist William E. Castle,[131] appreciated her data and engaged in collaborative projects with her. In her report for the Director in 1933, King announced that she and Castle had begun a study of linkage relationships in all known varieties of rats.[132] Their joint paper was published in 1935.[133]

One of these mutations was the subject of a long-term collaborative project. King suspected that there was a relationship between a mutation that occurred in her strain of mutant albino rats and one that long had been observed in mice. The so-called "waltzing" mutation was the subject of King's investigation and one on which she collaborated with Castle. She wanted to obtain enough of these rats to determine the cause of their peculiar movements. Suspecting that the cause was a defect in the central nervous system, she indicated that "psychological tests may also be made to supplement the study on waltzing mice made some years ago by Doctor Yerkes."[134] King published a paper on the waltzing mutation in 1936.[135]

Waltzing rats caught newspaper reporters' fancies, and an article in the March 21, 1937, Philadelphia *Record* was headlined "Rats Waltz Beside the Beautiful Schuykill, Not to Eat, Not for Love – They Can't Help it." Complete with photographs of a "husky white rat" and a

[130] Ibid.

[131] Only a small fraction of Castle's correspondence is available at the APS and these letters mainly refer to his retirement interest in breeding horses. Consequently, I have relied upon printed papers and King's brief notes to gain an understanding of their collaboration.

[132] Wistar Institute, Report of the Director, 1933.

[133] Castle and King, 1935.

[134] Wistar Institute, Report of the Director, 1933.

[135] King, 1936.

serious looking King, the article reported that "the famous pedigreed rats of Wistar Institute are a family of versatile performers." Under King's supervision, "some of the more intricate details of animal inheritance" could be studied.[136]

King continued to provide the newspapers with good copy about other mutations found in the rat colony. Reporters delighted in anthropomorphic descriptions of these mutations, and one gets the impression that King gleefully played to their prejudices. The September 11, 1939, issue of the Philadelphia *Evening Ledger* described three of King's mutants, the "wabbly," the "waltzer" (see above), and the "hairless." King, in describing the wabbly rat, reported that "it acts as if it is on a perpetual binge. It can never from infancy to old age, walk a straight line."[137]

The Fate of the Rat Colony

In 1938, it became evident that the threat of war was affecting genetic research. Investigators in Europe, fearing the loss of their stock, sent animals to the United States. The correspondence between L.C. Dunn and King reflects this European concern. Dunn explained that J.B.S. Haldane's laboratory in London had sent a new rat mutant to him in order to secure the strain and that H. Gruneberg also sent a stock of these mutants, hoping "during the war crisis in September" these animals could be maintained in the United States.[138] But the Wistar as a repository for different mutant strains of rats was changing.

The direction of research and the destiny of the rat colony changed with the death of Milton J. Greenman in 1937 and Herbert H. Donaldson in 1938. After Greenman's death, the Institute reorganized under a Board of Managers and an executive director, E.J. Farris. Farris gradually scaled down the numbers of rats in the colony not directly related to the research of Wistar scientists.[139]

King reflected the new emphasis when considering L.C. Dunn's request to house the Gruneberg mutants at the Wistar and supply other researchers with the stock.

> Because of the great expense involved, the Wistar Institute has discontinued its former policy of maintaining a large stock of

[136] Philadelphia *Record*, 1937.

[137] Philadelphia *Evening Ledger*, 1939.

[138] King to Dunn, 1938. January 4. LCD papers.

[139] Organization Chart. The Wistar Institute of Anatomy and Biology, 1939.

> various kinds of rats from which investigators in other laboratories could obtain animals for experimental work. In the future, rats are to be raised only for the use of investigators working at the Wistar Institute, although surplus stock is available to others.

She further explained that her colony was not maintained in the same building as the general stock colony "the rats in it are only those needed for my own work." However, if Castle agreed that linkage tests should be made between the waltzing rats and the new mutant, she promised to accept a few rats for this work. She made it clear that she could not consent to maintaining the stock indefinitely supplying it to other investigators. "Cage room is at a premium in my colony at present, and I do not want any of these new mutants unless I need to use them."[140]

Later Association with Eugenics

King followed the path that many geneticists took during the third decade of the 20th century. Eugenics as a stimulus to her research was hardly mentioned in her later works. Changing scientific and social values partially explain why King and others moved away from eugenics. Both science and society were changing. Geneticists began to understand that the complexity of human inheritance made the elimination of a dysgenic trait next to impossible. Developments in the social sciences such as anthropology and psychology threatened the Eurocentric assumptions of most eugenicists. Franz Boas (1858–1942), Ruth Benedict (1887–1948), and Margaret Mead (1901–1978), among others, stressed the importance of culture, not heredity, in defining persons. The notion of IQ, became further complicated as psychologists found that it was difficult to sort out cultural influences from inherited ones.[141]

The growth of Nazism in Germany, contributed to eugenics' loss of respectability. Hitler's dismissal of non-Aryan scientists concerned many American geneticists, although Pearl was optimistic that the situation was temporary and that these scientists would drift back to their old positions,[142] L.C. Dunn was much more pessimistic and, as it were, more realistic about the future of these scientists. As atrocities were

[140] King to Dunn, 1938, December 16. LCD papers.

[141] Ibid., pp. 126–127.

[142] Pearl to L.C. Dunn, 1933, May 24. LCD papers.

committed in Germany in the name of eugenics, many Americans disassociated themselves with this movement.[143]

As we have seen, by 1936 when King summarized ideas on inbreeding, many geneticists were uncomfortable with the implications of eugenics. But King, although she seldom referred to her ideas on eugenics in her general research made it clear that she was still a "true believer." She concluded her article with a plea.

> When the time comes that an enlightened people take thought for the well being of the generations to come and realize the great value of favorable combinations of genetic factors that produce unusual ability, marriage will be based not only on the physical fitness of the individuals but also on their recorded pedigree for several generations. The race can then be vastly improved through consanguineous marriages in families in which the members show exceptional mental and physical endowment in ways that are of value to themselves and to the community at large. Many of the ills to which man is at present subject will vanish. Superior and desirable traits will appear in an ever increasing number of individuals and eventually become the heritage of the race.[144]

New Colleagues, New Research

In order to change with the times and avoid becoming redundant, the aging King found new collaborators who reflected the Wistar's change in focus. Although she continued to work on linkage studies with Castle and other earlier collaborators, most of her later work was on cancer research with a new group of young investigators. She was able to help her new colleagues by providing expertise in the life cycle of the rat, but it is probable that she left the chemical part of the investigation to them. For the remainder of her career King combined her interest in her old projects with a readiness to adapt to new situations (Figure 5).

[143] Ludmerer, 1972, pp. 128–129.

[144] King, 1936.

Figure 5. An aging Helen Dean King. Courtesy of the Wistar Institute, Wistar Archive Collections, Philadelphia, Pennsylvania.

The End of Her Career and Life

A brief note in the 1949 Annual Report noted King's retirement at 80 years of age. Praising her, the report stated that she had published "85 papers on her investigations dealing with fundamental genetics and linkage studies in the rat" and "established that inbred strains, if properly selected, could be maintained without detriment to the stock." Although the Wistar promised to maintain the "unusual strains of rats in Dr. King's colony," her influence gradually waned.[145] In 1950 she remained on the Advisory Board in a special section for retired members. In 1953, her colony "the former King Colony" was renamed Colony 2, but the Institute "still retained about two cages each of 14 strains of rats once maintained by King for her investigations."[146] However, "the great majority of the space in Colony 2 was required for raising of rats used in the cancer program." Still, the institute found that it could generate some income from the sale of rats from King's former colony."[147]

[145] Wistar Institute, Report of the Director, 1949.

[146] Wistar Institute, Report of the Director, 1953.

[147] Ibid.

In 1954, King was still listed in the Annual Report as retired, but the 1955 report contained no reference to her death on March 7th of that year.[148] King died without family and outlived most of her close colleagues.[149] Although there was a brief obituary in the Minutes of the Board of Managers, it was a slim tribute to the woman who had dedicated her life to her science and to the Wistar Institute.[150] King was a member of a number of scientific organizations, including the American Society of Zoologists (former vice president), the Society of Experimental Biology and Medicine, and the American Society of Naturalists as well as Sigma Xi and Phi Beta Kappa. After her death, The Wistar Institute placed a notice of its plans to discontinue its "seven Mutant Strains of rats, developed by the late Dr. Helen Dean King, in the June 10 issue of Science [sic]. These rats were offered free to any scientist or institute willing to maintain them for breeding purposes. Five requests were received, three of which were for research purposes and not breeding. Some of the requests were filled."[151]

Conclusion

A retrospective on King's career reveals a woman scientist who was involved in many of the issues confronting geneticists in the early 20th century. She is best known for her series of carefully constructed inbreeding experiments demonstrating that given proper selection inbreeding was not detrimental to the offspring. Although some experimenters had concluded that inbreeding *per se* was harmful she claimed it was because they had ignored unsuitable environmental factors and had used hybrid strains in the original crosses (ignoring Mendelian recombination). King corrected the environmental problems on her own rats and initiated her inbreeding experiments with animals

[148] Wistar Institute, Report of the Director, 1954; 1955.

[149] King lived alone at the Fairfax Apartments, 43d and Locust Streets in Philadelphia, and when she died on March 7, 1955, she left little in the way of personal information. We know that she was a member of the Church of the Saviour on 38th Street above Chestnut; however, no details of this affiliation is available. According to an article in the *Philadelphia Bulletin*, she left an estate estimated at $5000 to a friend, Esther H. Richardson of Downingtown, Pennsylvania. King's funeral service was held on March 10th at 3:00 P.M. at Oliver H. Blair's Funeral Parlor, at 1820 Chestnut and her interment was in Owego, New York. That she was buried in her home town indicated that she had no hard feelings toward Owego. Philadelphia Bulletin, 1955.

[150] Wistar Institute. Minutes of the Board of Managers, 1955, May 1955.

[151] Wistar Institute. Minutes of the Board of Managers, 1955, October 9.

as homozygous as possible. Agricultural scientists such as Shull, East, and Jones found her results applicable to their work, especially in inbreeding and hybridization of maize.

King was deeply involved in the eugenics movement and was convinced that society would benefit from the selection of superior humans and was not shy about applying her results on rats to humans. In making this application, she agreed with other geneticists who were concerned about the effect inferior heredity was having on the quality of the U.S. citizenry. King's experiments with inbred rats, led to her later work on the inheritance of domestication. One of the results of these breeding experiments was the appearance of various mutations. King collaborated with other geneticists in studying the genetics of the mutant forms.

The Wistar Institute promoted King's career by providing a research animal eminently suitable for her projects. Not only was the Wistar Rat important for King's research it also provided her with a means of meeting other scientists involved in projects that required a nearly homogeneous strain of rats. The Wistar Rat had once provided an important source of income for the Institute. However, when the Institute's financial resources waned and the market for inbred rats declined, the Institute rebelled against keeping rats that were not being used for research. The decline began before the death of King's two mentors at the Wistar. After their death the Institute changed its course and the emphasis was on cancer research rather than theoretical genetics. King gamely changed direction and became involved with the cancer research of the redefined Institute. However, her most creative years were behind her.

Although gender issues played an important part in the course of King's career, she was able to minimize their impact. During the early 20th century, well-educated, talented women scientists were struggling to find their niche in the world of science, and King used the strategy of volunteering to wedge her way into a paid position. Her two mentors, H. H. Donaldson and Milton Greenman quickly recognized her skill and indefatigable energy which she displayed during her first year as a volunteer. With their blessing, she forged a place for herself in a world of science generally inhospitable to women. King was fortunate to have the institutional backing of the Wistar, and the opportunity to interact with the leading geneticists of her day.

When the opportunity came to increase her salary her raise was comparable to that of the men researchers. She also was chosen for a newly created assistant professorship, supported by the Wistar men. On

the other hand, the Wistar exploited King's devotion to her work. Without family responsibilities she was usually available to carry on tasks that her colleagues were unwilling to perform, such as the Wistar Bibliographic Service that took an enormous amount of time to execute. After the deaths of Greenman and Donaldson, King was less appreciated by the new executives.

It is difficult to determine how gender affected King's relationship to her academic colleagues. She was clearly important to her male colleagues at the Wistar and to the geneticists with whom she collaborated. However, one wonders why she was not mentioned in L.C. Dunn's book on 20th century genetics when most of her male colleagues were. King represented the dilemma that women scientists faced. Unlike their male counterparts, scientists such as Nettie Stevens, Marie Curie, and King found it essential to collect an extensive amount of data to support their hypotheses. Women scientists were meticulous in their research protocols in their efforts to deflect male criticism. Unwilling to leap to unsupported conclusions King went to unprecedented lengths to assure the accuracy of her experimental data. More than just a technically proficient scientist of her time and an energetic experimenter, King was a creative scientist who took advantage of her opportunities to defend her hypothesis on inbreeding as well as the importance of mutation and linkage.

King's work also attracted popular interest in the Wistar's experimental program. The public, as noted above, was fascinated by this woman scientist whose specialty involved breeding rats. Her popularity was evident when the *Philadelphia Evening Public Ledger* wrote an article, complete with picture, in celebration of her birthday. The first sentence read, "The Pied Piper lives again." The article confirmed King's total commitment to her scientific work, explaining that she devotes most of her time to study. "The only day, with the exception of holidays, that she hasn't been in her laboratory for some time was last year – the day she delivered a paper on rodents at an international genetics congress."[152]

An unidentified newspaper article by Rose D. Weston headlined "Woman Professor in Biology Research Roots for Phillies" provides a more human look at King. It describes her as an avid Phillies fan and a person who "shakes hands heartily, laughs merrily, and asks you if you are not rather impatient with the Athletics and proud of the Phillies. ..." She also admitted, this report remarked, that her favorite form of literature was the detective story. This same article, probably written in

[152] Philadelphia *Evening Public Ledger*, 1933.

about 1916, suggests that King was catapulted into fame now "that the public and the world of science has just awakened to the fact that a woman, the only woman in America who holds a full professorship in research work for the last seven years has been carrying on a study in heredity, which absolutely revolutionizes and upsets the traditions and theories of centuries."... "Suddenly the scientific world has become aware of the magnitude of her experiments. Journals of research have sent representatives to interview her, scientists from all parts of the world are writing to the Wister [sic] Institute for the result of her investigations." Although these research notebooks have not been found to date and may have suffered the fate of many of the Wistar's records, this article indicated that they contain information on the life histories of the rats she has studied and are of "tremendous value and represent the work of years of observation and notation."

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