Critical Periods in Science and the Science of Critical Periods: Canine Behavior in America

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Summary: This article offers a canine history of the "critical period" concept, situating its emergence within a growing, interdisciplinary network of canine behavior studies that connected eugenically minded American veterinarians, behavioral geneticists, and dog lovers with large institutional benefactors. These studies established both logistical and conceptual foundations for large-scale science with dogs while establishing a lingering interdependence between American dog science and eugenics. The article emphasizes the importance of dogs as subjects of ethological study, particularly in the United States, where some of the earliest organized efforts to analyze canine behavior began. Further, the article argues that the "critical period" is important not only for its lasting prominence in multiple fields of scientific inquiry, but also as a historiographical tool, one that invites reflection on the tendency of historians to emphasize a particular narrative structure of scientific advancement.

Keywords: ethology, animal behavior, dogs, critical period, eugenics, Rockefeller Foundation, Scott, Stockard, wolves

For over seventy years, scientists have been fond of "critical periods." Linguist Eric H. Lenneberg's influential Biological Foundations of Language introduced the "critical period" for language acquisition in 1967, the idea that languages are most easily learned during particular developmental phases.¹ The United States "Head Start" program, established by President Lyndon B. Johnson in 1965, provided early childhood education to low-income families and emerged during a period of psychological focus on "critical periods" in children's

¹ Lenneberg 1967.
development. For adults, on the other hand, therapists have explored whether there are “critical periods” for intervention into psychosis, and, more recently, neuroscientists have used the “critical period” to describe phases of neuronal plasticity. As psychologist John Colombo argues, the elasticity of the “critical period” concept allows “the inclusion of many phenomena from a wide range of disciplines.”

Variants on the term exist, but “critical period” remains a dominant way of understanding developmental change across fields. Following the citational trail of contemporary uses, however, returns us to an unexpected place: mid-century studies of canine social behavior, a project led by behavioral geneticist and comparative psychologist John Paul Scott at the Jackson Memorial Laboratory in Bar Harbor, Maine. Scott’s influential overview of the concept, “Critical Periods in Behavioral Development,” which appeared in *Science* in 1962, has framed discussion, and everyone from Lenneberg to the students of neuronal plasticity link their work, however elliptically, to Scott’s.

This article, in turn, offers a canine history of the “critical period” concept, situating its emergence within a growing, interdisciplinary network of canine behavior studies that connected eugenically minded American veterinarians, behavioral geneticists, and dog lovers with large institutional benefactors, especially the Rockefeller Foundation. Jackson was preceded by the “Dog Farm” of anatomist Charles Rupert Stockard, who turned to dogs in order to test hypotheses about the endocrine system and human “racial degeneration.” Although historians of biology have typically regarded Stockard as an embarrassing oddity, I argue that this project established both logistical and conceptual foundations for large-scale studies of dogs, while also revealing a lingering interdependence between American dog science and eugenics.

Research with dogs as experimental subjects, the article shows, involved a more complicated network of stakeholders than work with other laboratory organisms; dogs were discipline-defying, inviting analyses of genetics, psychology, and behavior as well as emotions, personality, and heredity, which pushed studies in multiple simultaneous directions and disrupted efforts at unification. The article is thus simultaneously a history of canine behavior studies and a

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2 “To some extent, this obsession arose because psychology was overwhelmed by the ethological concept of critical periods,” write Edward Zigler and Victoria Seitz 1982, on 84.
3 Birchwood et al. 1998.
4 Fagiolini and Hensch 2000.
5 Colombo 1982, on 260.
6 Scott 1962.
7 Panofsky 2014 followed Paul in suggesting minimal eugenic connection between Jackson and earlier programs. On Whitney’s eugens in a transnational perspective, see Küh 1994. On Whitney in America, see Lovett 2007. On American eugenics more broadly, see Kevles 1995; Cooke 1998; Godin 2007. An excellent historiographical overview is Paul 2016. On Stockard’s embryology and broader irrelevance, see Clarke 1987; Pauly 2002. Pauly 1996 notes there is no significant biographical account of Stockard.
prehistory of canine “ethology”: a story of the numerous cross-cutting fields which attempted to understand what dogs do.  

I trace the origin of the Jackson studies from Stockard’s aborted project as well as a shared interest in dogs between the Rockefeller Foundation’s Alan Gregg and Jackson director Clarence Cook Little. I argue that the practical complexity of training and understanding the behavior of dogs, especially the financial costs of doing so during a period when “standard” animals became a de facto expectation for animal experimentation, encouraged researchers to focus on the early stages of life – “critical periods” – because preliminary mistakes could undermine years of careful research. In telling this story, the article emphasizes the importance of dogs as subjects of behavioral study, particularly in the United States, where some of the earliest organized efforts to analyze canid behavior began.

The article builds on existing studies of experimental animals and “model organisms,” work which has revealed how nonhuman beings become crucial elements within both the conceptual and practical infrastructure of scientific work. Because dogs are expensive research subjects, large-scale experimentation on historically required wealthy institutional funders, whose own aims and proclivities shaped the forms that canine behavior studies took, and the article thus emphasizes the importance of external funders in producing canine science. Yet dogs have been comparatively undertheorized as research organisms by historians of science, and, concomitantly, canine studies have been treated as minor pieces in the development of the science of behavior. One key reason is that it was only in the late twentieth century that social behavior studies of dogs were (re)conceptualized as canine ethology: during the development of the discipline of ethology, dogs appeared too complex for the study of “instinct” that Richard W. Burkhardt argues characterized the early field. Most historical writing about ethology thus focuses on the key research organisms of the field’s founders: notably, birds and fish. That focus has been important, but it has left historians and philosophers with few tools to approach the contemporary prominence of studies of canine behavior, which have seen a sharp increase over the last thirty years and made dogs a behavior “scholar’s best friend.” The article ends by exploring two outgrowths of the Jackson work, comparative studies of the behavior of dogs and wolves by Raymond and Lorna Coppinger and Harry and Martha Frank, which reveal how Scott and Fuller’s “social behavior” program was reimagined as a founding moment in the development of canine “ethology.”

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8 In this article, I generally use “ethology” in its more common usage as a reference to the scientific study of behavior. The term has been traditionally associated with the three winners of the 1973 Nobel Prize for Physiology or Medicine: Karl von Frisch, Konrad Lorenz, and Nikolaas Tinbergen. See also Dhein 2022, this issue.

9 On Little, see Rader 2004; Brandt 2009. Few have explored the significance of his attention to dogs or the implications of the behavior program. Exceptions include Paul 1991.

10 For a recent overview of the literature on model organisms, see Ankeny and Leonelli 2020.

11 In Burkhardt’s thorough study of ethology, dogs receive only occasional reference. See Burkhardt 2005. On dogs as research subjects, see: Todes 2003; Kirk 2010; Kirk 2014; Bolman 2018.

12 Aria et al. 2021.
Inattention to dogs has also produced gaps in our understanding of the most influential concept to come from canine behavior research: the “critical period.” I argue that the “critical period,” which Scott and Fuller rearticulated and popularized, is important not only for its lasting prominence in multiple fields of scientific inquiry, but also as a historiographical device. The Jackson project emerged at what many understood to be a “critical period” in American scientific activity and behavioral study, which allowed for pathbreaking research that could not be replicated later; the popularizers of the term also used it to understand their own lives. By historicizing both the studies and the concept, I aim to reveal tensions in its use as a framing device. Histories of science have long been tied, both implicitly and explicitly, to a critical period approach focused on particular early moments of dramatic expansion or insight for scientific projects. That approach has value, but I argue also for an attunement to knowledge production which appears less critical. The excavation of canine behavior science here offers an abbreviated example of how this might proceed.

1. Dog Farming

Late in 1925, primatologist Robert Mearns Yerkes received a request for Yale’s support in research on experimental breeding in dogs. “The races of dogs are just as numerous as the races of men,” explained young dog breeder Leon F. Whitney, former Executive Secretary of the American Eugenics Society. Whitney was a prominent, if at times controversial, voice in the American eugenics movement: his popular book *Sex and Birth Control* suggested a path to racial “improvement” through controlling the reproduction of “degenerates.” As Stefan Kühl has shown, Whitney was also important in bridging America and Nazi Germany, expressing his admiration for Nazi sterilization laws and sending a copy of his *The Case for Sterilization* to Adolf Hitler. For Whitney, canine studies offered essential evidentiary support for such projects: “I believe that so much of eugenical and genetical importance can be found out from dogs.” Yerkes, another noted eugenicist, was supportive, but Whitney’s proposal arrived just a few months late: that March, Charles Rupert Stockard had received funding from John D. Rockefeller’s General Education Board (GEB) to undertake a similar program with nearly parallel justifications, bringing far more scientific prestige than Whitney himself.

Stockard, a leading American anatomist and embryologist, graduated from Columbia in 1906 and began teaching at Cornell Medical College in New York City. There he would rise to chair the anatomy department and remain for the rest of his career. In 1925, he met with Wickliffe Rose, head of the GEB, to inquire about support for “a breeding experiment with dogs.”

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13 Caudill 1993, on 1–2.
14 Kühl 1995, on 85.
15 Leon Fradley Whitney to Robert M Yerkes, 19 October 1925, p. 1, Robert Mearns Yerkes papers (MS 569), Manuscripts and Archives, Yale University Library, Box 52, Folder 1007.
requesting $12–20,000 in order to purchase a fifty-acre farm, hire staff, construct relevant buildings, and acquire animals. Stockard’s focus was the endocrine system and inheritance of “glandular types.” The glands, historian Michael Pettit argues, offered a useful framework for theorizing biological determinants of individual character before DNA. Such research was frequently coextensive with eugenic studies, and Stockard’s was no exception: “Many of these breeds of dogs have been bred pure for several hundred years,” he noted, “and show definite glandular complexes entirely comparable to similar glandular conditions seen in peculiar human beings.” His embryological work also attuned Stockard to the early stages of organismic development — what he called, like some other developmentally-attuned biologists, “critical moments.” Stockard thought breeding experiments with dogs might reveal the importance of such moments with explicit lessons for human beings.

In The Physical Basis of Personality, an adaptation of his Lane Medical Lectures at Stanford University in 1930, Stockard offered some of the first conclusions from the ongoing work, which he anticipated would take at least another decade to bear fruit. “[I]t is of great significance,” he noted, “that certain human freaks practically parallel in their growth and form these diversified canine types.” Many of the modern dog breeds were evidence of glandular defects, Stockard wrote, and “Strangely enough, dog fanciers have been unconsciously selecting and preparing a splendid array of material, most ideally suited for a scientific investigation both of the inheritance of endocrine gland disturbance and of the effects of such disturbances on the growth and form of the mammalian body.” In their pursuit of unique appearances and capacities, dog breeders had completed most of the leg work of producing an excellent laboratory organism for eugenic analysis.

Stockard’s “Experimental Morphology Station,” which most knew as the “Cornell Dog Farm,” received over $400,000 (close to $8 million today) during its years of operation. What the GEB and later Rockefeller Foundation (RF) received from their investments, however, was less clear: the Dog Farm released no annual or monthly reports, and Stockard published minimally about the work. One reason was the unanticipated difficulty of working with dogs as experimental subjects: scattered notes reveal that the project’s earliest years were spent simply determining how to breed, feed, and keep dogs in a healthy and sustainable manner. Dogs could not live entirely inside, like the hamsters Stockard was used to, but outdoor life invited parasites, which spread easily between animals. “As quickly as the animals are cleaned of hookworm they become reinfected by larvae eggs from the ground,” Stockard moaned in

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16 “Stockard, Dr. Charles R. (Extract from Interviews with Doctor Rose),” 18 March 1925, General Education Board records (FA058), Rockefeller Archive Center [henceforth GEB RAC], Box 703, Folder 7235.
17 Pettit 2013.
18 Charles Rupert Stockard to Wickliffe Rose, 30 March 1925, GEB RAC, Box 703, Folder 7235.
19 Stockard 1921.
20 Ibid., on vii.
21 Ibid., on 223.
February 1928.\textsuperscript{22} Constantly thinking of the dogs as human analogs, he compared the laboratory’s disease challenges to those of urbanization: “It is much the same sanitary proposition which a human community faces in growing from a sparsely settled village condition into a thickly populated town.”\textsuperscript{23} Dogs made for persuasive experimental subjects, but their management was far beyond what Stockard predicted.

Stockard was himself obsessively focused on the glands, but the dogs seemed to demand broader, behavioral consideration, so in 1932 he brought in William T. James, who worked at Cornell under experimental psychologist Howard Liddell, one of the leading American practitioners of Pavlovian conditioning.\textsuperscript{24} James constructed new experimental apparatuses to hold dogs in place during physiological studies and found that heredity strongly influenced the presence of dominance behaviors, in turn determining how well dogs responded to laboratory conditioning.\textsuperscript{25} Stockard, however, died unexpectedly in 1939, leaving James’ work and his own magnum opus on the dog studies unfinished. “In regard to the behavior of the different types, the work has just begun,” James wrote in a memo on the future of Stockard’s farm.\textsuperscript{26} Desperate to keep his research active, James suggested converting the farm into a more general experimental facility for those interested in dogs, or perhaps a production site for purebred laboratory animals. His pleas held little sway: the “Dog Farm” disappeared shortly thereafter, and James returned to Ithaca, with Liddell’s help, where he used equipment and animals from Stockard’s facilities to build a new experimental dog kennel, shaping canine research at Cornell for years to come.\textsuperscript{27}

\section{2. Little’s Dogs}

Alan Gregg, head of the Rockefeller Foundation Medical Sciences Division, which funded Stockard’s research in later years, had hoped the project would generate insights into the inheritance of mental ability, with implications for educational policy. Even after, he remained interested in further work on dogs, and contacted prominent scientific figures between 1942 to 1943 about the possibility of such dog studies.\textsuperscript{28} Edwin B. Wilson, a statistician at Harvard’s School of Public Health, suggested Clarence Cook Little, director of the Jackson Memorial Laboratory: Little had already started breeding dogs for his

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\textsuperscript{22} Charles Rupert Stockard to Abraham Flexner, 23 February 1928, GEB RAC, Box 703, Folder 7235.
\textsuperscript{23} Stockard 1931b, on 262.
\textsuperscript{24} On Liddell, see Kirk and Ramsden 2018. On the American Pavlovian use of dogs, see Ramsden 2018.
\textsuperscript{25} James 1939.
\textsuperscript{26} William T. James, “[Dog Farm Memorandum],” 1939, p. 1 Rockefeller Foundation records, Rockefeller Archive Center [henceforth RF RAC], SG 1.1, Series 100, Box 81, Folder 977.
\textsuperscript{27} William T. James, “Autobiography of William T. James,” 1988, on 14, William T. James papers, University of Georgia Archives, Box 2, Folder 17.
\textsuperscript{28} Paul 1991, on 273.
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cancer studies and even judged in the Boston Dog Show.\footnote{Edwin Bidwell Wilson to Alan Gregg, 27 December 1943, RF RAC, SG 1.2, Series 200 A, Box 133, Folder 1189.} Before turning to mice during his graduate studies with Harvard biologist William Castle, Little had “wanted to follow in his father’s footsteps and breed dogs […] for genetic study,” and continued to publish small articles and book reviews on doggy and eugenic topics.\footnote{Rader 2004, on 25.} In a review of Elliott Humphrey and Lucien Warner’s \textit{Working Dogs} in 1935, Little noted that “dogs, properly studied, would provide a sorely needed foundation for a great deal of progress in comparative psychology.”\footnote{Little 1935. See also Rader 2004, on 253.} Gregg’s suggestion found open ears.

The logistics were manageable, Little felt, and a laboratory could outsource the housing of dogs to local farmers in order to save money. Without explicitly volunteering Jackson, he made clear that his facilities could handle the project – Stockard’s histologist, Emilia M. Vicari, was also already working there. To run the program, Little recommended Hans Grüneberg, a geneticist working with J. B. S. Haldane in England. Grüneberg and Little had corresponded over the years about mice, and Little thought the young émigré could sustain the dog program after his own eventual retirement. In 1944, Little inquired whether Grüneberg might be interested in participating in something that would be “far greater” than what “Stockard and others” had attempted,\footnote{Clarence Cook Little to Hans Grüneberg, 16 October 1944, 1, Grüneberg, Professor Hans, „Codebreakers: Makers of Modern Genetics,” Professor Hans Grüneberg papers, Wellcome Library, online: https://wellcomecollection.org/works/jzjgce9q (accessed 2 December 2021).} a possible reference to Grüneberg’s caustic criticism of Stockard’s work as a “nightmare dog show” in \textit{The Eugenics Review}.\footnote{Grüneberg 1942.} The Jackson job, Little insisted, was “the best opportunity that exists today in mammalian genetics.”

Little further proposed that John Paul Scott, whose “traits and abilities […] would supplement those of Gruneberg successfully,” be brought in as second-in-command.\footnote{Clarence Cook Little to Alan Gregg, 17 October 1944, RF RAC, SG 1.2, Series 200 A, Box 133, Folder 1189.} University of Chicago geneticist Sewall Wright, whom Little frequently consulted, had recommended Scott, a former student who had visited Jackson as a summer researcher in 1938 and 1939.\footnote{Scott 1989, on 408.} Scott jumped at the opportunity, excited to escape a frustrating position at Wabash College and to pursue a new interest: from 1938–1942, he had become acutely interested in applying biological techniques to the study of sociality, a new approach which he called “sociobiology.”\footnote{Cora Stuhrmann traces the development of “behavioural ecology” and its intersections with the more popular variant of “sociobiology.” See Stuhrmann 2022, this issue.} From this work, Scott developed the concept of the “behavior pattern,” a unit of behavior with definite function, one which paralleled Tinbergen’s “ethogram” – Scott claimed he was not aware of Tinbergen until much later.\footnote{Scott 1989, on 406.} Jackson appeared to be the ideal place to expand...
on this early approach. Grüneberg, caught up in the hostilities of World War II, could neither accept nor refuse, so planning continued without him.

Dog work was expected to take place at “Hamilton Station,” a fifty-five-acre farm across from Jackson’s main building, donated in 1940. The site had three barns, which could be retrofitted to house dogs and other facilities, as well as a small histopathology lab. Its size revealed the infrastructural challenges of work with canines: where mice could be kept within a few large rooms, dogs were thought to require large pens as well as frequent access to the outdoors – an increase of space by multiple orders of magnitude. If kennelled too tightly together, fighting and disease outbreaks tended to rise up, which had been Stockard’s great challenge. In addition, the cost of continuously feeding even a dozen dogs was significant, and researchers routinely complained about how much of their budgets went to food.

When Grüneberg ultimately declined Little’s offer, it was left to Scott, whose intellectual inclinations were broader than Little or Gregg recognized, to run the program. In an early memo, Scott specified interest in “differences in the physiological background of behavioral and emotional differences,” and under his guidance the Jackson study of the genetics of intelligence quickly became a study of genetics and behavior, with growing emphasis on the latter.38

3. The School for Dogs

The new study was announced to the public in The New York Times in May 1945.39 Representatives from America’s humane societies promptly wrote to Little in protest, but he brushed away the concerns: their precious little dogs, locked away in apartments, were treated worse than the study’s animals would be. Broadly, however, the project was met with support: in November, Gregg met with British statistician and biologist Ronald Fisher – another prominent eugenicist – who noted that “one of the most valuable things that could be done in genetics would be work with dogs in studying temperament and nervous disposition.”40 Walker M. Dawson, who had planned a study of canine intelligence at the Department of Agriculture’s Beltsville experiment station to follow up Stockard’s project – later scrapped due to World War II – arrived toward the end of January 1946 to advise.41

As construction neared completion on the “behavior laboratory” in February, Scott planned a conference on “Genetics and Social Behavior,” intending to bring together leading lights and promising young scientists to

38 Alan Gregg to Clarence Cook Little, 16 March 1945, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1190.
39 [Anon.] 1945.
40 Alan Gregg, “Diary,” 1945, on 216, RF RAC, RG 12, Officers’ Diaries, F–L, „Gregg, Alan,“ online: https://dimes.rockarch.org/objects/Xxa5PUBegYeDCqZpppWMP (accessed 2 December 2021).
41 Friendly 1939; Dawson 1937.
“build up enthusiasm and lay the foundations for cooperative work.” A list of key topics for the conference heavily emphasized the behavioral elements of the research, but included a significant number of comparative psychologists, too, because many moved somewhat fluidly between the fields of “behavior” and “psychology.” Little was preoccupied with lab management and other concerns, while Gregg was slowly edging toward retirement and avoided dictating the direction of research projects funded by Rockefeller. As both increasingly took a backseat, behavior’s centrality grew. Rather than carefully interbreed dogs to identify particular visual or cognitive traits, as Stockard had done, or set out to produce a hyper-intelligent dog, as Gregg and Little had imagined, the program of research emerging from the conference placed a heavy emphasis on using learning tasks and behavioral observation to understand the social life of dogs. For Scott and many others, the violence of World War II had demonstrated the necessity of analyzing the causes of both aggressive and cooperative behaviors.

With Grüneberg out of the picture, Scott needed his own second-in-command and invited John L. Fuller, an MIT-trained physiologist who spent the war years at the University of Maine working on submarine detection and marine biology, to join the staff in the summer of 1947. With an additional grant, Scott was able to purchase an electroencephalograph machine for Fuller to carry out brain measurements, which were considered essential to understand the cognitive aspects of canine behavior. Scott also invited James to visit Hamilton and to guide Fuller on the construction, assembly, and testing of apparatuses to restrain dogs in experimental settings. Stockard’s project thus left a technological imprint on the work at Jackson, and a lively exchange between the dog project at Jackson and work at Cornell continued: Scott visited the dog facilities which James built at Cornell for inspiration in 1945, and, in exchange, James brought dogs from Jackson to the University of Georgia for his own new colony. Jackson had begun raising five breeds of dog, selected originally by Little to represent different “personality” types: Basenji, Beagle, Cocker Spaniel, Shetland Sheep Dog, and Wire-haired Fox Terrier. Each breed also reached a similar size at maturity, alleviating the need for testing devices of multiple dimensions, which was particularly important because apparatuses, including specially crafted test boxes, were often built by the laboratory at no small cost.

The “School for Dogs,” as Scott and Fuller sometimes called their project, progressed rapidly. Aware of the challenges that befell Stockard, Gregg urged them not to mine “more than you can smelt,” and to “run the smelting as much as possible”: publish often, in other words, rather than wait for the

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42 John Paul Scott to Alan Gregg, 26 December 1945, RF RAC, SG 1.2, Series 200A, Box 134, Folder 1190; John Paul Scott to Alan Gregg, 6 February 1946, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1190.
43 John Paul Scott to Robert S. Morison, 26 April 1946, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1190.
44 John Paul Scott to Robert S. Morison, 22 January 1947, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1191.
45 Fuller 1985, on 98.
By March 1948, the lab had isolated multiple behavioral “abnormalities,” such as excessive fearfulness, and planned twenty-four outdoor pens in order to establish a baseline for what constituted “normal” behavior in a somewhat controlled setting. In August, Fuller indicated they had identified genetic differences in juvenile adjustment to group behavior and in the attitude of female dogs to weaning.

Because staff was limited, Scott and Fuller took on responsibility not just for overseeing the project, but also for caring for the dogs. Scott required “strict adherence” to rules of interaction with the dogs: physical punishment and loud noises were not permitted, special handling and petting were to be avoided, and rewards for participation in tests had to be uniform. The resulting experimentation was a mix of traditional pet training strategies and problem-solving and behavioral tasks — the type of conditioning work pioneered by Liddell, James, and others — carried out by experimenters (or “teachers,” as they were sometimes called). As an example of the former, one of the lab’s crucial early tests was leash training, which involved rewards for walking with an experimenter on a leash. This contrasted with more complicated experiments to ascertain differences in breed ability, such as a tracking test in which “fish juice was smeared on metal plates” which were placed alongside non-treated plates to see how dogs differentiated between smells.

Some canine behavior tests preexisted Jackson: Pavlov, for instance, had pioneered tests of how dogs learned to avoid stimuli. But the Jackson lab carefully revised these tests and devised numerous others, such as the leash test or a test of “climbing” ability that involved having the dogs walk across a narrow, elevated plank. Results were carefully tracked using dozens of paper forms, carefully catalogued in relation to individually identifiable animals. The outcome was a sizable, quasi-bureaucratic apparatus documenting skill and ability, literalizing the “school” metaphor. The battery of tests was advanced enough that Scott and Fuller assembled a Manual of Dog Testing Techniques, which included not only guidance for carrying out tests but also for handling dogs and constructing devices. They forwarded it to universities and prominent scientists around the world, including members of the “Committee for the Study of Animal Societies Under Natural Conditions” (CSASUNC), the organization Scott was secretary of and which had emerged directly from

46 Alan Gregg to John Paul Scott, 13 November 1946, RF RAC, SG 1.2, Series 200A, Box 134, Folder 1190.
47 Clarence Cook Little to Alan Gregg, 22 May 1948, RF RAC, SG 1.2, Series 200A, Box 134, Folder 1191.
48 Robert S. Morison, “RSM Interview – Thursday, August 12, 1948,” n.d., RF RAC, SG 1.2, Series 200A, Box 134, Folder 1191.
49 Staff of the Division of Behavior Studies 1950.
50 Fuller 1985, on 100.
51 Scott and Fuller 1965, on 22.
52 Sophia Gräfe shows how central a multitude of both visual and observational tools were to the discipline of ethology more broadly. See Gräfe 2022, this issue.
the first Jackson conference. The manual’s short bibliography included only one book on husbandry: Leon Whitney’s *How to Breed Dogs* (staff member Edna DuBuis had visited Whitney for advice on doing so in 1948).

The lab also opened itself to short-term visits from experimenters eager to make use of high-quality dogs. So-called “standard” dogs, those with known ancestry and health histories, had become a focus of researchers in America and Europe during the end of the first half of the twentieth century, but remained difficult to raise or acquire. Jackson was one of the first places to make such animals available, and James was only the first of a steady stream of experts to visit Hamilton Station in order to work with them. Those who could not travel to Bar Harbor could also purchase dogs at a premium, one of the first instances in which purpose-bred “scientific dogs” could be bought directly. In this way, Hamilton Station instantiated many of James’ original hopes for the aftermath of Stockard’s farm: a semi-permanent site for the production of high-quality experimental dogs as well as for visiting researchers hoping to utilize the facilities.

### 4. The Critical Period

What kind of science was happening at Hamilton Station exactly? Scott and Fuller understood and described their research as a study of “genetics and social behavior.” They were interested, the two wrote in 1965, in “behavioral systems,” groups of related behavior patterns that possessed a common function, which situated their work in “the domain of the twin sciences of psychology and ethology.” Much of their work indeed mirrored ethological research, which Scott and Fuller described as a “collector’s job” of noting basic kinds of behavior, but it differed in refusing the concept of “instinct,” which was “too inexact to be of much value in modern scientific work in the description of behavior.” Canine behavior was too complex for bifurcation into “instinctive” and “learned” behaviors: patterns and behavioral systems were intricately interwoven and learned.

How, then, did behavioral systems work? In 1950, Scott and Mary-’Vesta Marston first publicly invoked the “critical period,” a concept which would frame the lab’s work for years after, in an article describing key developmental phases in dogs’ learning. Scott’s grant proposal in 1949 contained his own first explicit reference to “critical periods,” but historian Gregg Mitman notes that Scott’s graduate training included a strong emphasis on the interaction between

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53 John Paul Scott to Alan Gregg, 11 May 1950, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1192.
54 Staff of the Division of Behavior Studies 1950, on 72.
55 See Bolman 2021.
56 Scott and Fuller 1965, on 60.
57 “Future Plans for Research on Genetics and Social Behavior at the Division of Behavior Studies, Roscoe B. Jackson Memorial Laboratory: Report to the Rockefeller Foundation,” 23 December 1949, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1191.
organism and environment during development, which “infused” the “notions of thresholds and critical periods in developmental biology” into his research.\footnote{Mitman 1990, on 9.} In graduate work with “monster” guinea pigs, for example, he had shown growth could be accelerated at a “particular period” by certain genes, a finding that Scott connected to Stockard’s “critical moment,” the phase when “abnormal” development could be avoided.\footnote{Scott 1937.} Lorenz’s “imprinting,” from the 1930s, was also influenced by embryological approaches such as Stockard’s, the same ones that geneticist Richard B. Goldschmidt drew upon to argue for a “critical period” in the production of “phenocopies” in \textit{Scientific American} in 1949.\footnote{Goldschmidt 1949, on 47. Scholars often treat “imprinting” and “critical period” synonymously: John Colombo, for instance, credits Lorenz with originating the “critical period” despite the latter not making particular use of it. See Colombo 1982.} Scott was familiar with much of this literature and saw a constellation of “critical period” research connecting Stockard, Lorenz, and himself.

Yet where “imprinting” referred to specific attachments formed at particular moments in the lifecycle (and implied \textit{instinct}), Scott behavioralized the “critical period,” rearticulating the term as a general way of naming rapid changes to behavioral systems during multiple phases of development. Scott’s emphasis in the lab was on early experience, and preparatory studies of basic canine behavior, undertaken to ensure that as much as possible was known about each dog so results would not be marred by improper care or treatment, had revealed the existence of “certain natural periods in development during which the puppy is unusually susceptible to environmental influences.”\footnote{Scott and Marston 1950, on 25.} Frugal necessity thus partly inspired the lab’s key concept, but so did its setup and Scott’s long-term attention to noting behavior patterns: Jackson had just enough dogs, experimenters worked closely enough with each of them, and dog behavior appeared complex-but-recognizable enough that periods of learning and behavioral change could be tracked and quantified in a more highly systematic way than comparable primate labs could.

Quickly, the “critical period” dominated research at Hamilton. The same year as Scott and Marston’s article, summer student Barbara Arndt explored the effect of environment on the “critical period” for young beagles,\footnote{Barbara Arndt, „Effects of environmental differences during the critical period on a litter of beagle dogs,“ \textit{Summer and Academic Year Student Reports} 58, The Joan Staats Library, online: https://mouseion.jax.org/strp/58/.} and Fuller and others followed with a study of conditioned avoidance in puppies which adopted the “critical period” frame.\footnote{Fuller et al. 1950.} Researchers carefully observed and noted the appearance of behaviors, such as nursing and crawling in the “neonatal” period or walking and play-fighting in the “transition” period. Persistent conditioning, the tool of choice for dogs generally and part of the lab’s commitment to training tests, revealed temporal demarcations between the periods: after about ten days of life, puppies were dramatically more capable of learning new skills than beforehand. In much of this work, which
detached the “critical period” from embryology and connected it instead to behavior and learning across an organism’s life, the concept remained a “postulate” or “hypothesis.” But Scott also promised in 1950 that the hypothesis, “which has been a contribution of the group as a whole,” would “lead to important progress” in understanding “abnormal behavior.”64 (For Scott, that particularly meant aggression and asocial tendencies.) The early eugenic project of producing “deviant” types and Little and Gregg’s vision of an “ideal” hyper-intelligent dog had set the stage for the “critical period,” but the latter’s emphasis on learned behavior shifted the focus away from inherent, genetic difference.

In 1951, Scott, Fuller, and associate Emil Fredericson published a more extensive inquiry into the concept. Scott’s preliminary research had shown that periods of extensive isolation for lambs produced marked antisocial behavior and pointed to “the major importance of early experience.” Yet similarly isolated puppies quickly readjusted themselves to social life with other animals, producing the “superficial conclusion” that early experiences were not important for shaping behavior.65 The existence of “critical periods,” which could differ across species, resolved the paradox and allowed for both results to hold simultaneously. “The changes which take place are so precisely timed and the metamorphosis in behavior which occurs just before three weeks of age is so remarkable that the dog is […] a wonderful animal for making experiments on the effects of early experience,” Scott wrote.66 The accelerated pace of canine lives, it was argued, could more quickly reveal such developmental milestones than studies of human beings.67

Not everyone agreed: external advisor Frank A. Beach, who long believed the lab should focus on genetics rather than social behavior, wrote Fuller to express misgivings about the thoroughness of proof regarding the “critical period.”68 In a 1954 review article for the Psychological Bulletin, Beach and Julian Jaynes noted that it was “tempting” to suggest similarities between the proposed critical periods in dogs and parallel phases in human development, “but this would be unwarranted on the basis of present knowledge.” That did not stop an eager public from doing so. Parade magazine writers Karl Kohrs and Sid Ross shared news in September 1950 from the “world-famous animal laboratory” of the “critical period” in which puppies needed to learn new behaviors. The findings, they explained, were suggestive for human development: “What researchers now want to know is this: ‘Is there a “critical period”

64 “Progress Report to the Rockefeller Foundation,” Research on Genetics and Social Behavior (Bar Harbor, ME: Division of Behavior Studies, Roscoe B. Jackson Memorial Laboratory, 1 July 1950), p. 2, RF RAC, SG 1.2, Series 200A, Box 134, Folder 1192.
65 Scott et al. 1951, on 162.
66 John Paul Scott to Robert S. Morison, 8 January 1951, p. 1, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1192.
67 Scott et al. 1951, on 162. For more on human ethological studies, see Odenwald 2022, this issue.
68 Frank A. Beach to John L. Fuller, 7 December 1950, Archives of the History of American Psychology, University of Akron, John L. Fuller papers, “Frank A. Beach”.
in the life of human beings?"69 Because Parade appeared across major American newspapers, much of the country was introduced to the Hamilton Station project that September; a similar, shorter article appeared in national newspapers months earlier.70 The critical period was, Scott noted, potentially "a long step forward in preventive mental hygiene."71 Although popular attention centered on its implications for human learning, dog owners were also quick to take up the concept, with three of the basic periods Scott emphasized (neonatal, socialization, and sexual maturity) becoming core phases in puppy training guidance, particularly for guide dogs.72

1950s America also offered a supportive social context for the term: it was a "critical period in our history," a "critical period in the Korean peace talks," a "critical period for corn production," or a "critical period in building up Western defenses," depending upon the day and the newspaper.73 In the post-war United States, many understood themselves to have witnessed profound historical change and to be standing at the precipice of further transformations. But the "critical period" also emerged at a threshold moment for Hamilton Station: with behavioral tests completed, the lab began crossbreeding its two behavioral "extremes" – cocker spaniels and basenjis; the former understood to be most human-oriented, the latter more "primitive" and wolf-like – to better understand how heredity shaped behavior, and Scott and Fuller published widely (Beach thought too many were of minor importance). After its neonatal period, spent building facilities and operational capacity, Hamilton was now ready to share and socialize.

But problems were not far off. Almost immediately after a positive progress report in 1953, a distemper epidemic swept through Hamilton and killed most of the puppies at a weaning stage, halting crossbreeding for nearly a year.74 In March 1955, as Scott and Fuller were planning for the future of the project, which would soon run out of funding, RF officers confidentially agreed the behavior studies were "not a project for which the Foundation would like to continue full support," due to concerns both about Scott's leadership abilities and the likely cost of future work.75 Yet many acknowledged that terminating the studies would eliminate one of the more substantial behavior programs in existence: "A similar meritorious project could not be conducted less expensively elsewhere," noted Kansas anatomist William C. Young in 1955.76 "It seems to me," wrote psychologist Donald O. Hebb, "that Bar Harbor and Orange Park [the site of Yerkes’ primatology lab] ought to be the two great assets of

69 Kohrs and Ross 1950.
70 Ellis 1950
71 Scott to Morison, 8 January 1951, p. 2, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1192.
72 Pfaffenberger and Scott 1959; Feuerbacher and Wynne 2011, on 56.
73 These examples were taken at random from prominent American dailies.
74 John Paul Scott to Robert S. Morison, 3 August 1955, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1194.
75 Robert S. Morison, “RSM Diary, New Haven, Connecticut,” 8 July 1955, p. 2, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1194.
76 William C. Young to Robert S. Morison, 29 October 1955, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1194.
American (and any other) psychology.”77 With an end nonetheless in sight, Scott insisted that the project would “stand as the best performed and most impressive piece of research which has ever been done in the field of genetics and behavior.”78 The differences of opinion were striking, and they reflected the ambiguous position of controlled behavioral studies of dogs, which interested some American researchers but convinced many others only of the necessity of further work on nonhuman primates – or human beings.

Scott and Fuller stayed at Jackson for a period, but the meat of their behavior work ended. The effects of their painstaking studies were diffuse, but no less significant for it. The lab spurred the CSASUNC, the Animal Behavior Society, and the New York Zoological Society’s “Wildlife Research Station” in Jackson Hole, Wyoming, and dogs were sent from Bar Harbor to labs across America and Europe. Hamilton Station, Beach noted, had “a very considerable effect on stimulating work on animal behavior in general.”79 This had always been Scott’s hope: “I have deliberately and strongly presented the critical period hypothesis in the hope that this will catalyze work elsewhere,” he explained in 1951. “A good research hypothesis has often had a very stimulating effect in other fields of research.”80 So it was with the “critical period.”

5. Wolves, Dogs, and Streets

Few could afford to produce an experimental system comparable to Jackson’s, where it took years and thousands of dollars to get close to “good” results. Breeding purebred animals was complicated and slow, and training the dogs required substantial investment and expertise. Hamilton Station had resolved many of Stockard’s early problems concerning keeping and feeding experimental dogs, but preparatory work took so long that it nearly cannibalized the study once more. Subsequent research on canid behavior followed, but nearly always with smaller and shorter-term experimental setups: many wanted to expand on Scott and Fuller’s studies, but few could afford to.81 Instead, with limited prospects for establishing full behavior laboratories, future work with canids would instead increasingly focus on applied research and comparative analysis of different canids, combining the techniques of Jackson with the methods of “natural” or outdoor observation more characteristic of European ethologists. Two of the more prominent examples reveal a remarkable degree of parallelism: they both drew heavily on Scott and Fuller’s work, were both

77 Donald O. Hebb to Robert S. Morison, 26 October 1955, p. 1, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1194.
78 Scott to Morison, 3 August 1955, p. 2, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1194.
79 Robert S. Morison, “RSM Diary, New Haven, Connecticut,” 8 July 1955, RF RAC, SG 1.2, Series 200A, Box 134, Folder 1194.
80 John Paul Scott to Robert S. Morison, 17 December 1951, p. 2, RF RAC, SG 1.2, Series 200 A, Box 134, Folder 1192.
81 Many other ethologists did manage to maintain large, long-term projects. See Milam 2022, this issue.
carried out by cooperative husband-wife pairs (Scott noted late in life that his own wife should have been a listed coauthor on most of his publications), and both ultimately resulted from curiosities about pet dogs. They also returned attention to the “critical period” and helped to ethologize canine behavior studies.

Raymond C. Coppinger studied animal behavior at the University of Massachusetts in Amherst, exploring experience and novelty as factors in the feeding behavior of birds; his wife, Lorna, studied their visual acuity. The two shared a semi-rural home in central Massachusetts and, after the chance purchase of a Husky-mix, visited veterinarian and former sled dog racer Charles Belford to ask if the dog could compete. The question, Belford explained, could ultimately be answered only by watching the dog run. After exploratory attempts, Coppinger caught the dog sledding bug: from the initial Husky, he purchased others, filled the yard with animals, won regional races, and gradually established his own strain of racing dogs. When Hampshire College opened in 1969, Coppinger became one of the founding faculty and turned increasingly to studying canine behavior, drawing on ethological approaches from his early work with birds. Much of his early research remained centered on sled dogs: analyses of how they maintained body temperature, for example, or sweated. Lorna, meanwhile, finished her degree and published one of the first histories of sled dog racing. In the mid-1970s, however, they began a new project on the performance of sheep-protecting dogs – with its own, distinct Rockefeller roots.

Winthrop Rockefeller, the grandson of John D. Rockefeller, built a 927-acre experimental farm on Petit Jean Mountain, northwest of Little Rock, Arkansas, called “Winrock Farms” in the 1960s. After his death in 1973, the property was converted into a charitable research and training facility known as the Winrock International Livestock Research and Training Center – “a Rand Corporation […] for animal agriculture,” as one commentator put it. In 1976, Winrock hosted leaders from the nation’s sheep industry along with scientists, such as the Coppingers, to discuss new strategies for effective range management. Wolves and other canids had wrought havoc on herds grazing on public lands after bans on a poison known as “compound 1080” in 1972. A 1979 directive requiring nonlethal, noncapture methods on federal lands exacerbated the challenge. Although a number of “modern” approaches to predator control were attempted, including chemical sheep collars and traps, few proved fully effective in slowing predation. Deploying dogs as protection, a practice common in Europe but relatively rare in the United States, emerged as an alternative. The Denver Wildlife Research Center had trained Hungarian “Komondor” dogs in 1976 for this reason, but the program was cancelled.

82 Scott 1989.
83 Coppinger and Coppinger 2001, on 13–14.
84 Sands et al. 1977; Phillips et al. 1981.
85 [Anon.] 1976.
86 Coppinger and Coppinger 1980.
despite evidence of success. William Dietel of the Rockefeller Brothers Fund, who knew the Coppingers from his time teaching at the University of Massachusetts and Amherst College, brought in Raymond and Lorna for the project. After a year traveling across the United States to visit farms for their "Livestock Dog Project," it became clear that the breeds currently in use were unsuccessful and untrusted – as likely to eat the sheep as protect them.

With funding from Winrock, the Coppingers visited Europe and acquired ten puppies from three Old World shepherding breeds: Italian Maermmano-Abruzzeses, Yugoslavian Šarplaninacs, and Anatolian shepherd dogs. They raised the puppies near Hampshire and placed seventy of the progeny on farms and ranches around the country. Contrary to some expectations, the dogs performed remarkably well in limiting wolf activity. More surprisingly, unlike herding breeds such as Border Collies, which required careful training, the guarding behaviors among European shepherd dogs appeared largely unlearned. The dogs adapted quickly to life with sheep, performing sexual and playful behaviors: as the Coppingers summarized, "The dog is treating the sheep like other dogs; the sheep are treating the dogs like other sheep." The findings accorded with what Scott and Fuller found at Jackson, but further emphasized the power of Lorenz's "imprinting": dogs bonded to sheep during early critical periods, yet guarding behaviors reappeared in each generation in contrast to other breeds raised under similar conditions.

As their explorations of canine behavior deepened, the Coppingers turned explicitly to Scott and Fuller’s Genetics and the Social Behavior of Dogs (1965), one of the first scientific books on dog behavior they could find, and Konrad Lorenz’s Man Meets Dog. Visiting Lorenz in 1977, they were greeted by a surprising statement regarding some of this theories of canine origins: "I just want to say, everything I’ve written about dogs is wrong." Rather than the specifics, then, they adopted Lorenz’s naturalistic ethological approach and his concept of imprinting, while they glommed on to the "critical period" from Jackson: the “period when dominance hierarchies are formed and dogs learn […] what species they belong to.” It was the critical period that seemed to explain differences in behavior between Border Collies and Maermmano-Abruzzeses. The pet dog industry, the Coppingers wrote, “still doesn’t seem to understand its significance for traits such as temperament and learning.” Still focused on determining which dogs were most “intelligent,” dog owners failed to recognize how “critical periods” shape behavior and that what dogs do is more important than what they are. The Coppingers affirmed what Scott considered the basic finding of the Jackson studies: “[F]or the most part, there

87 Linhart et al. 1979, on 239. See also, on shepherding dogs, Haraway 2003.
88 Coppinger and Coppinger 2016, on xv.
89 Coppinger and Coppinger 1980, on 18.
90 Ibid., on 24.
91 Coppinger and Coppinger 2001, on 35.
92 Ibid., on 106.
93 Ibid., on 223.
are relatively few differences in [...] pure intelligence, among dogs.” Instead, differences in behavior had to do with motivation and emerged from early life experiences. Almost fifty years later, Scott and Fuller had finally found an eager and attentive audience. But by publishing results in journals like *Ethology* and describing their work as “ethology” as much as “social behavior” studies, the Coppingers also helped to legitimate the dog as an object of mainstream ethological inquiry.

A parallel ethological project was started by Harry Frank, a psychologist at the University of Michigan in Flint, in the 1970s. While still a graduate student at the University of Colorado in 1969, Frank acquired a Malamute-Elkhound mix. After “being erroneously informed that malamutes are at least 1/8 wolf,” he began to notice similarities in his dog’s behavior and that of wolves, triggering an interest in comparisons of the two canids. Frank and his wife, Martha G. Frank, acquired a few wolves from a Minnesota game park and raised the animals themselves, studying their behavior from 1979 to 1981 as part of what they called the “University of Michigan canine information-processing project.” To explore how the animals learned and evaluated information, the Franks employed a series of cognitive tasks, most of which came from Scott and Fuller’s *Manual of Dog Testing Techniques*, and drew on unpublished data that Scott shared with them directly to establish cross-species comparisons.

Because they also added a few newly developed tests, the Franks employed four of their own Alaskan Malamute puppies for comparative results. Malamutes, unlike the breeds employed at Hamilton Station, were imagined to be relatively free of selection for specialized traits, were “lupine” in their size and general morphology, and evolved in the same environment as the timber wolf, but Frank hypothesized evolutionarily divergent cognitive capabilities. Wolves would have “the capacity for foresight, mental representation, and the beginnings of an understanding of means-ends relations,” while domestic dogs would underperform on behavioral tasks except when the experimenter’s presence mattered. The Franks found those differences, but also noted caveats in normalizing the animals’ early experience. The wolves’ test performance was nearly identical to that of Scott and Fuller’s basenjis, for instance, suggesting little fundamental difference between dogs and wolves. What hamstrung the wolf project most was the limited nature of its sample: only one breed of dog and a handful of test subjects. The Franks could not replicate the expansiveness of Hamilton Station, which left definitive answers for future researchers somewhere down the line, but their study exists alongside the work of the Coppingers as two of the key projects in a “second-wave” of canine behavior studies that have today brought attention to dog ethology as a key area of academic and popular interest.

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94 Scott 1986, on 12.
95 Feuerbacher and Wynne 2011, on 62.
96 Frank and Frank 1987, on 145.
97 Feuerbacher and Wynne 2011, on 63.
98 Feuerbacher and Wynne 2011.
7. On Studying Critical Periods

Scott never gave up the critical period concept, continuing to publish about it long after he left Bar Harbor. Although he at first understood the “critical period” in connection to behavioral development, in 1974, he and co-authors argued that a “general theory” of critical periods could be used to understand organizational processes in any living system. Many others, in a wide array of fields, have taken up and made use of the term. But Scott also continued to use it as a way to understand his life, work, and place within history; all the world was a critical period, starting or ending. Reflecting on his career in 1986, Scott noted that he left Jackson for Bowling Green because the latter “was undergoing a critical period” during which he could help build the psychology program. His arrival to Jackson in 1945, too, was timed for the start of a critical period: “It was getting reorganized and expanding, and just about everything was possible.” If he stayed for his whole career, however, Scott worried that he would “run out of new ideas.” Why did some of his concepts catch on widely, while others struggled? “The answer seems to lie in timing […] for some of them the time was right.”

It is easy to dismiss the critical period as something Scott could not relinquish. But the concept also offers an approach, as he recognized, for understanding and describing the conditions for and state of scientific research. The dog behavior project at Hamilton Station emerged during a critical period of funding for biological programs in the United States and required many pieces to align perfectly: intersections of eugenics and dog breeding, Gregg’s institutional connections, Little’s canine fascination, the mid- and post-war period of expanded interest in behavior. The major sums of money funneled into the project allowed for an expansive research program that rapidly produced journal articles, conference presentations, new academic networks, a string of students, and a new understanding of canine behavior, including the “critical period” itself. Hamilton Station emerged at the right moment and, despite work in decades since, has been difficult to replicate or surpass. The Coppingers and Franks worked in the shadow of that critical period.

In this article, I have used Scott’s critical period, at multiple levels, to tell a new story about the science of canine behavior and its relation to ethology more broadly. Hopefully, that new account comes at the right time. In making this move explicitly, I also mean to draw attention to how historians of science are themselves attracted to critical periods: of scientific discovery, travel, and organizational or disciplinary growth; of conceptual “births,” work in its “infancy,” and “mature” scientific programs. Just as the scientific “critical period” moved within a constellation of parallel terms – essential moments, vital phases, important periods – so, too, have historians participated within a broader discursive formation we could think of as a critical period approach. Much history of science, as well as Science and Technology Studies, notes

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99 Scott et al. 1974.
100 Scott 1986, on 24.
101 Scott 1989, on 428.
historian Dániel Margócsy, “tends to focus on beginnings and growth” rather than breakdowns and endings.\textsuperscript{102} The early moments or productive middle phases in experimental communities remain key set pieces in stories of the development of science. Perhaps they should be: Scott’s insistence on the concept might lead us to ask whether there truly are “critical periods” in science. But that approach can also generate an analytic perspective that overlooks subtler, subterranean processes which may support both the emergence and disappearance of scientific projects. Canine behavior studies are not the center of the story of ethology, but they are still significant to it, woven from lost and forgotten roots. Attention to failed programs and network breakdowns, to “how experiments age,” might be essential for understanding how some periods become (regarded as) so critical.\textsuperscript{103}

My approach here has been to tie the “critical” periods to those less obviously so, to use Scott’s concept to understand the humans who produced it, as much as the dogs. Numerous scholars of science have focused on the Jackson project’s emergence, yet few have carefully analyzed its linkages to Stockard, without whom it would have been unthinkable. The breakdown of Stockard’s network freed up individuals, such as James, who transferred devices and techniques to Jackson and elsewhere. Stockard, in turn, required the sudden arrival of substantial institutional funding, but equally the American eugenics movement’s ambiguous relation to the breeding of dogs. Many of the same actors, such as Whitney, floated across projects, often at the margins, sometimes accomplishing but just as often frustrating their hopes. More recent scientific studies of canine behavior, including work by the Coppingers and Franks, relied upon the prolific critical period at Hamilton Station, but they also emerged from their own particular moments, propelled by a resurgence of interest in pet and working dogs. Those studies, joining broader ethological attention to larger mammals, resituated dogs and other canids as key pieces in the work and the story of ethology, one that we are only beginning to fully understand.

References
Ankeny, Rachel A., and Sabina Leonelli, \textit{Model Organisms: Elements in the Philosophy of Biology} (Cambridge, UK: Cambridge University Press, 2020).
[Anon.], “Genetic Study Planned,” \textit{The New York Times}, 7 May 1945.
[Anon.], “Downwind,” \textit{UpCountry}, May 1976.
Aria, Massimo, Alessandra Alterisio, Anna Scandurra, Claudia Pinelli, and Biagio D’Aniello, “The Scholar’s Best Friend: Research Trends in Dog Cognitive and Behavioral Studies,” \textit{Animal Cognition} 24, no. 3 (1 May 2021): 541–553.
Birchwood, Max, Pauline Todd, and Chris Jackson. “Early Intervention in Psychosis: The Critical Period Hypothesis.” \textit{The British Journal of Psychiatry} 172, no. S33 (June 1998): 53–59.
Bolman, Brad, “How Experiments Age: Gerontology, Beagles, and Species Projection at Davis,” \textit{Social Studies of Science} 48, no. 2 (2018): 232–258.

\textsuperscript{102} Margócsy 2017, on 308.
\textsuperscript{103} Bolman 2018. See also Marshall 2021.
Brad Bolman

Bolman, Brad, “Dogs for Life: Beagles, Drugs, and Capital in the Twentieth Century,” *Journal of the History of Biology* 55, no. 1 (2022).

Brandt, Allan, *The Cigarette Century: The Rise, Fall, and Deadly Persistence of the Product That Defined America* (New York, NY: Basic Books, 2009).

Burkhardt, Richard W., *Patterns of Behavior: Konrad Lorenz, Niko Tinbergen, and the Founding of Ethology* (Chicago, IL: University of Chicago Press, 2005).

Caudill, Edward, “Science in the Publicity Laboratory: The Case of Eugenics,” Paper presented at the Annual Meeting of the American Journalism Historians Association (Salt Lake City, UT, October 6–9, 1993), online: https://files.eric.ed.gov/fulltext/ED362904.pdf (accessed 2 December 2021).

Clarke, Adele E., “Research Materials and Reproductive Science in the United States, 1910–1940,” in *Physiology in the American Context: 1850–1940*, ed. Gerald L. Geison (Bethesda, MD: American Physiological Society, 1987), 323–350.

Colombo, John, “The Critical Period Concept: Research, Methodology, and Theoretical Issues,” *Psychological Bulletin* 91, no. 2 (1982): 260–275.

Cooke, Kathy J., “The Limits of Heredity: Nature and Nurture in American Eugenics before 1915,” *Journal of the History of Biology* 31, no. 2 (1998): 263–278.

Coppinger, Lorna, and Raymond C. Coppinger, “So Firm a Friendship,” *Natural History* 89, no. 3 (March 1980): 12–26.

Coppinger, Raymond C., and Lorna Coppinger, *Dogs: A Startling New Understanding of Canine Origin, Behavior & Evolution* (New York: Scribner, 2001).

Dawson, Walker M., “Heredity in the Dog,” *USDA Yearbook of Agriculture* (1937): 1315–1349.

Dheim, Kelle, “From Karl von Frisch to Neuroethology: A Methodological Perspective on the Frischean Tradition’s Expansion into Neuroethology,” *Berichte zur Wissenschaftsgeschichte* 45, no. 1–2 (2022).

Ellis, Paul F., “Puppy Studies Help Determine Why Children Have Bad Habits,” *The Austin American*, 27 June 1950.

Fagiolini, Michela, and Takao K. Hensch, “Inhibitory Threshold for Critical-Period Activation in Primary Visual Cortex,” *Nature* 404, no. 6774 (2000): 183–186.

Feuerbacher, Erica N., and Clive D. L. Wynne, “A History of Dogs as Subjects in North American Experimental Psychological Research,” *Comparative Cognition & Behavior Reviews* 6 (2011): 46–71.

Frank, Harry, and Martha G. Frank, “The University of Michigan Canine-Information Processing Project (1979–1981)” in *Man and Wolf: Advances, Issues, and Problems in Captive Wolf Research*, ed. Harry Frank (Dordrecht: DR W. Junk Publishers, 1987), 143–167.

Friendly, Alfred, “Dogs Refusing To Bite at Trick Baffle Experts,” *The Washington Post*, 29 October 1939.

Fuller, John L., “Of Dogs, Mice, People, and Me,” *Leaders in the Study of Animal Behavior: Autobiographical Perspectives*, ed. Donald A. Dewsbury (Lewisburg, PA: Bucknell University Press, 1985): 93–120.

Grüneberg, Hans, “Dogs and Eugenics,” *The Eugenics Review* 34, no. 2 (July 1942): 62–64.
Haraway, Donna J. *The Companion Species Manifesto: Dogs, People, and Significant Otherness* (Chicago, IL: Prickly Paradigm Press, 2003).

James, William T., “Further Experiments in Social Behavior Among Dogs,” *The Pedagogical Seminary and Journal of Genetic Psychology* 54, no. 1 (1939): 151–164.

Kevles, Daniel J., *In the Name of Eugenics: Genetics and the Uses of Human Heredity* (Cambridge, MA: Harvard University Press, 1995).

Kirk, Robert G. W., “A Brave New Animal for a Brave New World: The British Laboratory Animals Bureau and the Constitution of International Standards of Laboratory Animal Production and Use, circa 1947–1968,” *Isis* 101, no. 1 (March 2010): 62–94.

Kirk, Robert G. W., and Edmund Ramsden, “Working across Species down on the Farm: Howard S. Liddell and the Development of Comparative Psychopathology, c. 1923–1962,” *History and Philosophy of the Life Sciences* 40, no. 24 (2018): 23–24.

Kohrs, Karl, and Sid Ross, “Puppies: A Key to Your Happiness?,” *Parade*, 24 September 1950.

Kühl, Stefan, *The Nazi Connection: Eugenics, American Racism, and German National Socialism* (Oxford: Oxford University Press, 1994).

Lenneberg, Eric H., *Biological Foundations of Language* (New York, NY: John Wiley & Sons, Inc., 1967).

Linhart, Samuel B., Ray T. Sterner, Timothy C. Carrigan, and Donald R. Henne, “Komondor Guard Dogs Reduce Sheep Losses to Coyotes: A Preliminary Evaluation,” *Journal of Range Management* 32, no. 3 (1979): 238–241.

Little, Clarence Cook, “Canine Psychology,” *Journal of Heredity* 26, no. 5 (1 May 1935): 199–200.

Lovett, Laura L., *Conceiving the Future: Pronatalism, Reproduction, and the Family in the United States, 1890–1938* (Chapel Hill, NC: The University of North Carolina Press, 2007).

Margócsy, Dániel, “A Long History of Breakdowns: A Historiographical Review,” *Social Studies of Science* 47, no. 3 (1 June 2017): 307–325.

Marshall, Owen, “Un-Silencing an Experimental Technique: Listening to the Electrical Penetration Graph,” *Science, Technology, & Human Values*, 22 June 2021.

Milam, Erika L., “Landscapes of Time: Building Long-Term Perspectives in Animal Behavior,” *Berichte zur Wissenschaftsgeschichte* 45, no. 1–2 (2022).

Mittman, Gregg, “Dominance, Leadership, and Aggression: Animal Behavior Studies during the Second World War,” *Journal of the History of the Behavioral Sciences* 26 (January 1990): 3–16.

Odenwald, Jakob, “Ethologists in the Kindergarten: Natural Behavior, Social Rank, and the Search for the ‘Innate’ in Early Human Ethology (1960s–1970s),” *Berichte zur Wissenschaftsgeschichte* 45, no. 1–2 (2022).

Panofsky, Aaron. *Misbehaving Science: Controvery and the Development of Behavior Genetics* (Chicago, IL: The University of Chicago Press, 2014).

Paul, Diane B., “The Rockefeller Foundation and the Origins of Behavior Genetics,” in *The Expansion of American Biology*, ed. Keith R. Benson, Jane Maienschein, and Ronald Rainier (New Brunswick, NJ: Rutgers University Press, 1991): 262-283.

Paul, Diane B., “Reflections on the Historiography of American Eugenics: Trends, Fractures, Tensions,” *Journal of the History of Biology* 49 (2016): 641–658.

Paul, Philip J., “How Did the Effects of Alcohol on Reproduction Become Scientifically Uninteresting?,” *Journal of the History of Biology* 29 (1996): 1–28.

Paul, Philip J., *Biologists and the Promise of American Life* (Princeton, NJ: Princeton University Press, 2002).

Pettit, Michael, “Becoming Glandular: Endocrinology, Mass Culture, and Experimental Lives in the Interwar Age,” *The American Historical Review* 118, no. 4 (1 October 2013): 1052–1076.
Pfaffenberger, Clarence J., and John P. Scott, “The Relationship between Delayed Socialization and Trainability in Guide Dogs,” *The Journal of Genetic Psychology* 95, no. 1 (1 September 1959): 145–155.

Phillips, Carleton J., Raymond P. Coppinger, and David S. Schimel, “Hyperthermia in Running Sled Dogs,” *Journal of Applied Physiology* 51, no. 1 (1 July 1981): 135–142.

Rader, Karen A., *Making Mice: Standardizing Animals for American Biomedical Research, 1900–1955* (Princeton, NJ: Princeton University Press, 2004).

Ramsden, Edmund, “A Neurotic Dog’s Life: Experimental Psychiatry and the Conditional Reflex Method in the Work of W. Horsley Gantt,” *Isis* 109, no. 2 (1 June 2018): 276–301.

Sands, Michael W., Raymond P. Coppinger, and Carleton J. Phillips, “Comparisons of Thermal Sweating and Histology of Sweat Glands of Selected Canids,” *Journal of Mammalogy* 58, no. 1 (1977): 74–78.

Scott, John Paul, “The Embryology of the Guinea Pig: III. The Development of the Polydactylous Monster. A Case of Growth Accelerated at a Particular Period by a Semi-Dominant Lethal Gene,” *Journal of Experimental Zoology* 77, no. 1 (1937): 123–157.

Scott, John Paul, “The Social Behavior of Dogs and Wolves: An Illustration of Sociobiological Systematics,” *Annuals of the New York Academy of Sciences* 51, no. 6 (1950): 1009–1021.

Scott, John Paul, “Critical Periods in Behavioral Development,” *Science* 138, no. 3544 (1962): 949–958.

Scott, John Paul, “John Paul Scott Oral History,” *Oral History Collection* 3 (1986), online: https://mouseion.jax.org/oral_history/3/ (accessed 2 December 2021).

Scott, John Paul, “Investigative Behavior: Toward a Science of Sociality,” in *Studying Animal Behavior: Autobiographies of the Founders*, ed. Donald A. Dewsbury (Chicago, IL: The University of Chicago Press, 1989).

Scott, John Paul, and Mary-Vesta Marston, “Critical Periods Affecting the Development of Normal and Mad-Adjustive Social Behavior of Puppies,” *The Journal of Genetic Psychology* 77 (1950): 25–60.

Stockard, Charles Rupert, and John L. Fuller, “Experimental Exploration of the Critical Period Hypothesis,” *Personality* 1, no. 1 (January 1951): 162–183.

Stockard, Charles Rupert, John M. Stewart, and Victor J. De Ghett, “Critical Periods in the Organization of Systems,” *Developmental Psychobiology* 7, no. 6 (1974): 489–513.

Staff of the Division of Behavior Studies, *Manual of Dog Testing Techniques* (Bar Harbor, ME: Roscoe B. Jackson Memorial Laboratory, 1950).

Stockard, Charles Rupert, “Developmental Rate and Structural Expression: An Experimental Study of Twins, ‘Double Monsters’ and Single Deformities, and the Interaction among Embryonic Organs during Their Origin and Development,” *American Journal of Anatomy* 28, no. 2 (1921): 115–277.

Stockard, Charles Rupert, *The Physical Basis of Personality* (New York, NY: W. W. Norton & Company, 1931a).

Stockard, Charles Rupert, “An Experimental Dog Farm for the Study of Form and Type,” *The Collecting Net*, 29 August 1931b.

Stuhmann, Cora, “‘It Felt more like a Revolution’: How Behavioral Ecology Succeeded Ethology, 1970–1990,” *Berichte zur Wissenschaftsgeschichte* 45, no. 1–2 (2022).

Todes, Daniel P., *Pavlov’s Physiology Factory: Experiment, Interpretation, Laboratory Enterprise* (Baltimore: Johns Hopkins University Press, 2001).

Zigler, Edward, and Victoria Seitz, “Head Start as a National Laboratory,” *The ANNALS of the American Academy of Political and Social Science* 461, no. 1 (1 May 1982): 81–90.