The Affect of Experiment

The Turn to Emotions in Anglo-American Physiology, 1900–1940

*By Otniel E. Dror**

ABSTRACT

The author argues that during the late nineteenth and early twentieth centuries Anglo-American physiologists discovered that the emotional experiences of their laboratory animals influenced their experiments. Asserting that previous generations had ignored the affective dimension of experimentation, these physiologists developed practices for recording, reporting, managing, and controlling the emotions of laboratory animals during physiological encounters. The author also argues that emotion became a powerful conceptual, rhetorical, political, and practical tool of the modern laboratory and that physiologists invoked emotion in order to contain and interpret numerous physiological facts and artifacts, promulgate alternative forms of knowledge-making, privilege new knowledge claims, and diffuse mounting political pressures. The study of the affect of experiment aims to contribute to the history of experimentation, knowledge, and emotion.

A segment [of intestinal muscle] from a timid . . . rat will give a reversed or irregular reaction to . . . [sodium carbonate] stimulation.
—Milton J. Greenman and F. Louise Duhring (1931)

THE "LARGE TIGER CAT . . . SHOWED SOME LITTLE EXCITEMENT" and was "possibly slightly depressed," Ernest Lyman Scott noted in his laboratory notebook on 23 December 1912. Scott was working on "problems related to blood sugar" in the Department of Physiology at Columbia University; his laboratory notebooks and published dissertation (June 1914) reveal a profound preoccupation with the emotions of laboratory

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cats.[1] One cat "was somewhat nervous in lab?" he jotted down, with a hint of hesitation, on 3 November 1913; another "showed a little excitement" on 19 November; and yet another displayed only "*very slight* excitement" a year later. His exacting attention to and meticulous recording of the emotional experiences of laboratory cats appeared in numerous entries over the course of five years (1912–1917): "appeared glad to get out [of its chamber]," he remarked of one cat on 27 January 1915; "there had previously been considerable crying in a strange cage," he remarked of another on 10 July 1917.[2]

During these five years Scott pursued his research on sugar metabolism and explored the ways in which emotions contaminated his experiments. He restrained, injected, and caged cats, noting their individual emotional reactions and their concomitant blood sugar levels. He discovered, for example, that the physical confinement of cats and the injection of small amounts of salt did not, "of themselves," affect blood glucose levels, as other authors had suggested; but if the cats "resented" these manipulations or became emotionally "excite[d]" then (and only then) blood sugar levels began to fluctuate. (See Figure 1.)[3]

Scott's pursuit of emotions emerged from his concern with the discrepant, irreproducible, and extremely variable results that different authors reported for the normal blood glucose level of cats. In his published dissertation, "The Content of Sugar in the Blood under Common Laboratory Conditions," he proposed a new laboratory standard for the blood sugar level of cats that he had discovered and established by maintaining a cohort of emotionally controlled and "tranquil" cats. His new normal value was lower, less variable, and more reliable than previous determinations. By micromanaging the affective states of laboratory organisms, Scott circumscribed the range of the "simulated" variability reported by previous investigators and revealed what he perceived to be nature's true constant state.[4]

AN ECOLOGY OF EMOTIONS

Scott's focus on the emotional dimensions of laboratory cats mirrored and contributed to the concerns of a much larger community of physiologists. From the late nineteenth century

[1] Notebook: "Record of Sugar Metab. Experiments Vol I. Pancreatic Extracts, Record of Experiments, Book I. (prob. 1912)," p. 1, 23 Dec. 1912, box 5, Ernest Lyman Scott Papers, MS. C 165, National Library of Medicine, Bethesda, Maryland. Scott did his master's degree under A. J. Carlson at Chicago. For the larger context of Scott's work on sugar metabolism see Michael Bliss, *The Discovery of Insulin* (Chicago: Univ. Chicago Press, 1982); for the citation see p. 32. Bliss does not refer to Scott's interest in emotions. For the epigraph see Milton J. Greenman and F. Louise Duhring, *Breeding and Care of the Albino Rat for Research Purposes,* 2nd ed. (Philadelphia: Wistar Institute of Anatomy and Biology, 1931), p. 64.

[2] Notebook: "Sugar in the blood of cats Book II 1913. Blood sugar 7/23/13-12-17," p. 51, 3 Nov. 1913, p. 77, 19 Nov. 1913, box 5; Notebook: "Sugar in the Blood of cats, Book III, 1913–1914. Blood Sugar Dec. 17 1913 to Aug 10 1914," p. 11, 9 Jan. 1914, box 6; Notebook: "Sugar in Blood of Cats Book IV 1914–1917 Oct 22 1914–June 25, 1917," p. 34, 27 Jan. 1915, box 6; and Notebook: "Sugar in Blood of Cats Book V 1917–" p. 12, 10 July 1917, box 6, Ernest Lyman Scott Papers.

[3] Ernest Lyman Scott, "The Content of Sugar in the Blood under Common Laboratory Conditions," *American Journal of Physiology,* 1914, *34*:271–311. Scott's laboratory notebooks are replete with references to the emotional experiences of laboratory cats. For additional entries see Notebook: "Sugar in the Blood of cats, Book III, 1913–1914. Blood Sugar Dec. 17 1913 to Aug 10 1914," p. 81, 16 June 1914, p. 89, 13 July 1914, box 6; and Notebook: "Sugar in Blood of Cats Book V 1917–," pp. 8, 10, 12, 10 July 1917, box 6, Ernest Lyman Scott Papers.

[4] See Scott, "Content of Sugar in the Blood," table 9, on p. 296, for a comparison between his own values and those of previous investigators. Scott used the term "simulated" in order to characterize the high blood sugar levels of males as compared to females. He argued that the "greater excitability" of male cats could simulate a higher blood glucose level during the measurement and lead one to conclude, mistakenly, that the blood glucose level of male and female cats was different. His work demonstrated that in "tranquil" male and female cats the blood sugar level was nearly identical as well as constant: *ibid.,* p. 291.

No. of Exp.	Sex	Body wt. k.	Blood drawn gm.	Blood per k. body wt. gm.	Gm. % glucose recovered	Var. from stand. mean-Table 5		Gm. % calculated to 30 gm. blood per k. body wt.		Remarks
						Absolute	% of mean	Concentration	Variation in % of stand. mean	
51	F	2.60	75.57	29.06	0.102	+ 0.033	48	0.101	46	Nervous in laboratory before killing
52	M	3.50	107.65	30.76	0.078	+ 0.009	13	0.078	13	In bag 1¾ hrs. before killing, quiet
64	M	2.11	66.03	31.29	0.169	+ 0.100	145	0.170	146	Excited when brought to laboratory
71	M	3.31	61.36	18.54	0.098	+ 0.029	42	0.091	32	In bell jar 3 min. just before killing
90	M	3.45	105.63	30.62	0.133	+ 0.064	93	0.133	93	Slight excitement before killing
92	F	2.10	61.90	29.48	0.149	+ 0.080	116	0.149	116	Excited by confinement in apparatus
108	F	2.19	45.86	20.94	0.122	+ 0.053	77	0.116	68	As 64: also held rigidly 3 min. before killing
110	F	2.20	56.86	25.85	0.086	+ 0.017	25	0.084	22	Held as 108 for 8 min., previously quiet

Figure 1. *Table from Ernest Lyman Scott's dissertation, showing that the ordinary handling of laboratory animals may affect their blood sugar levels. Notice the notations in the righthand column. (From Ernest Lyman Scott, "The Content of Sugar in the Blood under Common Laboratory Conditions,"* American Journal of Physiology, *1914,* 34:*271–311, on page 294.)*

these physiologists fashioned emotion into a powerful conceptual, rhetorical, political, and practical tool for containing and interpreting numerous physiological facts and artifacts, promulgating alternative forms of knowledge-making, privileging new knowledge claims, and diffusing various political pressures. They argued that the routine practices of the laboratory evoked emotions in organisms and that these emotions were expressed physiologically: as sudden surges in blood sugar level, rapid fluctuations in blood pressure, swift changes in digestive function, or brisk elevations in metabolic rate, for example. Thus every conceivable aspect of laboratory life (every object, act, presence, or manipulation) could lead to profound physiological changes through its effects on the animal's emotions.[5]

Asserting that this emotional dimension of laboratory life had been ignored by previous generations, they reconceptualized the laboratory as an ecology of experiences and emotions: they appealed to the "affective psychosis" or "experience" of laboratory organisms; suggested new emotion-sensitive laboratory procedures; identified, recorded, and controlled emotions during various laboratory manipulations; devised new models for interactions between humans and animals; and introduced qualitative emotional descriptors into the quantitative language of their experimental science.[6] Characterizations, such as

[5] For the general background on experimental physiology during this period see William Coleman and Frederic L. Holmes, eds., *The Investigative Enterprise: Experimental Physiology in Nineteenth-Century Medicine* (Berkeley: Univ. California Press, 1988). For the British context see Gerald L. Geison, *Michael Foster and the Cambridge School of Physiology: The Scientific Enterprise in Late Victorian Society* (Princeton, N.J.: Princeton Univ. Press, 1978). For the American context see Geison, ed., *Physiology in the American Context, 1850–1940* (Baltimore: Waverly, 1987); and W. Bruce Fye, *The Development of American Physiology: Scientific Medicine in the Nineteenth Century* (Baltimore: Johns Hopkins Univ. Press, 1987).

[6] For the notion of "affective psychosis" see Charles S. Sherrington, *The Integrative Action of the Nervous System* (New Haven, Conn.: Yale Univ. Press, 1906), p. 251. For "experience" see H. F. Newton, R. L. Zwemer,

"temperamental," "sensitive," "good natured," "excitable," "timid," and "nervous"; and emotional states, such as "fear," "anger," "jealousy," "joy," "apprehension," "anxiety," and "restlessness," permeated physiological journals and laboratory entries. These subjective evaluations captured and negotiated aspects of laboratory life that the rigorous language of numbers and curves failed to articulate.

By the 1920s the *affect of experiment* had grown from a relatively narrow late nineteenth-century concern of a few Continental physiologists to a major preoccupation of the foremost physiologists in the Anglo-American context. Of the sixty-four North American "domestic elites" of physiology in the years between 1900 and 1940 that Gerald Geison has identified, fifteen—just under 25 percent—engaged in work that focused specifically on the significance of emotions for routine physiological investigations. Among these fifteen were five of the ten leaders of American physiology: A. J. Carlson at Chicago, Frank C. Mann at the Mayo Clinic, Walter B. Cannon at Harvard, W. E. Burge at Illinois, and S. W. Britton at Virginia.[7] In addition, numerous other physiologists who were not on Geison's list of the "elite," such as W. H. Howell, John F. Fulton, Howard Liddell, W. Horsley Gantt, Ernest Lyman Scott, Henry H. Donaldson, and Edmond J. Farris; and a number of biological chemists, such as Otto Folin and Philip Shaffer, were concerned with emotions in various physiological (and biochemical) contexts.

A similar pattern of concerns emerged in the United Kingdom among members of the British physiological elite: Charles Scott Sherrington at Liverpool, Joseph Barcroft at Cambridge, E. G. T. Liddell at Oxford, Augustus D. Waller at University College London, and F. W. Pavy at Guy's Hospital. In the Anglo-American context emotions captured the imagination of the physiological community in its broadest sense.[8]

In this essay I examine the turn to emotions in Anglo-American physiology. After briefly surveying its European origins, I explore its basic characteristics and manifestations in the United States and the United Kingdom. In focusing on the history of emotions in physiology, I wish to portray an important and hidden aspect of twentieth-century experimentation and to study some of the complex historical relationships between knowledge and emotions.[9]

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and W. B. Cannon, "Studies on the Conditions of Activity in Endocrine Organs, XXV: The Mystery of Emotional Acceleration of the Denervated Heart after Exclusion of Known Humoral Accelerators," *Amer. J. Physiol.,* 1931, *96*:377–391, on p. 379. See also Joseph Barcroft and J. G. Stephens, "Observations upon the Size of the Spleen," *Journal of Physiology,* 1927, *64*:1–22, on p. 1, for a discussion of the "spirits" of a laboratory animal.

[7] The other ten were G. H. Whipple at Rochester, F. G. Benedict at the Carnegie Institution, A. B. Luckhardt at Chicago, H. E. Himwich at Yale, F. A. Hartman at Buffalo, Walter C. Alvarez at the Mayo Clinic, Arthur Grollman at Johns Hopkins, L. B. Nice at Oklahoma and Ohio State, J. M. D. Olmsted at Toronto and Berkeley, and J. J. R. Macleod at Western Reserve and Toronto. See Gerald L. Geison, "International Relations and Domestic Elites in American Physiology, 1900–1940," in *Physiology in the American Context,* ed. Geison (cit. n. 5), pp. 115–154.

[8] In the United States these physiologists belonged to what Bruce Fye has defined as the "second generation": Fye, *Development of American Physiology* (cit. n. 5). This community of physiologists was only one branch in a tripartite endeavor that also included psychologists and clinicians. These three emotion-centered communities shared similar practices, conceptual frameworks, technologies, and concerns in approaching emotions. They did not necessarily borrow from each other and during the nineteenth century seem to have been oblivious to their mutual concerns. In this essay I focus on physiologists who worked with animals. On parallel developments in the clinic see Otniel E. Dror, "Creating the Emotional Body: Confusion, Possibilities, and Knowledge," in *An Emotional History of the United States,* ed. Peter N. Stearns and Jan Lewis (New York: New York Univ. Press, 1998), pp. 174–193. Behaviorists also focused on emotions but distinguished between their own concerns and those of the physiologists. See, e.g., John B. Watson, *Psychology from the Standpoint of a Behaviorist* (Philadelphia: Lippincott, 1919), pp. 19–21, 194–230.

[9] Primary sources for this essay are from the following collections: Walter C. Alvarez Papers, Alfred Blalock Correspondence, Walter B. Cannon Papers, Stanley Cobb Papers, George Washington Crile Papers, John Far-

THE EXPERIENCE OF EXPERIMENT: NEW WINE IN OLD BOTTLES

We must . . . suppress the pain in animals as well as in man in order to remove causes for error brought about by suffering.
—Claude Bernard (1876)

In the introduction to his treatise *Fear* Angelo Mosso, the Italian physiologist, articulated one of the earliest arguments from emotion. Recounting the 1854 observations of the physiologist Moritz Schiff on the artery supplying the rabbit's ear, Mosso described Schiff's discovery of "alternate movements of contraction and expansion." Observing that these rhythmic movements of the blood vessel did "not [correspond] to the systole and diastole of the heart," Schiff concluded that the artery functioned as an "accessory heart."[10]

Thirty years later Mosso repeated Schiff's observations on the "accessory heart" and explained: "I used certain precautions which others would perhaps have thought superfluous. Instead of watching the rabbit while holding it in my hand, I thought to spare it all emotion, by enabling myself to observe the ears without its becoming aware of the fact." Mosso constructed a special cage that enabled him to "watch quite easily, without being seen," and observed that the "rapid movements of dilatation and contraction of the blood-vessels of the ear . . . were no longer visible" in his "tranquil" rabbits. Rejecting Schiff's proposed "accessory heart," Mosso explained that the rhythmic contraction of the blood vessel was a physiological expression of the rabbit's emotional reaction to the experimental situation. Schiff's error, Mosso implied, resided in his inability to perceive that the encounter between observer and observed produced emotion and, in this particular instance, a rabbit's "blush."[11] Mosso's emotionless model of the rabbit's artery represented the rabbit's *true*—blushless—physiology.[12]

Mosso's appeal to the emotional experiences of laboratory animals during physiological encounters had deep roots in older physiological traditions. In fact, Schiff had invoked these traditions in his lectures on the auricular blood vessel. Demonstrating a series of

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quhar Fulton Papers, W. Horsley Gantt Papers, Howard Liddell Correspondence, Hugo Münsterberg Papers, Ernest Lyman Scott Papers, Harold G. Wolff Papers, Animal Defence and Anti Vivisection Society Papers, and miscellaneous reports and communications of the Rockefeller Foundation and Commonwealth Fund. Exact citations will be given in the footnotes that follow.

[10] Angelo Mosso, *Fear,* trans. E. Lough and Frederich Kiesow, 5th ed. (London/New York: Longmans, Green, 1896), p. 11. The first Italian edition appeared in 1884. Claude Bernard is cited in Georges Canguilhem, *The Normal and the Pathological,* trans. Carolyn R. Fawcett (1966; New York: Zone, 1991), p. 147.

[11] Mosso, *Fear,* trans. Lough and Kiesow, pp. 11–14, on pp. 11, 12. Mosso could reproduce the contractions and expansions of the now-debunked "accessory heart" by deliberately exposing the rabbits to psychic stimulations. For his part, Schiff was not unaware of the physiological significance of emotions. In his discussion of dilator nerves he described an experiment in which he deliberately evoked emotional reactions in laboratory dogs in order to demonstrate that vasodilation was an active process rather than the absence of vasoconstriction. See M. Maurice Schiff, *Leçons sur la physiologie de la digestion* (Florence/Turin: Hermann Loescher, 1867), p. 263. In his lectures on the "accessory heart" Schiff did not discuss the possible significance of the emotional interactions between experimenter and animal for routine physiological observations. See *ibid.,* lectures 11 and 12.

[12] Mosso employed a very similar argument in rejecting contemporary reports on the body temperature of dogs. His research demonstrated that body temperature depended on the animal's psychic state. Any temperature measurement that did not include a detailed description of the dog's psychic state was therefore unreliable. See Ugolino Mosso, "Influence du système nerveux sur la température animale: Recherches," *Archives Italiennes de Biologie,* 1886, *7*:306–340, on pp. 337–340. It was no accident that Mosso chose the "blush" phenomenon to contradict Schiff's observations on the auricular blood vessel. On the blush see, e.g., Mary Ann O'Farrell, *Telling Complexions: The Nineteenth-Century English Novel and the Blush* (Durham, N.C./London: Duke Univ. Press, 1997); and Janet Brown, "Darwin and the Expression of the Emotions," in *The Darwinian Heritage,* ed. David Kohn (Princeton, N.J.: Princeton Univ. Press, 1985), pp. 307–326.

experimental manipulations on the rabbit's ear, Schiff warned his students to heed the effects of pain on physiological observations: "These interesting experiments [on the rabbit's ear] always succeed, if the pain of the animal is not so strong as to interfere momentarily with the action of the heart." In case of "excessive pain," he continued, "wait for 8 to 10 seconds" before making the physiological observation. Physiological knowledge in general, and successful replication of his observations on the rabbit's blood supply in particular, demanded painless conditions. The eradication of pain was not "merely an optional noble gesture" but "aided correct scientific observations."[13]

Similar arguments concerning pain and physiological observations go back to the famous eighteenth-century debates on irritability and sensitivity. During these early physiological controversies the vitalists, who opposed Hallerian ideas, rejected Albrecht von Haller's strict dichotomy between sensibility and irritability by arguing that he had observed animals in pain. As Roselyne Rey argues, Haller was well aware of these criticisms and addressed them in his *Mémoire sur la nature sensible et irritable du corps animal*: "One must allow the animal to have time to calm down completely from the pains of the incision. One can easily identify the timing of this tranquillity, by observing the rest, the silence and a relaxation in the suffering countenance of the animal. . . . One would . . . be sure of being mistaken if one dealt with an animal in pain."[14]

In the early nineteenth century Johannes Müller invoked the animal experience in resolving the controversies that ensued in the wake of François Magendie's discovery of the anterior and posterior spinal nerve roots. Criticizing previous experimenters for operating on mammals, Müller argued that the surgical procedure produced such pain that the physiologist could not ascertain whether the animals were indeed sensible to stimulation of the spinal nerve roots. In his own experiments Müller eliminated suffering by choosing an insensitive animal—the frog; he argued for the privileged status of his pain-free frogs over suffering mammals in elucidating the function of ventral and dorsal spinal nerve roots.[15]

Other leading physiologists, such as Xavier Bichat, Claude Bernard, Carl Ludwig, Elie de Cyon, Angelo Mosso, R. Boehm, F. A. Hoffman, and, late in the century, Ivan Pavlov, expressed similar concern with and awareness of the effect of pain on physiological observations. Pain distorted normal physiology and hindered successful replication. Physiological knowledge demanded pain-free animals.[16]

[13] Schiff, *Leçons* (cit. n. 11), p. 243 (all translations from the French are my own); and Patrizia Guarnieri, "Moritz Schiff (1823–1896): Experimental Physiology and Noble Sentiment in Florence," in *Vivisection in Historical Perspective,* ed. Nicolaas A. Rupke (1987; London: Routledge, 1990), pp. 105–124, on p. 111. On Moritz Schiff's relations with the societies for the protection of animals in Florence and, especially, in Geneva see Jean Jacques Dreifuss, "Moritz Schiff et la vivisection," *Gesnerus,* 1985, *42*:289–303. Schiff was a student of Claude Bernard.

[14] Haller is quoted in Roselyne Rey, *The History of Pain,* trans. Louise Elliott Wallace, J. A. Cadden, and S. W. Cadden (Cambridge, Mass.: Harvard Univ. Press, 1995), pp. 112–113. As Rey explains, Fouquet's article "Sensibilité," which appeared in the *Encyclopédie,* argued that pain also modified the animal's reactions and behavior. These early physiological arguments against pain during experimental manipulations preceded the ethical arguments that began with the French Revolution.

[15] Frederic L. Holmes, "The Old Martyr of Science: The Frog in Experimental Physiology," *Journal of the History of Biology,* 1993, *26*:311–328, on pp. 321–322.

[16] For Bichat see Théodule Ribot, *The Psychology of the Emotions* (London: Walter Scott, 1897), p. 29. For Bernard see Canguilhem, *Normal and the Pathological,* trans. Fawcett (cit. n. 10); and Claude Bernard, *Leçons sur les propriétés physiologiques et les altérations pathologiques des liquides de l'organisme* (Paris: J. B. Baillière, 1859), pp. 10–21 (discussion of the "physiological conditions" of animals during experimentation). I thank one of the anonymous referees for directing me to Bernard's discussion. For Ludwig see Angelo Mosso, "Charles Ludwig," *Revue Scientifique,* 1895, *4*:97–105. For Cyon see Elie de Cyon, *Methodik der physiologischen Experimente und Vivisectionen* (Giessen: Ricker, 1876), pp. 9, 32. For Mosso see Albert Leffingwell, *The Vivisec-*

Mosso's critique of Schiff's emotional blind spot was, therefore, deeply embedded in older physiological traditions, yet it introduced a new element—emotion. His particular focus on the emotional aspects of laboratory encounters emerged from his broader interests in the physiology of mental and affective states.

PHYSIOLOGY OF EMOTIONS

The emotional states of the rat are very important. . . . It is highly probable that all physiological responses are definitely modified by the emotional state of the rat.
—Henry H. Donaldson (1924)

The beginnings of laboratory-based physiological investigations of emotions can be traced to Claude Bernard's early kymographic tracings of the heart during emotions. In his lecture "On the Physiology of the Heart" (1865), Bernard examined the physiological relationships between the brain, emotions, and the heart. Following in Bernard's footsteps was the Russian physiologist Elie de Cyon, who also studied the heart in relation to the brain and emotions. For both Bernard and Cyon the heart was unique: both a mechanical pump and an organ of emotion. In their respective lectures they described the biological mechanisms that collapsed the heart's physiology (as a pump) with its psychology (as an organ of emotion).[17]

Bernard's and Cyon's lectures on the heart introduced important conceptual and representational innovations, yet neither inaugurated a program of sustained research on emotions. Their particular focus on the heart as an organ of emotion remained relatively unknown to late nineteenth- and early twentieth-century physiologists of emotions. Their most important manifest contribution to the physiology of emotions was through Cyon's pupil at St. Petersburg University, Ivan Pavlov, who, like his mentor, recognized the effect of emotions on physiological processes.[18]

The central figure in the physiology of emotions was Angelo Mosso, whose extensive researches from the late 1870s marked the beginnings of a sustained physiological science of emotion.[19] Mosso, a student of César Lombroso and Carl Ludwig, focused on the physiological concomitants of emotions and mental states. He created, measured, quantified, and replicated emotions and produced graphic and numeric representations of various

tion Question (New Haven, Conn.: Tuttle, Morehouse & Taylor, 1901), p. 113. For Boehm and Hoffman see R. Boehm and F. A. Hoffman, "Beiträge zur Kenntniss des Kohlehydratstoffwechsels," *Archiv für Experimentelle Pathologie und Pharmakologie,* 1878, *8*:271–308, on pp. 301–304. On Pavlov see Daniel P. Todes, "Pavlov's Physiology Factory," *Isis,* 1997, *88*:205–246, on p. 214.

[17] Claude Bernard, "Sur la physiologie du coeur et ses rapports avec le cerveau," in *Leçons sur les propriétés des tissus vivants,* ed. M. Émile Alglave (Paris: Germer Baillière, 1866), pp. 421–471; and M. E. Cyon, "Le coeur et le cerveau," *Revue Scientifique de la France et de l'Étranger,* 1873, *21*:481–489. Both Bernard and Cyon attributed an active role in the formation of emotion to the heart. For the cultural context of Bernard's concerns see the discussion of Auguste Comte in Wolf Lepenies, *Between Literature and Science: The Rise of Sociology,* trans. R. J. Hollingdale (Cambridge: Cambridge Univ. Press, 1988), pp. 19–46. For the epigraph to this section see Henry H. Donaldson, *The Rat,* 2nd ed. (Philadelphia: Wistar Institute of Anatomy and Biology, 1924), p. 134.

[18] The essays of Bernard and Cyon were mentioned by, e.g., Ribot and Darwin. See Ribot, *Psychology of the Emotions* (cit. n. 16), pp. 117–118; and Charles Darwin, *The Expression of the Emotions in Man and Animals* (New York/London: Appleton, 1872), pp. 68–69. I thank Daniel P. Todes for clarifying the close relationship between Cyon and Pavlov.

[19] Darwin's work on emotions was central to some of these endeavors. He concluded his book by suggesting that "our subject . . . deserves still further attention, especially from any able physiologist": Darwin, *Expression of the Emotions,* p. 366. However, Darwin did not engage in the kind of experimental work that Bernard, Cyon, Mosso, and their followers undertook in the laboratory. Mosso had read Darwin's book on emotions.

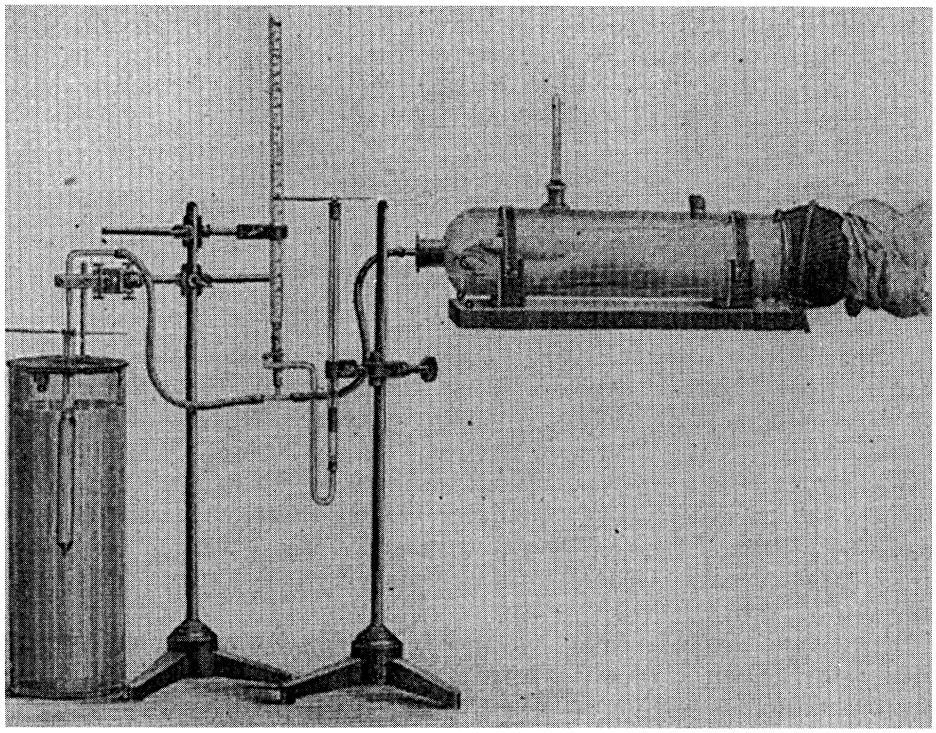

Figure 2. *Mosso's plethysmograph. The device recorded changes in blood volume during emotional stimulation. Results were obtained in the form of a graph. (From Christian A. Ruckmick,* The Psychology of Feeling and Emotion *[New York/London: McGraw Hill, 1936], on page 291.)*

affective states.[20] His observations on blood flow changes during different mental experiences, his physiological and laboratory-based approach to human and animal emotion, and his application of various instruments for investigating affect (e.g., the plethysmograph) inaugurated an important tradition and left a substantial legacy. (See Figure 2.) His work was widely hailed and imitated by late nineteenth- and early twentieth-century psychologists in France, Italy, Germany, and the United States.

Central figures in the psychophysiological investigation of emotions, such as Charles Féré, Alfred Binet, Alfred Lehmann, and Wilhelm Wundt, adopted various aspects of Mosso's approach to the emotions. Mosso's work was celebrated at Wundt's institute during the late nineteenth century, and Wundt expressed an interest in Mosso's graphic methods. Frederich Kiesow, one of Wundt's students, studied at Mosso's institute at Turin and returned to Leipzig with Mosso's sphygmomanometer. This sphygmomanometer became the basis for the construction of Lehmann's plethysmograph (hydrosphygmograph).

[20] On Mosso see James Rowland Angell and Helen Bradford Thompson, "A Study of the Relations between Certain Organic Processes and Consciousness," *Psychological Review,* 1899, *6*:32–69, on pp. 35–38; J. G. Beebe-Center, *The Psychology of Pleasantness and Unpleasantness* (New York: Van Nostrand, 1932), pp. 37–38; Paul V. Trovillo, "A History of Lie Detection," *Journal of Criminal Law and Criminology/American Journal of Police Science,* 1939, *29*:848–881, on pp. 858–861; and Charles Féré, *Sensation et mouvement: Études expérimentales de psycho-méchanique* (Paris: Félix Alcan, 1887), pp. 108–112. Mosso's interest in emotions and blood circulation began in the late 1870s and appeared in his work on the pulse. See Angelo Mosso, *Die Diagnostik des Pulses in Bezug auf die Localen veranderungen desselben* (Leipzig: Veit, 1879), p. 12.

Lehmann's work during the 1890s and the publication of his treatise *Die Hauptgesetze des menschlichen Gefühlslebens* had an important effect on Wundt's physiological investigations of feelings and followed directly from Mosso's experiments. "It was chiefly on the strength of Lehmann's results with his new instrument that Wundt later formulated his new theory of the emotions."[21]

Mosso's work on the relationships between mental states and organic changes was also imitated and acknowledged by Charles Féré, Alfred Binet, Georges Dumas, and Léon Binet in France; by, James Angell, T. E. Shields, and John G. Beebe-Center in the United States; and by César Lombroso in Italy. Lombroso, for example, applied the plethysmograph and hydrosphygmograph to the psychological study of the "delinquent"—in order "to penetrate, as with an instrument of precision, into their inner psychology." His early work with Mosso's plethysmograph had important implications for the development of the lie detector test.[22]

Mosso's early critique of Schiff's emotional blind spot and his direct pursuit of emotions as objects of knowledge represented two different, but largely overlapping, lines of physiological preoccupation. The latter work was taken up by a discrete community of experimenters who considered emotions as objects of knowledge in their own right; while the former—the focus of this essay—involved the community of physiologists at large. These physiologists studied various biological processes, such as glucose or fat metabolism, blood pressure regulation, renal or digestive function, and so forth, and accidentally "discovered" emotions in their laboratories. Their concerns targeted the relationships between physiological knowledge and emotion.[23]

[21] Frederich Kiesow, "Autobiography," in *A History of Psychology in Autobiography,* ed. Carl Murchison (1930; New York: Russell & Russell, 1961), pp. 163–190, on p. 178. On Wundt see, e.g., Karl Bühler, "The Psychophysics of Expression of Wilhelm Wundt," in Wilhelm Wundt, *The Language of Gestures* (The Hague: Mouton, 1973), pp. 30–54. On Lehmann see Ingemar Nilsson, "Alfred Lehmann and Psychology as a Physical Science," in *Wundt Studies: A Centennial Collection,* ed. Wolfgang G. Bringmann and Ryan D. Tweney (Toronto: Hogrefe, 1980), pp. 258–268; and Alfred Lehmann, *Die Hauptgesetze des menschlichen Gefühlslebens* (Leipzig: O. R. Reisland, 1892).

[22] César Lombroso, *L'homme criminel,* 2nd ed. (Paris: Félix Alcan, 1895), pp. 336–346, on p. 345. In addition to the sources cited in note 20, above, see Alfred Binet and J. Courtier, "Influence de la vie émotionnelle sur le coeur, la respiration et la circulation capillaire," *Année Psychologique,* 1896, *3*:65–126; Léon Binet, "L'éxcitation émotionnelle," *Revue des Deux Mondes,* 1939, *54*:588–595; T. E. Shields, "The Effect of Odours, Irritant Vapours, and Mental Work upon the Blood Flow," *Journal of Experimental Medicine,* 1896, *1*:71–111; and Eugene B. Block, *Lie Detectors: Their History and Use* (New York: McKay, 1977), pp. 11–19. The science of emotions was also indebted to the work of Etienne-Jules Marey and his various inscription devices. Bernard, Mosso, and others applied or developed variants of Marey's instruments. Mosso, in particular, spent much time with Marey, who frequented Mosso's institute at Turin. On Marey's work and his relationship with Mosso see Marta Braun, *Picturing Time: The Work of Etienne-Jules Marey (1830–1904)* (Chicago: Univ. Chicago Press, 1992); and François Dagognet, *Etienne-Jules Marey: A Passion for the Trace,* trans. Robert Galeta and Jeanine Herman (New York: Zone, 1992). On the history of graphic methods in physiology and medicine see, e.g., Robert G. Frank, Jr., "The Telltale Heart: Physiological Instruments, Graphic Methods, and Clinical Hopes, 1854–1914," in *Investigative Enterprise,* ed. Coleman and Holmes (cit. n. 5), pp. 211–290; Frederic L. Holmes and Kathryn M. Olesko, "The Images of Precision: Helmholtz and the Graphical Method in Physiology," in *The Values of Precision,* ed. M. Norton Wise (Princeton, N.J.: Princeton Univ. Press, 1995), pp. 198–221; Anson Rabinbach, *The Human Motor: Energy, Fatigue, and the Origins of Modernity* (New York: Basic, 1990), pp. 84–119; Lisa Cartwright, "'Experiments of Destruction': Cinematic Inscriptions of Physiology," *Representations,* 1992, *40*:129–152; and Otniel E. Dror, "The Scientific Image of Emotion: Experience and Technologies of Inscription," *Configurations* (forthcoming).

[23] Some experimenters pursued both agendas in their different research programs, so that on an individual basis it is often impossible to differentiate between these two groups. In this essay I occasionally refer to some of the practices that were developed in the context of the direct pursuit of emotions. Anglo-American physiologists who pursued the emotions did not refer to Mosso or to the psychological literature on the physiology of emotions. Mosso's work seems to have been assimilated and appropriated by psychologists. Primary sources

NARRATIVES OF DISCOVERY: THE AFFECT OF KNOWLEDGE

At every moment there lie within us many more physiological possibilities than physiology would tell us about.
—Réné Leriche (1939)

In order to obtain uniform results for . . . normal cats it was necessary to avoid exciting them unduly when catching and conveying them to the laboratory.
—W. E. Burge and E. L. Burge (1917)

Charles Scott Sherrington, the author of *The Integrative Action of the Nervous System,* "discovered" emotions during his sojourn in Turin with his "friend Professor Mosso." His chance encounter with emotions was reported in his 1900 essay "Experiments on the Value of Vascular and Visceral Factors for the Genesis of Emotion." Though Sherrington's essay was frequently cited for its experimental refutation of the James-Lange-Sergi theory of emotions, his by-the-way discovery of emotions was not remarked upon by future generations.[24] Nonetheless, Sherrington's account, like Walter B. Cannon's more celebrated late nineteenth-century discovery of emotions, represented a prototypical narrative of an encounter with emotions.

Sherrington's surprise encounter occurred during an experiment on vasomotor reflexes:

> in order to be sure that all was ready, I closed the electric key . . . [a] harsh rattling noise [from the inductorium] . . . lasted for a few seconds. . . . Turning thereupon toward the arterial record [of the dog], I was a little disappointed to see that a marked oscillation had suddenly upset the . . . line that had to serve as starting level. . . . I waited; the disturbance of the arterial pressure subsided. [See Figure 3.] . . . [I] soon found that each time the noise was repeated the disturbance of the circulation followed. . . . I then remembered that in examining this animal from week to week, I had at several times employed the inductorium . . . and no doubt had caused sensations of unpleasant quality. The recurrence of the sound to the awakening animal occasioned now emotional anxiety.[25]

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demonstrate that some physiologists, e.g., Cannon, were familiar with the psychological literature. Cannon, for example, read Ribot on emotions but did not refer to the psychological literature because "it seemed to me so distinctly superficial that I did not give it page room." See Diary 1911–1914, 24 July 1911, box 167, Walter Bradford Cannon Papers (H MS c4O), Rare Books and Special Collections, Francis A. Countway Library of Medicine, Boston; and Walter B. Cannon to George W. Crile, 2 Dec. 1915, folder 61, container 20, George Washington Crile Papers (MS 2806), Western Reserve Historical Society, Cleveland, Ohio.

[24] C. S. Sherrington, "Experiments on the Value of Vascular and Visceral Factors for the Genesis of Emotion," *Proceedings of the Royal Society of London,* 1900, *64*:390–403, on p. 393. William James, Carl G. Lange, and Giuseppe Sergi independently formulated theories of emotions whose main argument was that the organic changes in the body preceded the emotion and were, in fact, responsible for the experience of the emotion. On the James-Lange-(Sergi) theory of emotions (only a few writers used Sergi's name in referring to this theory) see William James, "What Is an Emotion?" *Mind,* 1884, *9*:188–205; James, "The Emotions," in *Principles of Psychology* (New York: Henry Holt, 1890), Ch. 25; and Carl Georg Lange, "The Emotions: A Psychophysiological Study," in Lange and James, *The Emotions* (Baltimore: Williams & Wilkins, 1922), pp. 33–90 (James's essays are also in this volume). See also Sherrington, *Integrative Action of the Nervous System* (cit. n. 6), pp. 235–268; Walter B. Cannon, "The James-Lange Theory of Emotions: A Critical Examination and an Alternative Theory," *American Journal of Psychology,* 1927, *39*:106–124; and Cannon, "Against the James-Lange and the Thalamic Theories of Emotion," *Psychol. Rev.,* 1931, *38*:281–295. For secondary literature see, e.g., H. M. Gardiner, Ruth Clark Metcalf, and John G. Beebe-Center, *Feeling and Emotion: A History of Theories* (New York: American Book Company, 1937); and James Hillman, *Emotion: A Comprehensive Phenomenology of Theories and Their Meanings for Therapy* (1960; Evanston, Ill.: Northwestern Univ. Press, 1992). For the epigraphs to this section see Canguilhem, *Normal and the Pathological,* trans. Fawcett (cit. n. 10), p. 100 (Leriche, whom Canguilhem is quoting, was referring to the relationship between physiology and pathology/disease); and W. E. Burge and E. L. Burge, "The Effect of the Emotions on the Catalase Content of the Liver," *Amer. J. Physiol.,* 1917, *44*:75–79, on p. 78.

[25] Sherrington, "Experiments on the Value of Vascular and Visceral Factors," p. 394.

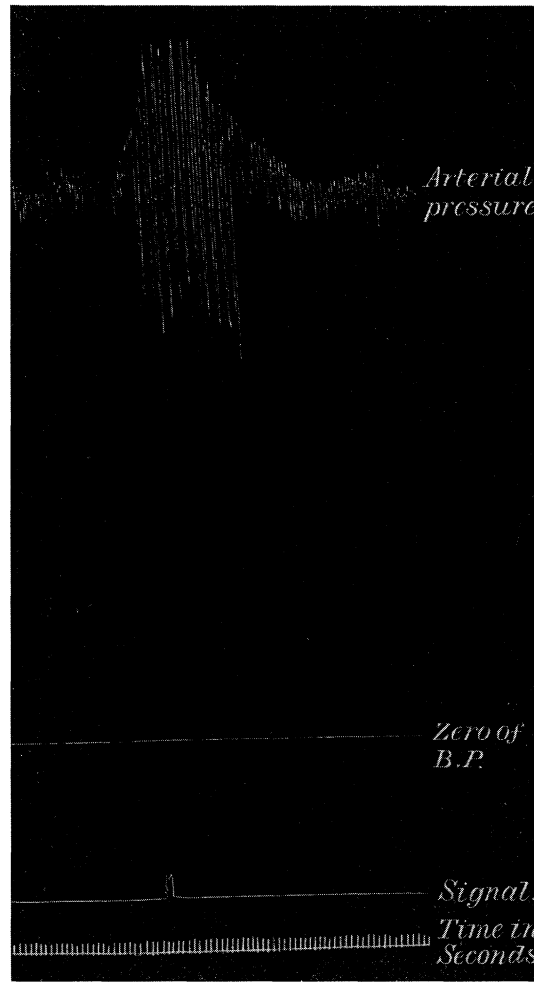

Figure 3. *Record of the arterial pressure in a dog. For the short period marked by the signal, the noise of the vibrator of an inductorium sounded and was heard by the animal. (From C. S. Sherrington, "Experiments on the Value of Vascular and Visceral Factors for the Genesis of Emotion,"* Proceedings of the Royal Society of London, *1900,* 64:*390–403, on page 395.)*

Cannon's encounter with emotions, which became a *cause célèbre* in the physiological literature on emotions, transpired during his research on the digestive tract. Studying gastric movements with the aid of the new Roentgen rays, Cannon observed a striking difference between the gastric physiology of male and female cats: while "peristalsis [was] seen with only a few exceptions in female cats[, it] failed to appear in most of the males, although both received exactly the same treatment." At first Cannon attributed the observed differences between the sexes to the physical effects of the "violent struggles" that typified the restrained male cats. But in October 1897 an accidental observation—the profound effect on gastric motility of "reassuringly" stroking a struggling female cat—made him realize that the observed differences between the sexes were due not to the "struggles" but to the

emotional states of male and female cats. Similar discoveries were reported by, among others, Frank C. Mann, L. Brouha, and Shinkishi Hatai during the twentieth century.[26]

Following the reported instant of discovery, a typical narrative usually included an account of a postdiscovery period. During this period the physiologist detoured from his original physiological investigations and focused on the relationships between emotions and the physiological process that he had pursued during the intrusion. The physiologist deliberately induced emotions in laboratory animals and studied their physiological manifestations. Then he implemented a series of correctives that targeted emotions and eliminated their destructive effects on the production of physiological knowledge.

This exploratory phase also served a second purpose. By eliminating, controlling, or containing the physical dimensions of the protocol, the physiologist isolated its emotional dimensions and demonstrated that the culprit was emotion.[27]

In the course of these narratives emotions were transformed into an important laboratory resource. They explained and contained various facts and artifacts; they privileged new forms of physiological knowledge; they represented the laboratory as the (emotionally) ideal locus for the production of knowledge; they undergirded and justified new physiological practices; and more.

In making these claims for emotions physiologists adopted various approaches. Some, for example, argued that in spite of standardizing their instruments, materials, procedures, and animals they failed to replicate their own findings—until they considered and standardized emotion. Others argued that their particular attention to and control of emotions led to new physiological discoveries. A. J. Carlson, for example, attributed his discovery of type II and type III gastric contractions to his "method of handling the animals." Previous investigators (e.g., V. N. Boldyreff) had failed to observe these contractions because they had, unwittingly, observed "restless" dogs. Type II and type III contractions, however, did not occur in emotionally excited animals.[28] Others explained cross-laboratory discrepancies by appealing to the difference in emotional states of organisms across laboratories. And still others invoked the common observation that during the first few days in the laboratory the organism's physiology changed: as the animal became "accustomed" to its new environment, they argued, its emotional excitement gradually diminished and its red blood cell count, its pulse rate, its body temperature, its adrenaline levels, and even its physiological reaction to various chemicals gradually changed until it arrived at a more stable baseline. This baseline was defined by the subsidence of emotional excitement. A

[26] W. B. Cannon, "The Movements of the Stomach Studied by Means of the Röntgen Rays," *Amer. J. Physiol.,* 1898, *1*:359–382, on p. 380. See also Cannon, "The Movements of the Intestines Studied by Means of the Röntgen Rays," *ibid.,* 1902, *6*:251–277, fig. 10, on p. 275; and Cannon, *The Mechanical Factors of Digestion* (New York: Longmans, Green, 1911), p. 217. For work by other investigators see Estes H. Hargis and Frank C. Mann, "A Plethysmographic Study of the Changes in the Volume of the Spleen in the Intact Animal," *Amer. J. Physiol.,* 1925, *75*:180–200, on p. 191; L. Brouha, S. J. G. Nowak, and D. B. Dill, "The Role of the Vagus in the Cardio-Accelerator Action of Muscular Exercise and Emotion in Sympathectomized Dogs," *J. Physiol.,* 1939, *95*:454–463, on p. 457; and Shinkishi Hatai and F. S. Hammett, "Four Factors Causing Changes in the Type of Response of the Isolated Intestinal Segment of the Albino Rat (*Mus Norvegicus Albinus*) to Sodium Carbonate," *Amer. J. Physiol.,* 1920, *53*:312–322, on p. 312.

[27] Emotion was, thus, defined in negative terms. In order to argue for emotional causation, the physiologist had to exclude or eliminate physical causation from the protocol. This was an operational definition of emotions.

[28] See, e.g., Hatai and Hammett, "Four Factors Causing Changes" (cit. n. 26), p. 312; and Fred R. Griffith, Jr., "Reflex Hyperglycemia: A Study of the Carbohydrate Mobilization Effected by Afferent Crural, Sciatic, and Vagus Stimulation," *Amer. J. Physiol.,* 1923, *66*:618–658, on p. 624, for the argument that different routes of administering anesthetics evoke different emotional reactions in cats and discrepant blood sugar levels. Carlson also mentioned his different method of registration. See Anton Julius Carlson, *The Control of Hunger in Health and Disease* (Chicago: Univ. Chicago Press, 1916), p. 46.

standardized animal, they asserted, was an animal that arrived at and maintained the non-excited state.[29]

A number of physiologists adopted a more radical stance and directly challenged the existing corpus of knowledge. They had discovered that under emotionally controlled conditions certain physiological variables, such as body temperature, blood pressure, and blood glucose level, differed from the textbook values. And they proposed new "normal" values for physiology. As Philip Shaffer explained, after controlling for emotions the "results . . . show very definitely that the concentration of sugar in the blood of normal dogs [is] . . . about one-half or one-third of the values usually accepted as normal."[30] Or as Martha Jones observed, the new methods "tend to show that the normal blood sugar content of the rabbit is much lower than originally thought . . . [and] it is not improbable that all or most mammals may be found to have a rather constant blood sugar content."[31] The new emotion-controlled "normal" represented nature's true physiological state.[32]

The laboratory was, thus, represented as a potential source for various emotional experiences and as the ideal locus for the generation of a constant and standard emotional state. Physiologists targeted the laboratory's instruments, practices, and practitioners and other laboratory organisms as potential emotional stimuli: a "stranger in the laboratory," "the crying of a cat in an adjacent room," "the entrance of a friend (animal keeper)," "handling the switch of the treadmill," or "a scolding word"—all evoked emotional-qua-physiological reactions, especially in "sensitive animals."[33] These emotional intrusions were so disruptive that some physiologists were unable to interpret their experimental results. The laboratory's ability to normalize and standardize these and other emotional intrusions made it the ideal locus for the production of physiological knowledge and for

[29] For appeals to cross-laboratory variations see, e.g., Mosso, "Influence du système nerveux" (cit. n. 12), p. 337 n 1; Scott, "Content of Sugar in the Blood" (cit. n. 3), table 9, on p. 296; and Walter B. Cannon, *Bodily Changes in Pain, Hunger, Fear, and Rage: An Account of Recent Researches into the Function of Emotional Excitement,* 2nd ed. (New York/London: Appleton, 1929), p. 73. On the "standardized animal" see, e.g., A. B. Clawson, "Normal Rectal Temperatures of Sheep," *Amer. J. Physiol.,* 1928, *85*:251–270; T. R. Elliott, "The Control of the Suprarenal Glands by the Splanchnic Nerves," *J. Physiol.,* 1912, *44*:374–409; and H. D. Clough, R. S. Allen, and E. W. Root, Jr., "A Study of the Rabbit as a Test Animal for Determining the Potency of Insulin Preparations," *Amer. J. Physiol.,* 1923, *66*:461–484.

[30] Philip Shaffer, "On the Normal Level of Blood-Sugar of the Dog," *Journal of Biological Chemistry,* 1914, *19*:297–302, on p. 301. See also J. J. R. Macleod and R. G. Pearce, "Studies in Experimental Glycosuria, IX: The Level of the Blood-Sugar in the Dog under Laboratory Conditions," *Amer. J. Physiol.,* 1915, *38*:415–424, on p. 415: "blood-sugar level in the dog and cat is really much below that usually taken as the 'normal' in experiments bearing on sugar metabolism."

[31] Martha R. Jones, "Studies on Carbohydrate Metabolism in Rabbits, II: Effect of Carbohydrate Feeding on Blood Sugar," *J. Biol. Chem.,* 1920, *43*:507–519, on p. 510. See also, e.g., M. Dresbach, "Observations upon the Blood Pressure of the Sheep," *Amer. J. Physiol.,* 1910, *25*:433–438; W. B. Cannon, "The Interrelations of Emotions as Suggested by Recent Physiological Researches," *Amer. J. Psychol.,* 1914, *25*:256–282; and John Q. Griffith and Edmond J. Farris, eds., *The Rat in Laboratory Investigations* (Philadelphia: Lippincott, 1942), p. 351.

[32] A minority of physiologists saw in these attempts only a means to standardize physiological variables and increase intersubjectivity. Most physiologists, however, argued that the new normal was not only a norm, but also the true normal.

[33] A. J. Carlson, "Contributions to the Physiology of the Stomach, VI: A Study of the Mechanisms of the Hunger Contractions of the Empty Stomach by Experiments on Dogs," *Amer. J. Physiol.,* 1913, *32*:369–388, on p. 376; Brouha *et al.,* "Role of the Vagus" (cit. n. 26), p. 454; and Walter Alvarez, "Ways in Which Emotion Can Affect the Digestive Tract," *Journal of the American Medical Association,* 1929, *92*:1231–1237, on p. 1234. See also Diary 1911–1914, 24 Nov. 1913, box 167, Walter Bradford Cannon Papers; and H. I. Schou, "Some Investigations into the Physiology of Emotions," *Acta Psychiatrica et Neurologica,* 1937, *14*(Suppl.):3–111, on p. 62.

discovering nature's true state. Though there was no bureau of standards for emotions, there was a standard emotion, nonetheless.[34]

During the initial stage of these developments the concern with emotions appeared mainly in the physiological literature that focused on the digestive tract, the heart or vascular system, and sugar metabolism. This initial period was characterized by a compartmentalization of concerns. Physiologists working in any one of these domains ignored the similarities between their own preoccupation with emotions and those of other contemporary physiologists in neighboring domains. Thus, for example, when Adolf Bickel and K. Sasaki published their important essay on the physiological effects of anger and rage on gastric secretions they cited the work of Pavlov, Bidder and Schmidt, and Roeder and Sommerfeld—all of whom also focused on the digestive tract. They did not refer to similar contemporary concerns with emotions on the part of physiologists who studied other systems and processes in the body, such as F. W. Pavy or Charles Scott Sherrington.[35]

It was only during the 1910s and 1920s, with the important researches of Walter B. Cannon, that a shadow community of emotion-attentive physiologists began to congeal. Cannon's extensive investigations of emotions in different organ systems and functions put emotions themselves, rather than a specific organ or function, at the center of attention. His work crystallized the dispersed concerns with emotions that had begun several decades before his own researches. His famous treatise on emotions, *Bodily Changes in Pain, Hunger, Fear, and Rage: An Account of Recent Researches into the Function of Emotional Excitement,* discussed different physiological processes in the body—digestion, glucose metabolism, various functions and components of the blood, muscular fatigue, and "energy"—under the new organizing principle of emotions. Instead of discussing emotions in the context of a particular organ, system, or function, Cannon pursued the emotions in different organs, systems, and functions of the body.[36]

Though he was, doubtless, indebted to numerous predecessors and, in particular, to Pavlov's work, Cannon expanded these studies far beyond their original scope. His book on emotions was widely cited in physiological, medical, and psychological literature and was occasionally used as a high school textbook.[37] He corresponded extensively with

[34] The laboratory was not only an ideal space for maintaining a constant emotional state; it was also isolated (emotionally) from nature and society. See George Draper to Cannon, 4 Feb. 1936, folder 1738, box 124, Walter Bradford Cannon Papers. In this letter Draper makes an analogy between the laboratory and the hospital; they are emotionally isolated from nature and from society, respectively. For physiologists' difficulties in interpreting their results see Alvarez, "Ways in Which Emotion Can Affect the Digestive Tract" (cit. n. 33), p. 1234; Hargis and Mann, "Plethysmographic Study" (cit. n. 26), p. 191; and Kasanu Tashiro, "Studies on Urea-Nitrogen Concentration of the Blood, I: Physiological Variations of the Blood Urea-Nitrogen Concentration and the Influence of Fixation and Anaesthesia upon It," *Tohoku Journal of Experimental Medicine,* 1925, *6*:601–629, on pp. 619–620.

[35] Adolf Bickel and K. Sasaki, "Experimentelle Untersuchungen über den Einfluss von Affekten auf die Magensaftsekretion," *Deutsche Medizinische Wochenschrift,* 1905, *31*:1829–1831; and F. W. Pavy, *The Physiology of the Carbohydrates: Their Application as Food and Relation to Diabetes* (London: Churchill, 1894), p. 163.

[36] On Cannon's career see Saul Benison, A. Clifford Barger, and Elin L. Wolfe, *Walter B. Cannon: The Life and Times of a Young Scientist* (Cambridge, Mass.: Harvard Univ. Press, 1987); Donald Fleming, "Walter B. Cannon and Homeostasis," *Social Research,* 1984, *51*:609–640; and Chandler McC. Brooks, Kiyomi Koizumi, and James O. Pinkston, eds., *The Life and Contributions of Walter Bradford Cannon, 1871–1945: His Influence on the Development of Physiology in the Twentieth Century* (New York: State Univ. New York Press, 1975).

[37] James E. Peabody to W. W. Norton, New York, 10 Mar. 1932, folder 1854, box 131, Walter Bradford Cannon Papers. It is important to note that Cannon's book was read in high schools not for its physiology of emotions but, rather, for its radical Darwinian approach. Teaching Darwin's theory of evolution was prohibited in many regions, and Cannon's book was an alternative resource for teaching Darwinism through physiology, without mentioning evolution. On Pavlov see Todes, "Pavlov's Physiology Factory" (cit. n. 16); Daniel Todes, "From the Machine to the Ghost Within: Pavlov's Transition from Digestive Physiology to Conditional Reflexes," *American Psychologist,* 1997, *52*:947–955; and I. P. Pavlov, *The Work of the Digestive Glands,* trans. W. H. Thompson, 2nd English ed. (London: Charles Griffin, 1910), pp. 83–87, 89–94, 104–106.

psychologists, clinicians, and physiologists; participated in physiological, psychological, and clinical conferences; and published in physiological, psychological, and medical journals. He also gave numerous public lectures on emotions both in the United States and abroad.[38]

We can conclude that the concern with emotions in physiological circles began as a trend characterized by individual discoveries and insider citations. In the wake of Cannon's work, a shadow community of physiologists whose research focus was otherwise unrelated began to form around emotions. These physiologists worked with whole, fairly intact, awake mammalian organisms, especially rats, cats, rabbits, and dogs. Physiologists whose work involved anesthetized animals, nonmammalian organisms, or animal parts were as a rule not part of this community. Its members pursued different agendas, studied different physiological processes, and came from a variety of institutions. The glue that held them together was emotions. They cited each other and corresponded but rarely convened in order to discuss their mutual concerns. They also shared a common discourse, a particular thought style, and a set of practices that managed and controlled emotions in physiological laboratories.[39]

RABBITS THAT BLUSH

Cats have very various dispositions, some are ugly and savage, some friendly and affectionate, some restless, some quiet and serene, some playful, some indolent.
—Walter B. Cannon et al. *(1929)*

Rabbits are, as is well known, extremely timid animals.
—Angelo Mosso (1896)

The burden of controlling emotions in laboratories fell to the experimenters and attendants. They developed practices for selecting emotionally appropriate animals, manipulating experience, and controlling emotional states.[40]

In selecting animals for their protocols, physiologists constructed an implicit and, at times, explicit classification system that ordered animals according to a scale of emotional qualities and quantities. Each type of organism had its particular emotional repertoire, its

[38] Cannon's work should not, however, be regarded as a compendium of previous research or as a report on the state of emotions in physiology—as Helen Flanders Dunbar's book, *Emotions and Bodily Changes,* would be in the realm of psychosomatic medicine during the 1930s. There were many contemporary investigations on the emotions that Cannon did not discuss in his books or articles, such as the effect of emotions on basic metabolic rate or psychogalvanic reflex. See H. Flanders Dunbar, *Emotions and Bodily Changes: A Survey of Literature on Psychosomatic Interrelationships, 1910–1933* (New York: Columbia Univ. Press, 1935). The Walter Bradford Cannon Papers (and other archival sources) contain his extensive correspondence with psychologists, physiologists, and clinicians. See, e.g., his letter to Hugo Münsterberg: "In separate enclosure I am sending you a few reprints of papers which indicate that a physiologist may occasionally make excursions into psychology. Indeed, a tendency in that direction is not infrequently found among us." Cannon to Hugo Münsterberg, 7 Jan. 1913, mss. acc. 1608/Cannon, Walter Bradford, Hugo Münsterberg Papers (mss. acc. 1501–2499b), Boston Public Library. By courtesy of the trustees of the Boston Public Library.

[39] Physiologists who worked with nonanesthetized sleeping animals also participated in this community. See Arno B. Luckhardt, "Contributions to the Physiology of the Empty Stomach, XXXII: The Effect of Dreaming on the Gastric Hunger Contractions," *Amer. J. Physiol.,* 1916, *39*:330–334. For an exception to the generalization about animal parts see Hatai and Hammett, "Four Factors Causing Changes" (cit. n. 26); their work focused on isolated intestinal segments. On the notion of thought style see Ludwik Fleck, *Genesis and Development of a Scientific Fact,* trans. Fred Bradley and Thaddeus J. Trenn (Chicago: Univ. Chicago Press, 1979).

[40] For the epigraphs see W. B. Cannon *et al.,* "Some Aspects of the Physiology of Animals Surviving Complete Exclusion of Sympathetic Nerve Impulses," *Amer. J. Physiol.,* 1929, *89*:84–107, on p. 103; and Mosso, *Fear,* trans. Lough and Kiesow (cit. n. 10), p. 10.

specific emotional sensitivity, and its unique interactive characteristics. The production of physiological knowledge depended on the selection of animals with the right "personality qualities" or "temperament" for the job.

Organisms were classified according to an emotional menu. Some animals lacked specific emotions altogether: "the skunk, the porcupine, the turtle, have little or no fear." Others were noted for specific emotions: "the most common emotion in the cat is anger, rather than fear as in the rabbit."[41] More commonly, organisms were arranged along an imaginary scale according to their emotional excitability. It was generally argued that young animals were more excitable than older ones; that dogs were "much less likely to be disturbed by the nature of their surroundings than are rabbits and cats"; and that among the common laboratory-based organisms rabbits were the most sensitive, followed by cats and then dogs. Rabbits were often singled out as especially sensitive. Some physiologists avoided them altogether and "in reading any article on blood sugars . . . looked first as to what animal was used and if it were rabbits . . . went no farther," arguing that complete emotional control was highly unlikely in rabbit-based protocols. Others simply stated that "the rabbit is an animal subject to emotional . . . hyperglycemia to an unusual degree." And still others insisted that the rabbit was an "undesirable experimental animal" because its frequent emotional reactions (fright) often led to various pathological lesions—"similar observations regarding such marked effects of fright have been very rarely observed by us in dogs."[42]

More central to the selection process than organism-level taxonomies were the specific emotional responses that the physiologist elicited from particular animals. This was because organisms of the same species, age, and sex differed significantly in their emotional reactions. Even thoroughbred animals exhibited significant individual differences when it came to emotions.[43] The selection stage therefore depended on particular knowledge of individual animals.

We can discern two general types of knowledge that the physiologist had of his animals. The first was of long duration. Daniel Todes has investigated such relationships in his analysis of Pavlov's dogs. Anglo-American physiologists who engaged in similar long-term experiments (e.g., Charles Scott Sherrington, Joseph Barcroft, Howard Liddell, and W. Horsley Gantt) openly discussed the "personality qualities" of their animals in selecting a particular individual for the protocol.[44] Howard Liddell of Cornell University, for ex-

[41] George W. Crile, *The Origin and Nature of the Emotions: Miscellaneous Papers,* ed. Amy F. Rowland (London/Philadelphia: Saunders, 1915), p. 52 (see also folder 6 ["Working Papers, Dr. George W. Crile, December 19, 1932"], container 1, George Washington Crile Papers); and Ernest L. Scott and Thomas H. Ford, "The Concentration of Sugar in the Blood of the Rabbit during Inanition and after the Ingestion of Glucose," *Amer. J. Physiol.,* 1923, *63*:520–534, on p. 522.

[42] Mosso, *Fear,* trans. Lough and Kiesow (cit. n. 10), p. 12; Hatai and Hammett, "Four Factors Causing Changes" (cit. n. 26); Cannon, *Bodily Changes* (cit. n. 29), p. 73; Ernest Lyman Scott, "Biography," n.d., p. 36, folder "Biography (3)," box 1, Ernest Lyman Scott Papers; Martha Richardson Jones, "Studies on Carbohydrate Metabolism in Rabbits" (Ph.D. diss., Yale Univ., 1920), p. 44; and M. L. Menten and G. W. Crile, "Studies on the Hydrogen-Ion Concentration in Blood under Various Abnormal Conditions," *Amer. J. Physiol.,* 1915, *38*:225–232, on p. 228.

[43] For the emotional differences between thoroughbred animals see, e.g., M. C. Winternitz, "A Progress Report to the Commonwealth Fund, October 3, 1938," folder 3729, box 388, Series 18.1, Grants, Commonwealth Fund, Rockefeller Archive Center, Sleepy Hollow, New York.

[44] Todes, "Pavlov's Physiology Factory" (cit. n. 16). For "personality qualities" of dogs see "Conditioned Responses—Lecture to 1st year class Physiology—June 2, 1938," folder 21, box 8, Harold G. Wolff Papers, Archives, New York Weill Cornell Center of New York Presbyterian Hospital, New York. Wolff collaborated with W. Horsley Gantt on dogs (e.g., "Kompa") undergoing chronic experiments. Gantt had worked with Pavlov.

ample, "made a special study of a timid dog, selected by Dr. Anderson on the basis of his experience with dogs at the Cornell Anatomy Farm in Peekskill." Charles Scott Sherrington selected a particular "mongrel-bred fox-terrier" because of her "marked emotional characteristics." And Joseph Barcroft distinguished between "Blackey," an "extremely highly strung" dog, and "Tilley III," who was "of a temperament diametrically opposite."[45]

Evaluation of animals' emotions was not always based on long-term relationships. Often the experimenter's acquaintance with the animal lasted for a couple of days, hours, or even minutes. The emotional appraisal of the animal and the "careful selection of individuals . . . who so far as one could tell were not disturbed" by the manipulation or who "might be expected to remain quiet throughout the experiment" depended on short-term interactions. T. R. Elliott, for example, chose a "good tempered cat" in determining the amount of suprarenin in normal suprarenal glands, and Mosso "chose those [rabbits] . . . that blushed most easily and frequently" for his experiments on emotions.[46]

Other physiologists interacted with their organisms in order to gauge their general dispositions. E. G. T. Liddell chose "*friendly* female cats" for his experiments on blood pressure during the 1930s, and A. J. Carlson selected "*gentle* dogs" for his research on the physiology of gastric hunger contractions during the early 1910s.[47]

The selection of individual animals on the basis of emotions attributed to them was partly dictated and justified by the absence of a supply of emotion-standardized animals. Dogs and cats, in particular, came from a variety of different backgrounds. During the late nineteenth century experimenters often acquired animals on their own, occasionally purchasing rabbits at a local market. By 1907 most investigators in the United States depended on boys and young men to supply them with vagrant cats or dogs.[48] At the University of Pennsylvania Medical School, dogs were purchased from practically anyone. Many laboratories relied on dealers who bought the animals at auctions. By the 1920s the research

[45] H. S. Liddell to Robert A. Lambert, 8 Aug. 1939, folder 993, box 82, 200 A, Cornell Univ.—Reflex Behavior, 1939–1941, Series 200 United States, Record Group: 1.1 Projects, Rockefeller Archive Center; Sherrington, "Experiments on the Value of Vascular and Visceral Factors" (cit. n. 24), p. 397; and Joseph Barcroft and R. H. E. Elliott, "Some Observations on the Denervated Spleen," *J. Physiol.,* 1936, *87*:189–197, on pp. 192–193. See also E. G. T. Liddell and H. M. Carleton, "Dietary and Emotional Factors Affecting the Blood-Pressure of Cats, Observed by Exteriorization of the Carotid Artery," *Quarterly Journal of Experimental Physiology,* 1936, *26*:155–164; W. Horsley Gantt, *Experimental Basis for Neurotic Behavior: Origin and Development of Artificially Produced Disturbances of Behavior in Dogs* (New York/London: Hoeber, 1944); and Cannon to Walter Alvarez, 2 Aug. 1915, folder 1514, box 110, Walter Bradford Cannon Papers.

[46] Scott, "Content of Sugar in the Blood" (cit. n. 3), pp. 297, 306; Elliott, "Control of the Suprarenal Glands" (cit. n. 29), p. 379; and Mosso, *Fear,* trans. Lough and Kiesow (cit. n. 10), p. 13.

[47] The relevance of the animal's general disposition will become clear later in this essay. Liddell and Carleton, "Dietary and Emotional Factors" (cit. n. 45), p. 157 (emphasis added); and Carlson, "Contributions to the Physiology of the Stomach, VI" (cit. n. 33), p. 369 (emphasis added). As Carlson's text makes clear, "gentle" meant "submissive" or "cooperative." For other examples of the central role that emotional characterization played in selecting organisms see Cannon, *Mechanical Factors of Digestion* (cit. n. 26), p. 217; and Alvarez, "Ways in Which Emotion Can Affect the Digestive Tract" (cit. n. 33), p. 1233.

[48] On investigators supplying their own animals see *George Crile: An Autobiography,* ed. Grace Crile, 2 vols. (Philadelphia/New York: Lippincott, 1947), Vol. 2, pp. 28, 32 (dogs cost twenty-five cents apiece); Mosso, *Fear,* trans. Lough and Kiesow (cit. n. 10), p. 13; and Bernard, *Propriétés physiologiques* (cit. n. 16), p. 12. On boys and young men as suppliers see Benison *et al., Walter B. Cannon* (cit. n. 36), pp. 184, 282; and David L. Edsall to Stanley Cobb, 1 Feb. 1928, folder 69, box 3, Stanley Cobb Papers (H MS c53), Rare Books and Special Collections, Francis A. Countway Library of Medicine, Boston.

community increasingly relied on municipal animal shelters or pounds for animals. The establishment of reproducing colonies of cats or dogs for research was not pursued until the Rockefeller Foundation provided extensive support to Charles Stockard for developing a colony of genetically standardized dogs in the late 1930s.[49]

The history of rats differs from that of cats and dogs. From the late nineteenth century the wild rat was replaced by the far more docile white rat in animal experimentation. At the Wistar Institute the white rat was inbred for many generations and became a standard mammalian organism.[50] The concern with individual emotional reactions of particular rats, however, was no less apparent at the Wistar Institute than it was in laboratories that relied on vagrant cats and dogs.

In introducing the language of temperament and emotion into the selection process physiologists developed a flexible system that guided and justified their physiological choices and, as we shall see, contained and explained numerous facts and artifacts. Animals that did not display consistent physiological reactions, maintain a steady baseline, and develop a specific pattern of habituation to various stimuli or whose physiological responses fluctuated over time were "nervous." Other animals were "good natured" or "phlegmatic." Most experimenters preferred "good natured" and "tranquil" animals to "nervous," "resistant," and "timid" ones. These and other qualitative, subjective, and nonstandardized terms played an important role in the selection of particular individuals and the interpretation of physiological observations. As Joseph Barcroft explained in his paper on the effects of emotions on the spleen: "the present paper . . . is somewhat disjointed owing to the difficulty of obtaining suitable preparations on which to work. This difficulty centers largely about the very great differences in temperament exhibited by different animals."[51]

In choosing his organisms the physiologist was therefore guided by an informal emotional scale and his own interactions with specific individuals. The emotional characterization of organisms was significant because it provided information concerning the investigator's primary concern—the emotional *experiences* of laboratory animals. The emotional characterization of individual organisms allowed the investigator to choose, foresee, or have certain expectations concerning the organism's emotional-qua-physiological reactions to various laboratory manipulations during the experiment. Once the organism was selected, the physiologist's focus switched from the general question of the animal's place on the emotional scale of qualities and quantities to a more practical concern with its flow of emotional experiences and their accumulation in the laboratory.

[49] Susan E. Lederer, "The Controversy over Animal Experimentation in America, 1880–1914," in *Vivisection in Historical Perspective,* ed. Rupke (cit. n. 13), pp. 236–258, on p. 252; and Lederer, "Political Animals: The Shaping of Biomedical Research Literature in Twentieth-Century America," *Isis,* 1992, *83*:61–79, on pp. 65–66. See also Philip Bard to Alfred Blalock, 1 Dec. 1953, folder 5, box 11, Blalock Corr. Bard, P., Alan Mason Chesney Medical Archives, Johns Hopkins Medical School, Baltimore. On the Rockefeller support of Stockard's colony see Adele E. Clarke, "Research Materials and Reproductive Science in the United States, 1910–1940," in *Physiology in the American Context,* ed. Geison (cit. n. 5), pp. 323–350, on pp. 335–340.

[50] D. R. Griffin, *Animal Thinking* (Cambridge, Mass.: Harvard Univ. Press, 1984), p. 14; and Bonnie Clause, "The Wistar Rat as a Right Choice: Establishing Mammalian Standards and the Ideal of a Standardized Mammal," *J. Hist. Biol.,* 1993, *26*:329–349.

[51] Joseph Barcroft, "Some Effects of Emotion on the Volume of the Spleen," *J. Physiol.,* 1930, *67*:375–382, on p. 375. See also Barcroft and Elliott, "Some Observations on the Denervated Spleen" (cit. n. 45), pp. 192–193. In discussing temperaments Barcroft acknowledged the observations of Pavlov.

MANAGING EMOTIONS: THE DYNAMICS OF AFFECTIVE STATES

We always make note of any obvious fright or restlessness on the part of the animal during the taking of the blood sample.
—H. D. Clough (1923)

Against my better instincts, I find myself becoming a psychologist of cats.
—E. G. T. Liddell (1936)

Managing the emotions of animals was a multidimensional task that often began prior to the experimental protocol. During this preliminary stage organisms were prepared experientially. The physiologist literally and deliberately endowed the organism with a set of experiences that primed it for the physiological experiment to come. This preparatory stage was therefore unique in its conceptualization. Though animals in other contemporary contexts were also processed and prepared, the focus there was on the material aspects of the process.[52] Here, in contrast, the physiologist focused on the experiential priming of organisms.

The practical exigency of this attention to experiences was relatively straightforward—the experimenter had to attend to, manipulate, and plan the exact experiences to which the animal was to be exposed prior to the experimental protocols. Though various techniques were employed in preparing the organism experientially, they all shared a particular conceptual and practical framework, evident in the investigators' demand that the animals be "accustomed" to, "trained" for, and "acquainted" with the space of the laboratory, its nonhuman inhabitants (other animals), its various instruments, its manipulators (the experimenters and their assistants), and even its manipulations.

Conceptually, the aim of this experiential priming was to transform field organisms, with their past experiences of the field, into laboratory organisms, with a new set of experiences from the laboratory. Organisms were deliberately endowed with a repertoire of experiences from the laboratory. These tailored and controlled exposures served two purposes: they manipulated the animal's emotional reactions to different aspects of the laboratory (each physiologist choosing the exposures according to his agenda), and they obviated the need to know the animal's prelaboratory history.

The controlled exposures to the laboratory experience writ large began immediately upon the organism's incorporation into the space of the laboratory. First, the organism had to be exposed to its new surroundings. As Scott explained, the newly arrived cat was in a state of "mental excitement incident to the new conditions" of the laboratory. This mental excitement was manifest in its unusually high blood sugar levels. Scott determined that "a week seemed none too long" to accustom the cat to its new surroundings and eliminate its excitement-qua-hyperglycemia.[53] Only then could the physiologist use the cat for sugar metabolism experiments.

T. R. Elliott argued to the same effect almost contemporaneously. He had discovered

[52] It was the material-qua-material that was prepared. For some of the literature on materials in the life sciences see, e.g., the collection of essays "The Right Organism for the Job," *J. Hist. Biol.,* 1993, *26*:233–368; Clarke, "Research Materials" (cit. n. 49); and Robert E. Kohler, *Lords of the Fly:* Drosophila *Genetics and the Experimental Life* (Chicago/London: Univ. Chicago Press, 1994). For the epigraphs to this section see Clough *et al.,* "Study of the Rabbit" (cit. n. 29), p. 468; and "Pat" [E. G. T. Liddell] to John Fulton, 22 Mar. 1936, folder 1505, box 109, Series I, John Farquhar Fulton Papers, Manuscript Group 1236, Manuscript and Archives, Yale University Library, New Haven, Connecticut.

[53] Scott, "Content of Sugar in the Blood" (cit. n. 3), p. 278. Scott also includes a change of diet during this week as part of the preparation.

that "cats that have been admitted to the laboratory overnight and are still alarmed by their strange surroundings" differed in their physiology. Normal levels of adrenalin were found only in cats that "had been in the laboratory a week or more. . . . Recent admissions on the other hand were always sulky for a day or so, ready to snarl at their comrades, and very suspicious of their surroundings. In such, though their general bodily conditions might be good, the adrenalin value was always lower." Organisms required a minimum shelf life of a week in order to accumulate a sufficient amount of laboratory experience.[54]

From the 1910s numerous physiologists practiced controlled experiential exposure of organisms to the laboratory's surroundings prior to the experimental protocol, with the explicit intent of controlling emotional reactions. Estes H. Hargis and Frank C. Mann "placed [their dogs] under preliminary observations for increasing periods of time so that they will become accustomed to the surroundings." Toshio Uno "allowed [his rats] 3 days or more in the laboratory cage to become accustomed to their new surroundings before the tests were made." And E. G. T. Liddell and H. M. Carleton observed that "after the summer holidays, temporary readings 60 mm. above the normal [blood pressure] may be found at first" because of the protracted hiatus in laboratory experiences.[55] The organism's physiology depended on its history of experiences in the laboratory.[56]

Preparing the animal for its laboratory experience also included practices that targeted the emotional reactions of animals to the manipulators and the manipulations. One common practice was to *handle* the animals "daily in order to accustom them to the laboratory routine and manipulation." Abstaining from this preparatory experiential stage, when "some of the cats which it was found necessary to use were unaccustomed to being handled," made it "impossible," as E. W. E. Schear had discovered, to avoid excitement during the protocol itself.[57] More specific manipulations that literally enacted tailored segments

[54] Elliott, "Control of the Suprarenal Glands" (cit. n. 29), pp. 403, 379. Like Scott, Elliott mentions the importance of nutrition. Neither Scott nor Elliott specifies any particular activities for the cats—they simply had to experience the laboratory for a week. See Clawson, "Normal Rectal Temperatures of Sheep" (cit. n. 29), for a similar requirement concerning sheep.

[55] Hargis and Mann, "Plethysmographic Study" (cit. n. 26), p. 183; Toshio Uno, "Effect of General Excitement and of Fighting on Some Ductless Glands of Male Albino Rats," *Amer. J. Physiol.,* 1922, *61*:203–214, on p. 204; and Liddell and Carleton, "Dietary and Emotional Factors" (cit. n. 45), p. 159. See also Helen Dean King and Henry H. Donaldson, "Life Processes and Size of the Body and Organs of the Gray Norway Rat during Ten Generations in Captivity," *American Anatomical Memoirs,* 1929, *14*:63–68, for the arduous task of accustoming wild gray rats to the laboratory; and Greenman and Duhring, *Breeding and Care of the Albino Rat* (cit. n. 1), p. 119.

[56] For other examples see Griffith, "Reflex Hyperglycemia" (cit. n. 28), p. 624; Cannon, *Bodily Changes* (cit. n. 29), p. 181; C. Lyons, "Emotional Hypercholesterolemia," *Amer. J. Physiol.,* 1931, *98*:156–162; Lillian M. Moore, "Experimental Studies on the Regulation of Body Temperature, IV: The Maintenance of a Practically Uniform Temperature in Rabbits by Elimination of Random Movements," *ibid.,* 1921, *56*:361–364; and "Checkers: Experimental Routine," Folder 22 ("Dog data: Various dogs 'experimental routine' 1940–1945"), box 134, W. Horsley Gantt Papers, Alan Mason Chesney Medical Archives, Johns Hopkins Medical School, Baltimore. This is a page from Gantt's laboratory protocols where he recorded that his dog was "accustomed to lab and camera" by being repeatedly brought into the laboratory during July–December 1945. In this context see also Ivan Pavlov, "General Types of Animal and Human Higher Nervous Activity," in *Selected Works* (Moscow: Foreign Languages Publishing House, 1955), esp. pp. 316–317.

[57] H. L. Katz and L. B. Nice, "Changes in the Chemical Elements of the Blood of Rabbits during Emotional Excitement," *Amer. J. Physiol.,* 1934, *107*:709–716, on p. 710; and Edward Waldo Emerson Schear, "The Content of Sugar in the Blood of Cats under the Influence of Cocaine," *ibid.,* 1915, *38*:269–273, on p. 270. Schear was working under Scott at Columbia. See also Jones, "Studies on Carbohydrate Metabolism in Rabbits, II" (cit. n. 31), p. 510, for an emotional reaction of a rabbit that was "unaccustomed to close confinement or handling"; and Dresbach, "Observations upon the Blood Pressure of Sheep" (cit. n. 31), p. 434. For other examples of accustoming animals to "handling" see, e.g., J. M. D. Olmsted and M. W. Morgan, Jr., "Refraction of the Rabbit's Eye in the Unexcited and Excited State," *Amer. J. Physiol.,* 1939, *127*:602–604; and Nice and Katz, "The Specific Gravity of the Blood of Normal Rabbits and Cats and Splenectomized Rabbits, before, during and after Emotional Excitement," *ibid.,* 1935, *113*:205–208.

of the experiment ahead of time were also used by some physiologists. As H. I. Schou explained: "the difficulty of these experiments [on adrenalin levels] is that the puncture of a vein in itself may be an interference engendering emotion, which source of error can only be avoided through repeated punctures and thus familiarization with the interference." Philip Shaffer "accustomed [his dogs] to the operation" involved in sampling blood from the jugular vein prior to the protocol in which the operation was to take place. A. J. Carlson attempted to train his dogs to the "mechanical restraint" necessary for his observations, though they still developed "restlessness and evident distress, especially when [the restraint] continued for hours."[58] And Walter B. Cannon argued that "acquaintance with the observer, his assistant and the natural surroundings" facilitated the accuracy of the crucial "basal count" at the start of the protocols.[59]

The ideal of emotional control would also be written into the protocol's technical procedures, recasting specific maneuvers of the experiment. Philip Shaffer, working in the mid 1910s, dedicated a significant portion of his paper on blood sugar levels to the technique of drawing blood. He emphasized the importance of maintaining an unexcited emotional state by proposing a series of modifications: "the skin is shaved and cleaned . . . some hours before the blood is to be drawn"; "the animal is gently tied . . . to a comfortable board" and "a *sharp* medium sized needle" is plunged into the vein. Other experimenters, such as Ernest Lyman Scott, Frank C. Mann, and F. R. Griffith, introduced their own variations on conventional techniques. Scott changed the method of glucose loading by letting the animals drink the glucose by mouth instead of inserting the usual stomach tube; Mann and Hargis used a special mask to regulate carbon dioxide levels in the circulating blood of dogs because they wanted to use a "method which would not cause the animal discomfort"; and Griffith let his animals roam free in the laboratory while an anesthetic was taking effect instead of restraining them with a holder.[60]

[58] Schou, "Some Investigations into the Physiology of Emotions" (cit. n. 33), p. 82 (Schou was working on humans); Shaffer, "Normal Level of Blood-Sugar" (cit. n. 30), pp. 299–301; and Carlson, "Contributions to the Physiology of the Stomach, VI" (cit. n. 33), p. 371. See also Hargis and Mann, "Plethysmographic Study" (cit. n. 26), p. 188; they trained their dogs for intravenous injections and for observations.

[59] Cannon, *Bodily Changes* (cit. n. 29), p. 180. See also J. J. Izquierdo and W. B. Cannon, "Studies of the Conditions of Activity in Endocrine Glands, XXIII: Emotional Polycythemia in Relation to Sympathetic and Medulliadrenal Action of the Spleen," *Amer. J. Physiol.,* 1928, *84*:545–562, on p. 546. Less commonly used techniques did not target the emotional experiences of animals but, instead, avoided the effects of these experiences on the animal's physiology. One approach, which never developed into a method for emotional control in physiology but became a common clinical procedure, was to sever the sympathetic nerve supply to specific organs. Thus, instead of eliminating emotions, one could eliminate their effects in the body by literally disconnecting the body from the effects of emotional excitement. As several physiologists noted: "splanchnotomized dogs . . . [did] not show large variations in blood concentration due to excitement," and the "inhibition" of the stomach and bowel by emotional excitement could "be avoided by cutting the splanchnic nerves." See H. G. Barbour and W. F. Hamilton, "Blood Specific Gravity: Its Significance and a New Method for Its Determination," *Amer. J. Physiol.,* 1924, *69*:654–661, on p. 660; and Alvarez, "Ways in Which Emotion Can Affect the Digestive Tract" (cit. n. 33), p. 1233. See also Tashiro, "Studies on Urea-Nitrogen Concentration" (cit. n. 34), p. 624. A second technique for avoiding the effects of emotions was to measure the physiological variable before the emotion had time to take effect or even before it was initiated. Here the practice was rapidly to decapitate the animal and immediately procure a sample from its body. The rapid decapitation avoided the creation of any emotion and the sample (usually blood) would therefore be free of any effects caused by emotion. A third technique was to wait for the animal to calm down. This method was most visible in the dynamics of the experiment and in the delays to which some physiologists referred in their protocols—for example, Walter B. Cannon's "annoying wait": Cannon, *Bodily Changes,* p. 172.

[60] Philip A. Shaffer, "On the Determination of Sugar in Blood," *J. Biol. Chem.,* 1914, *19*:285–295, on p. 287. See also J. J. R. Macleod and R. G. Pearce's remark on the suggestions by Scott and Shaffer: "For purposes of following the blood-sugar level from day to day, the precautions advocated by . . . [Scott and Shaffer] must henceforth be strictly adhered to." Macleod and Pearce, "Studies in Experimental Glycosuria, IX" (cit. n. 30),

The demand for gentle interactions with organisms—in order to avoid emotional excitement—was a recurrent theme in early twentieth-century physiology. As T. R. Elliott explained, "[positive] results are obtained with animals that purr when stroked, and generally manifest a sense of *bien être.*" Physiological knowledge depended on keeping laboratory animals content, and so the importance of maintaining animals in an "unemotional . . . condition" or in a state of "good humor" was articulated by many experimenters.[61] "It was found essential that for at least four minutes prior to the reading, and during the reading as well, the rabbit be gently held quiet in a comfortable position." The ultimate aim was "to avoid excitement." Some experimenters provided a "comfortable cushion" for the animal when taking the initial "basal" measurement. Petting the animal, holding it gently, or providing a comfortable cushion were only three practices in a larger assemblage of informal rules governing the interactions between animals and humans. They represented a benevolent sensibility that Scott insightfully characterized as "quite apart from any humanitarian considerations."[62] The emotional well-being of laboratory animals served physiological ends.[63]

This unusual nexus between a fulminant utilitarianism and the sympathetic interactions with organisms that alone made them useful explains, perhaps, the lack of expressed dissonance from practitioners whose approach both promulgated a nurturing respect for the organisms and culminated in the calculated and cold-blooded killing of those organisms: a cat "put in box on window sill in shade and out of sun . . . was quiet, snuggling clam [*sic*] during entire period. Removed at 12:35 pm and killed at once," Scott recorded

p. 416. For the other work cited see Scott and Ford, "Concentration of Sugar" (cit. n. 41), p. 521; Hargis and Mann, "Plethysmographic Study" (cit. n. 26), p. 183; and Fred R. Griffith, Jr., "Further Evidence Regarding the Relationship of the Adrenals to the Amount of Sugar in the Blood," *Amer. J. Physiol.,* 1923, *66*:659–664, on p. 660. See also Menten and Crile, "Studies on the Hydrogen-Ion Concentration" (cit. n. 42), p. 227; and Griffith and Farris, eds., *Rat in Laboratory Investigations* (cit. n. 31), p. 2.

[61] Elliott, "Control of the Suprarenal Glands" (cit. n. 29), p. 403. See also Cannon, *Mechanical Factors of Digestion* (cit. n. 26), p. 217. On the importance of maintaining the animals' emotional equilibrium see George Whipple to Alvarez, 17 Jan. 1929, folder Alvarez/90.2/Whipple, George, box Alvarez/BMS/C 90.2/P-Z, Walter C. Alvarez Papers (B MS c90), Rare Books and Special Collections, Francis A. Countway Library of Medicine, Boston; and James S. McLester, "The Emotional Element in Surgical Diseases," *Bulletin of the American College of Surgeons,* 1937, *22*:96–98. See also Carlson, "Contributions to the Physiology of the Stomach, VI" (cit. n. 33), p. 369.

[62] On avoiding excitement see Olmsted and Morgan, "Refraction of the Rabbit's Eye" (cit. n. 57), p. 602. See also Dresbach, "Observations upon the Blood Pressure of Sheep" (cit. n. 31), p. 434; and Alvarez to Cannon 20 Jan. 1933, folder 1519, box 110, Walter Bradford Cannon Papers. For the "comfortable cushion" see Newton *et al.,* "Studies on the Conditions of Activity in Endocrine Organs" (cit. n. 6), p. 379. See also Griffith, "Further Evidence Regarding the Relationship of the Adrenals to the Amount of Sugar in the Blood" (cit. n. 60), p. 159; and Cannon, "Movements of the Stomach" (cit. n. 26), p. 380. For Scott's characterization see Scott, "Content of Sugar in the Blood" (cit. n. 3), p. 296. For a similar approach see W. B. Cannon and Daniel De La Paz, "Emotional Stimulation of Adrenal Secretion," *Amer. J. Physiol.,* 1911, *28*:64–70; and Liddell and Carleton, "Dietary and Emotional Factors" (cit. n. 45), p. 160.

[63] This was not an alternative female science or subculture; only a few women participated in these emotion-attentive endeavors. These physiologists held to their own variant of a "feeling for the organism"—to borrow Evelyn Fox Keller's depiction of Barbara McClintock's unique approach to her organisms. The "special kind of sympathetic understanding" that Keller argues heightened McClintock's "powers of discernment, until finally, the objects of her study [had] . . . become subjects in their own right . . . , [claiming] from her a kind of attention that most of us experience only in relation to other persons," clearly describes the relationship of these physiologists with their objects of study. But here this attention and sympathetic understanding were of a very different nature. See Evelyn Fox Keller, *A Feeling for the Organism: The Life and Work of Barbara McClintock* (San Francisco: Freeman, 1983), p. 200. On women in physiology see Toby A. Appel, "Physiology in American Women's Colleges: The Rise and Decline of a Female Subculture," *Isis,* 1994, *85*:26–56.

in his notebook.[64] Animals were literally petted and stroked while awaiting their planned—imminent—death.

The dynamics of emotional control modified additional aspects of the experiment. Physiologists moved laboratory animals from one site in the laboratory to another according to the perceived emotional significance for the animal. When the physiologist wanted the animal to assume its unexcited state, he placed it in a particular emotionally neutral spot; when he wished to evoke an emotional response, he moved the animal to a different location. The space for emotional induction and the space for emotional neutrality were different spaces in the physical continuum of the laboratory. The physical dynamics of the experiment created and maintained these emotional distinctions.[65]

Another space that received particular attention from these physiologists was the animal house. This extralaboratory space was imagined as a source of emotional experiences and served as a rich "reservoir of interpretive flexibilit[ies]."[66] No longer conceived solely as a storage or feeding facility, it was an emotional space with important physiological ramifications. The emotional experiences of animals during their sojourn in the animal house had important implications for their physiological behaviors in the laboratory.

The emotional "content" of the animal house was usually invoked when physiologists observed large variations between different animals. Walter B. Cannon, for example, accounted for variations in the effect of splanchnic stimulation on different cats by suggesting that the cats spent varying lengths of time in the animal house next to barking dogs. The variation in their physiological responses reflected their varying exposures to this emotionally frightening experience.[67]

Nonphysiologists, such as Milton J. Greenman and F. Louise Duhring from the Wistar Institute, also invoked the preexperimental emotional histories of animals. Greenman and Duhring's book, *Breeding and Care of the Albino Rat for Research Purposes,* described an elaborate and fascinating collection of practices that targeted the emotional ambiance of the colony. As the authors contended, "maintaining [the colony] in a condition of fearless contentment is . . . scientifically essential." The control of emotions in the colony guaranteed the knowledge produced in the laboratory.[68] The animal house was thus a reservoir of emotional experiences that the physiologist could negotiate in interpreting his physiological observations and, just as important, another locus for the implementation of practices that targeted the emotions.

[64] Notebook: "Sugar in the Blood of cats, Book III, 1913–1914. Blood Sugar Dec. 17 1913 to Aug 10 1914," p. 17, 14 Jan. 1914, box 6, Ernest Lyman Scott Papers. See also Scott and Ford, "Concentration of Sugar" (cit. n. 41), p. 521. On the ambiguous status of laboratory animals as both objects and pets or as both analytic and naturalistic entities see Arnold B. Arluke, "Sacrificial Symbolism in Animal Experimentation: Object or Pet?" *Anthrozoös,* 1988, *2*:98–117, on p. 116 ("the ambiguity of the status of the laboratory animal helps to explain why scientists and technicians are not riddled by conflict"); Michael E. Lynch, "Sacrifice and the Transformation of the Animal Body into a Scientific Object: Laboratory Culture and Ritual Practice in the Neurosciences," *Social Studies of Science,* 1988, *18*:265–289, esp. pp. 280–281; and Mary T. Phillips, "Proper Names and the Social Construction of Biography: The Negative Case of Laboratory Animals," *Qualitative Sociology,* 1994, *17*:119–158, which qualifies Arluke's argument.

[65] For an impressive example of how the emotional content of the space of the laboratory determined some of the dynamics of the protocol see Cannon, *Bodily Changes* (cit. n. 29), p. 181; and Izquierdo and Cannon, "Studies of the Conditions of Activity in Endocrine Glands" (cit. n. 59), p. 547.

[66] Todes, "Pavlov's Physiology Factory" (cit. n. 16), p. 215.

[67] Cannon, *Bodily Changes* (cit. n. 29), pp. 165–166.

[68] Greenman and Duhring, *Breeding and Care of the Albino Rat* (cit. n. 1), p. 64. Though Greenman and Duhring did not cite any sources, their examples (and justifications) were taken from the work of Shinkishi Hatai and F. S. Hammett at the Wistar Institute. Greenman was the director of the institute, Duhring the curator of the animal colony.

A different set of practices focused on the notation and observation of emotional events. Observing the animals for emotions was an important preoccupation of these physiologists, but despite the acknowledged importance of this physiological task, there was rarely a discussion of how such observations were made or of the criteria for determining that a particular behavior was emotional.[69] Occasionally, a physiologist might describe the observed reaction of an animal, such as crying or mewing, or explain the circumstances that led him to conclude that it was emotional (e.g., jealousy evoked by attention to another animal). In the majority of cases, however, the reports simply stated that the animal was "restless," "excited," "slightly nervous," "nervous," "quiet," "uneasy," "very much excited," and so forth.

The record of animals' emotions during experimentation ensured and assured the reader that the animals were maintained in the appropriate emotional state. It validated knowledge and provided a rationale for the practices of the laboratory: "If the animal showed signs of excitement during the drawing of the basal blood, this sample was discarded." Negative descriptions were also important. One physiologist observed during the procedure to obtain blood, "The rabbits did not, as a rule, resent this."[70]

The emotional record also served as an interpretive tool that contained and explained various physiological observations. As E. G. T. Liddell and H. M. Carleton explained in describing the emotional demeanor of one of their cats during pulse rate and blood pressure measurements,

> One animal, however, a stupid docile male, resentful of and somewhat resistive to sphygmomanometry had often at the end of the observation an increased pulse-rate, without much increase in blood-pressure, though he assumed after examination an attitude of calm detachment in spite of an increased pulse-rate. At other times, especially in the later months when thoroughly accustomed to the procedure, his calm was genuine, and his pulse-rate remained steady and slow during the whole proceeding.[71]

In addition to observing emotional reactions, a few physiologists developed objective techniques for identifying emotional intrusions during the protocol. Certain patterns allowed a physiologist to argue for the presence or absence of an emotion. As H. D. Clough and his colleagues argued in the early 1920s: "theoretically older animals, i.e., animals in use for a longer time, would be less likely to show . . . [fear] reactions." Therefore, when their rabbits showed "no progressive lowering of [blood sugar] level coincident with longer use," the experimenters concluded that they "need not consider . . . [fear or pain as] factors." If successive exposures of an animal to the same experience did not produce successive physiological changes, then the physiologist could conclude that the protocol and the animal were emotion-free, and vice versa.[72]

[69] A pointed example of the physiologist's skill in observing emotional expression was Cannon's discovery of an error in Darwin's *Expression of the Emotions* (cit. n. 18). See Cannon to Léon Binet, 22 May 1936, folder 722, box 55, Walter Bradford Cannon Papers. For a rare exception that does consider criteria for spotting emotional behavior see Sherrington, "Experiments on the Value of Vascular and Visceral Factors" (cit. n. 24), pp. 393, 396–397.

[70] Katz and Nice, "Changes in the Chemical Elements" (cit. n. 57), p. 711 (for a similar remark see Scott and Ford, "Concentration of Sugar" [cit. n. 41], p. 522); and G. S. Eadie, "The Variations of the Blood Sugar of the Rabbit throughout the Day and the Effect of the Subcutaneous Injection of Glucose," *Amer. J. Physiol.,* 1923, *63*:513–519, on p. 513.

[71] Liddell and Carleton, "Dietary and Emotional Factors" (cit. n. 45), p. 159.

[72] Clough *et al.,* "Study of the Rabbit" (cit. n. 29), p. 468. See also Clawson, "Normal Rectal Temperatures of Sheep" (cit. n. 29), pp. 262–269; and Izquierdo and Cannon, "Studies of the Conditions of Activity in Endocrine Glands" (cit. n. 59), p. 550.

On rare occasions, the physiologist monitored one physiological variable in order to verify that the animal remained unemotional while he investigated a different physiological variable. For example, a physiologist investigating mean blood pressure in sheep monitored the heartbeat of an animal and argued that a steady heart rate during the protocol proved that he had successfully eliminated emotions that might contaminate his results.[73]

Implicit in these various practices were a number of very explicit claims: that the standard affect was always, without exception, zero excitement; that the space for the production of reliable knowledge was the laboratory, precisely because of its capacity to control emotions; that the physiologist had to attend to and control the emotional aspects of the experiment; and that it was, in fact, possible to control emotions and achieve replication, universal knowledge, and decreased variability. The site for privileged knowledge was now characterized by its opposition to those sites in which nature (the organism) was in a state of emotional excitement.

The invention of practices for controlling emotions constrained the physiologist's appeal to emotions in interpreting aberrant or unexpected physiological observations. Once the physiologist implemented these practices he could not invoke emotional intrusions to explain unruly data. The collective practices of the community of physiologists thus limited and restricted the interpretive flexibility of any one physiologist—now that it was possible to reduce such intrusions to a minimum. These developments did not abolish the appeal to emotions but constrained and set specific limits to the use of this new interpretive tool.[74]

The practices for controlling and observing emotions created a new "economy of attention and the senses."[75] Physiologists observed, manipulated, and reported emotions and conceived of the laboratory as an emotional ecology. Emotions mediated between laboratory events and physiological facts and artifacts, motivated and rationalized various practices, inflected the dynamics of the laboratory, and gave an epistemological and rhetorical edge to those physiologists who used them in their arguments.

THE KEEPER OF KNOWLEDGE

Unless you become like outsiders, you shall never enter the domain of quantitative science.
—Theodore M. Porter (1995)

In spite of the pervasive standard of emotional control over all laboratory stimuli, there was one exception to the rule. This was the unique artifact identified in published papers as the "attendant" or "keeper" of the animals. At times a friend of the animals, at other times the source of anxiety or jealousy, this unique emotion-evoking object, the keeper, served multiple purposes in the laboratory. Though some of his functions were occasionally performed by the experimenters, physiologists usually maintained a strict division of labor

[73] Dresbach, "Observations upon the Blood Pressure of Sheep" (cit. n. 31), pp. 434–435.

[74] The practices for managing emotions were introduced occasionally, in passing or as rules of thumb. They were frequently absent from some protocols, while being conspicuously present in other papers by the same authors. They could appear in various parts of various papers. Thus, they were sometimes mentioned as part of the procedure; at other times they appeared in the introduction and at still others in the discussion. For a clear criticism of the overuse of emotions as an explanatory factor see Arthur Grollman, "Physiological Variations in the Cardiac Output of Man, IV: The Effect of Psychic Disturbances on the Cardiac Output, Pulse, Blood Pressure, and Oxygen Consumption of Man," *Amer. J. Physiol.*, 1929, *89*:584–588, on p. 587. In Pavlov's case, as Todes has shown, such a community of physiological practitioners did not exist; see Todes, "Pavlov's Physiology Factory" (cit. n. 16), pp. 226–228, 239–241.

[75] Lorraine Daston and Katharine Park, *Wonders and the Order of Nature, 1150–1750* (New York: Zone, 1998), p. 311.

when it came to emotions. While they supported and endorsed their own emotional transparency, they sanctioned the keeper's role as an important emotional object for the animals. Thus the keeper was singled out as the only permissible emotional stimulus in a setting that otherwise attempted to remain emotionally neutral.[76]

In discussing the contributions of the keeper to the protocol, experimenters focused on his or her special affective relationships with the animals.[77] This affective bond was now transformed into an explicit physiological resource, a laboratory instrument for manipulating the organism and its physiology. At times, the attendant's mere presence guaranteed the status of physiological knowledge. As Scott explained: as a "precaution against excitement, an attendant, from whom the animals were accustomed to receive food, brought them to the laboratory and assisted throughout the preparation of the animal and the collection of blood."[78]

Occasionally, the keeper's lap served as a special experiential enclave for controlling the affective state of laboratory animals. As A. J. Carlson explained: "We . . . tried the expedient of having an attendant keep the dog snugly in his lap during the observation period. This proved very satisfactory, except for the attendant. It is irksome, to say the least, to sit still for two to eight hours at a stretch. We can appreciate the reason for the dog's restlessness when restrained mechanically in a hammock or on a couch for that length of time."[79]

The keeper's lap was mentioned by several investigators. Some suggested that the dog's "abdomen or chest walls [be] . . . stroked or scratched gently" while the animal lay "in the lap of an assistant." Others argued that good results were "especially the case if the dog is covered up with a coat or a comforter" while "in the lap of an attendant." And Greenman and Duhring, in discussing the contributions of the attendant, explained: "individual attention [to rats], shown by handling and petting, is essential for . . . securing uniform reactions when used as research animals."[80]

The physiological significance of the affective bond between animals and keepers was also expressed indirectly. Liddell and Carleton reported in a paper that "the presence of an assistant *other than the usual one*" disrupted their experiment and "caused a rise [in blood pressure] to 145 mm. Hg" in one of their cats. Or, as King and Donaldson noted

[76] This practical and conceptual difference between the keeper, who was marked as an emotionally significant object, and the investigator, who was usually emotionally transparent, fits well with Mary Douglas's analysis of pollution and the construction of boundaries. See Mary Douglas, *Purity and Danger: An Analysis of the Concept of Pollution and Taboo* (1966; London/New York: Ark Paperbacks, 1989), esp. pp. 114–128. For a contemporary analysis of the affective relationships between laboratory technicians and animals see Arnold B. Arluke, "Uneasiness among Laboratory Technicians," *Lab Animal,* 1990, *19*:21–39. For the epigraph to this section see Theodore M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton, N.J.: Princeton Univ. Press, 1995), p. 85.

[77] Most of the physiologists refer to men when they discuss their attendants. However, some institutions, e.g., the Wistar Institute, had women as caretakers. I have not found any indications that female keepers were singled out as more able in handling animals affectively.

[78] Scott, "Content of Sugar in the Blood" (cit. n. 3), p. 285.

[79] Carlson, "Contributions to the Physiology of the Stomach, VI" (cit. n. 33), p. 371; and A. J. Carlson, "Contributions to the Physiology of the Stomach, XV: The Nervous Control of the Gastric Hunger Mechanism (Man, Dog)," *Amer. J. Physiol.,* 1914, *34*:155–171, on p. 159.

[80] On the keeper's lap see, e.g., Cannon *et al.,* "Some Aspects of the Physiology of Animals Surviving Complete Exclusion of Sympathetic Nerve Impulses" (cit. n. 40), p. 92. For the quotations see Shaffer, "Determination of Sugar in Blood" (cit. n. 60), p. 287; Carlson, "Contributions to the Physiology of the Stomach, VI," p. 369; and Greenman and Duhring, *Breeding and Care of the Albino Rat* (cit. n. 1), p. 63. Though Duhring, as an attendant, had good reasons to emphasize the contribution of the caretakers to the successful running of the protocol and to science, the justification for the assertions in the book came from the work of physiologists at the Wistar Institute. See note 68, above.

with regard to one of the caretakers at the Wistar Institute: "she could handle . . . [gray rats] at will throughout their lives. They were always very nervous, however, and would not submit to being held by any one who was not a constant worker in the colony." Walter Alvarez, of the Mayo Clinic, also observed that the "mere presence of a stranger in the laboratory was enough to inhibit the movements of the bowel" in dogs.[81] These passing observations emphasized the unique nature of the bond between particular animals and individual keepers or manipulators. The affective nature of this bond differentiated between "insiders" and "outsiders" of the laboratory writ large.

The affective bond between animal and keeper was also a tool for controlling the behavior of the animal and gently persuading it to conform to the experimenter's intentions. This latter function was particularly important, because in laboratories concerned with emotions the manipulators depended on the cooperation of the animal. Any resistance on the part of the animal to the manipulator's designs could only be met, literally, with gentle persuasion. This was a fundamental tension in these laboratories: the manipulators wanted to control every aspect of the experiment but could not impose their will by brute force. Such tactics would lead to emotional excitement on the part of the organism and would be self-defeating. "Handling" animals was thus a multiply important function; the term refers not only to the technical abilities of keepers but also to the singular affective relationships that these keepers forged with their rats, cats, dogs—and even gorillas.[82] The success of the protocol could well depend on the attendant's skill in manipulating the organism: "When the attendant knows how to handle dogs even a very hungry dog will lie in his lap quietly for hours"—allowing the experimenter to observe and maintaining the animal in its physiologically appropriate condition, the unexcited state.[83]

Local and personal affective interactions were necessary for conducting physiological experiments and, more important, for guaranteeing the status of physiological knowledge. The producers of knowledge and, especially, the attendants were not interchangeable parts in a smoothly running physiological factory. Replication and standardization of knowledge demanded a controlled (standard) affect; and a controlled affect depended on particular "insiders." The same technique produced different results in the hands of different individuals. The late nineteenth-century ideals of "interchangeable observers" and "impersonal" exchange were challenged by the unique nature of the affective relationships between animals and manipulators in physiological laboratories.[84]

[81] Liddell and Carleton, "Dietary and Emotional Factors" (cit. n. 45), p. 160 (emphasis added); King and Donaldson, "Life Processes" (cit. n. 55), p. 65; and Alvarez, "Ways in Which Emotion Can Affect the Digestive Tract" (cit. n. 33), p. 1234. See also Sherrington, "Experiments on the Value of Vascular and Visceral Factors" (cit. n. 24), p. 399; and McLester, "Emotional Element in Surgical Diseases" (cit. n. 61), pp. 96–97, for the effect of a person whom a dog dislikes on the yield of gastric juice.

[82] As John Fulton noted in his diary during a visit to the exhibition of Herbert Park at the Philadelphia zoo: "The keeper subdued their big gorilla and gave me an opportunity of studying his plantar reflexes." See John F. Fulton Diary, 8 Aug., 1930–19 Aug., 1931, Thursday, 11 June 1931, John Farquhar Fulton Papers, Cushing/Whitney Medical Library, Yale University, New Haven, Connecticut.

[83] Carlson, "Contributions to the Physiology of the Stomach, VI" (cit. n. 33), p. 371. It is important to note that the dog will lie for hours without moving and that it will remain emotionally unexcited.

[84] Lorraine Daston, "Objectivity and the Escape from Perspective," *Soc. Stud. Sci.*, 1992, *22*:597–618, esp. pp. 607–612; and Porter, *Trust in Numbers* (cit. n. 76), esp. pp. 21–32. The noninterchangeable aspect of the producers of knowledge was even more evident in discussions that focused on human physiology. For a discussion of local knowledge in the clinical realm see John Harley Warner, *The Therapeutic Perspective: Medical Practice, Knowledge, and Identity in America, 1820–1885* (Princeton, N.J.: Princeton Univ. Press, 1986), pp. 76–80.

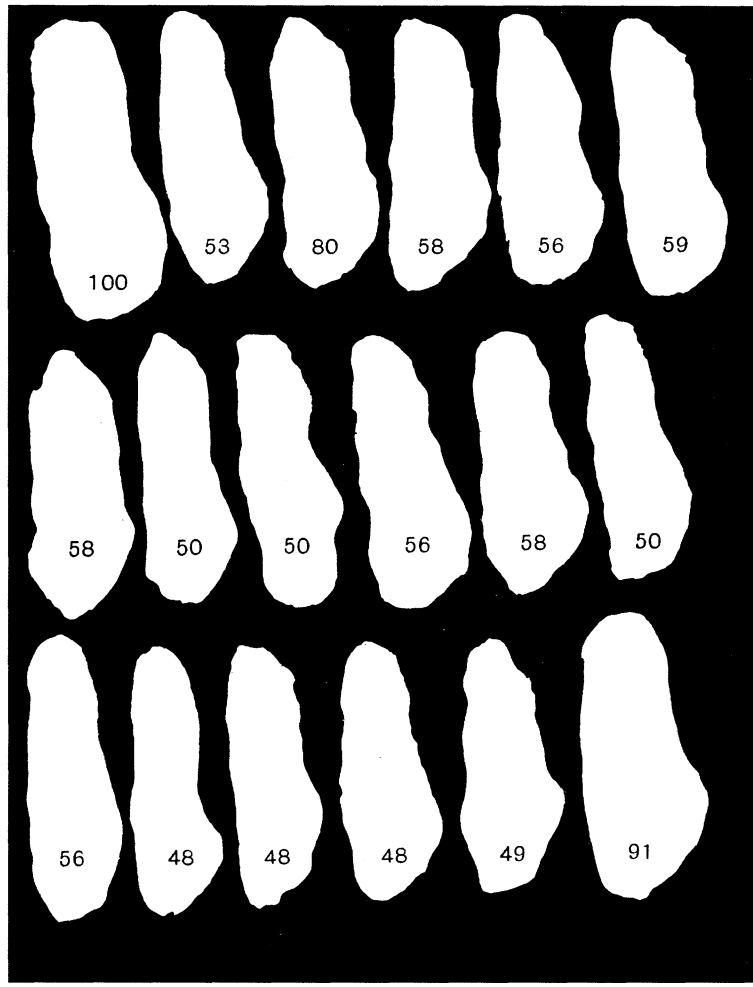

Figure 4. *Dynamic representation of the approximate volumes of a dog's spleen reckoned as a percentage of the volume at the commencement of the experiment. The affective bond between a dog, Tilley, and its keeper is responsible for the observed fluctuations in Tilley's spleen. The keeper was told to enter and exit from the room. (From Joseph Barcroft, "Some Effects of Emotion on the Volume of the Spleen,"* Journal of Physiology, *1930, 67:375–382, on page 377.)*

The special status of the keeper as an experience-sustaining tool and the occasional contributions of the experimenter as a source of emotional control could, on occasion, come into conflict with the explicit objective of the protocols. One experimenter described his predicament in exposing a cat to a "furiously" barking dog in order to produce fear: the cat, "beyond a slight squirming at first . . . would apparently ignore the disturbance, occasionally glancing at us as though it were perfectly safe as long as we were nearby." The mirror image of this conflict of objectives could be observed when the alter-status of the keeper—as an emotional experience in his own right—came to the fore. As Carlson explained, during attempts to observe normal gastric hunger contractions "the entrance of a friend (animal keeper) into the room cause[d] almost as marked an inhibition as fear or

anger."[85] Similar observations by other experimenters fed into some of the experimental protocols. In such cases the effect of the keeper would be used to manipulate the organism into an emotional experience: "the animal was laid out on the table and held lightly in position by another attendant. The keeper was sent out of the room, on which the spleen of the dog contracted, owing to anxiety to follow him. When the spleen showed any sign of relaxation the keeper was recalled, and after the dog had seen him he was again sent outside and again with consequent contraction." (See Figure 4.)[86] The keeper shifted between two different experiential roles: at times he was himself an emotional experience, and at other times he actively sustained the emotional experience of the animal. These roles depended, ultimately, on the nature of the interactions and affective relationships between the animal and its manipulator before, during, and after the protocols.

Like the practices for accustoming animals to their surroundings and for managing the dynamics of emotions, the new rules for interacting with animals created a new niche in the laboratory. There was no formalized code for the special connections that the keeper or attendant forged with the animals. Neither was there an explicit technique for being gentle, for petting or stroking the animals. Most of the experimenters did not integrate these rules of conduct as explicit elements of their techniques. Rather, they imposed a new set of constraints on existing techniques. These constraints regulated the interactions between organism and manipulator, controlled the emotional experiences of the organism during the protocol, and served as means for gentle persuasion.

The keeper and his special rapport with the animals played a significant role in physiological work. His bodily presence sustained the organism in the appropriate experiential state and gently coerced it into a cooperative disposition. Infrequently, this special rapport between manipulator and organism might interfere and come into conflict with the objectives of the experiment. In general, these interactive practices and their silent participants went unreported in physiologists' accounts of their work. Some experimenters, however, integrated this utilitarian-sympathetic ethos into their protocols, where it was explicitly expressed in the fine details of the experimenter's techniques or in the explicit use of the keeper as a visible laboratory stimulus.[87]

THE POLITICS OF EMOTIONS

The little model illustrating your early work on a cat's stomach with the x-ray, is coming along fine. . . . So as not to enrage the anti-vivisectionists I don't plan to show the cat tied down in any way; besides, if I remember correctly from your description your best results were obtained when you held the cat gently.
—Walter C. Alvarez (1933)

Animals in the laboratory shall receive every consideration for their bodily comfort; they shall be kindly treated. . . . The same care shall be taken to minimize discomforts during the convalescence as in a hospital for human beings.
—Committee on the Protection of Scientific Research of the AMA (1910)

[85] F. A. Hartman, H. A. McCordock, and M. M. Loder, "Conditions Determining Adrenal Secretion," *Amer. J. Physiol.,* 1923, *64*:1–34, on p. 29; and Carlson, "Contributions to the Physiology of the Stomach, VI" (cit. n. 33), p. 376.

[86] Barcroft, "Some Effects of Emotion" (cit. n. 51), p. 376. See also Sherrington, "Experiments on the Value of Vascular and Visceral Factors" (cit. n. 24), pp. 393, 397, 401; and Schiff, *Leçons* (cit. n. 11), p. 263. It is important to note that in Schiff's *Leçons,* unlike in twentieth-century literature, the *experimenter,* not the attendant, is represented as an important emotional stimulus for the animals.

[87] In this essay I have deliberately focused on those papers in which the attendant's role is mentioned. On this topic see Steven Shapin, "The Invisible Technician," *American Scientist,* 1989, *77*:554–563.

The emphasis on gentle interactions and the representation of the laboratory as an emotional haven coincided with the rise of the animal protection and antivivisection movements in the Anglo-American context. The concurrence of these two developments, and the striking similarities between the physiological rationale for considerate treatment of the animals and antivivisectionist demands, raises the question of the possible political dimensions of the turn to emotions in Anglo-American physiology. As Susan Lederer has shown in her analysis of the *Journal of Experimental Medicine,* the antivivisection movement exerted a real influence on the content and language of scientific reports. Other authors, studying the British context, have also argued for the role of animal protectionists and antivivisectionists in changing the practices of physiologists and molding the nature of animal welfare debates.[88]

As I have argued, the concern with the elimination of pain had a long and rich history in physiological circles and preceded some of the ethical debates on animal experimentation.[89] The conceptual chasm separating physiologists and animal welfare advocates—their mutual concerns with the elimination of pain notwithstanding—was well illustrated during the late nineteenth century, when ardent physiological advocates of pain elimination such as Claude Bernard, Elie de Cyon, and Moritz Schiff topped the antivivisectionists' list of infamous vivisectors.

The concern with the emotional welfare of animals had a similar history. Physiologists' concerns for the emotional welfare of animals did not preclude practices that were emotionally or physically unpleasant. George W. Crile—the "arch-vivisector"—for example, was attentive to the emotional well-being of his animals during some experimental protocols, yet others required extreme violence. Even Cannon, whose work emphasized the gentle handling of animals before and during the protocol, could exhibit a calculating indifference to his long-term experimental subjects, cats that had been in the laboratory for years. Scott's laboratory notebooks, as we have seen, illustrate a similar pattern of detached concern.[90]

[88] Lederer, "Political Animals" (cit. n. 49). Stewart Richards argues that the Cruelty to Animals Act of 1876 changed the laboratory practices of various British physiologists. See Stewart Richards, "Anaesthetics, Ethics, and Aesthetics: Vivisection in the Late Nineteenth-Century British Laboratory," in *The Laboratory Revolution in Medicine,* ed. Andrew Cunningham and Perry Williams (Cambridge: Cambridge Univ. Press, 1992), pp. 142–169. On the antivivisection movement see Lederer, "Controversy over Animal Experimentation" (cit. n. 49); Richard D. French, *Antivivisection and Medical Science in Victorian Society* (Princeton, N.J.: Princeton Univ. Press, 1975); Benison *et al., Walter B. Cannon* (cit. n. 36); James Turner, *Reckoning with the Beast: Animals, Pain, and Humanity in the Victorian Mind* (Baltimore: Johns Hopkins Univ. Press, 1980); Harriet Ritvo, *The Animal Estate: The English and Other Creatures in the Victorian Age* (Cambridge, Mass.: Harvard Univ. Press, 1987); Mary Ann Elston, "Women and Anti-vivisection in Victorian England, 1870–1900," in *Vivisection in Historical Perspective,* ed. Rupke (cit. n. 13), pp. 259–294; Hilary Rouse, "Gendered Reflexions on the Laboratory in Medicine," in *Laboratory Revolution in Medicine,* ed. Cunningham and Williams, pp. 324–342; Hilda Kean, "The 'Smooth Cool Men of Science': The Feminist and Socialist Response to Vivisection," *History Workshop,* 1995, *40*:16–38; and Coral Lansbury, "Gynaecology, Pornography, and the Antivivisection Movement," *Victorian Studies,* 1985, *28*:413–437. For the epigraphs to this section see Alvarez to Cannon, 20 Jan. 1933, folder 1519, box 110, Walter Bradford Cannon Papers; and Edsall to Cobb, 1 Feb. 1928, folder 69, box 3, Stanley Cobb Papers. Edsall's letter quotes from the guidelines formulated by the Committee on the Protection of Scientific Research of the AMA. As Edsall explained, the committee "prepared a placard to be put in a conspicuous place on the wall or bulletin board of every laboratory in which animals were used for scientific purposes."

[89] See the sources cited in notes 14–16, above.

[90] For the description of Crile see newspaper clipping: Susan Drake Bishop, "Kill Conscience First," *Herald New York,* 23 Dec. 1913, folder 289, container 70, George Washington Crile Papers. See also the pamphlet by the American Anti-Vivisection Society (Philadelphia), n.d., *ibid.;* and Peter C. English, *Shock, Physiological Surgery, and George Washington Crile: Medical Innovation in the Progressive Era* (Westport, Conn.: Greenwood, 1980), for Crile's work on shock. For an example of Crile's concern with emotions see Menten and Crile, "Studies on the Hydrogen-Ion Concentration (cit. n. 42). See also Cannon to S. W. Ranson, 25 Nov. 1930, folder 1783, box 127, Walter Bradford Cannon Papers; and Notebook: "Sugar in the Blood of cats, Book III, 1913–1914. Blood Sugar Dec. 17 1913 to Aug 10 1914," p. 17, 14 Jan. 1914, box 6, Ernest Lyman Scott Papers.

We should also recall that the turn to emotions had negative, as well as positive, public relations implications. Because the emotional traumas of laboratory animals became important elements in the physiologist's explanatory framework, the emphasis on a benevolent laboratory environment went hand in hand with a heightened visibility of unpleasant emotional experiences. The same physiological imperative that dictated gentle interactions also decreed that disagreeable emotional experiences (e.g., in cases of experimental failure, aberrant observations, and so forth) should be detailed in the experimental record. Reports of restless, angry, jealous, distressed, terrified, anxious, and fearful dogs, cats, rabbits, and rats—usually hidden from public view—were now advertised in physiological journals. If political prudence, as Lederer has shown, dictated a reduction in the "emotional content" of published papers and a diminished presence of animals and their experiences in the *Journal of Experimental Medicine,* then the physiologists I have considered in this essay were guided by a different—and potentially politically destructive—set of concerns that increased the "emotional content" of their papers and emphasized the animals' experience.[91] For them, the turn to emotions was, politically, a two-edged sword.

The fate of rats in these laboratories reinforces the argument that the driving force behind the turn to emotions was not political prudence. Unlike cats and dogs, rats were not targeted by the antivivisection movement, and physiologists were given a free hand in their manipulation.[92] Nonetheless, rats received the same special attention as other animals and were similarly managed through gentle interactions. Finally, it should be noted that some of the practices for managing emotions in laboratories were not animal friendly—particularly those that accustomed the animals to the manipulations of the experiment (e.g., repeated injections) ahead of time.[93] Some of these preparatory manipulations were conspicuously absent from the British literature, where the operational conditions of the 1876 Cruelty to Animals Act dissuaded physiologists from carrying out such procedures.[94]

Ultimately, however, physiologists represented their laboratories as emotional havens for animals and, no less important, publicly proclaimed their deference to animal welfare. Cannon's code of regulations governing laboratory procedures involving animals, for example, was explicitly written with the antivivisectionists in mind and with the objective of disarming their criticism. Like many of his contemporaries, he adopted the approach of the late nineteenth-century physiologists who repeatedly emphasized their humanitarian concerns and their use of anesthetics when confronted by antivivisectionists' charges,

[91] Lederer, "Political Animals (cit. n. 49), p. 71. The emphasis on the experiences of animals and their emotions in these laboratories argues against the contemporary observations of Michael Lynch and of Mary T. Phillips, who describe the suppression of the "naturalistic" animal or animal-as-pet—what Lynch defines as "subjugated knowledges"—by the investigators. See Lynch, "Sacrifice and the Transformation of the Animal Body" (cit. n. 64); and Phillips, "Proper Names and the Social Construction of Biography" (cit. n. 64).

[92] On dogs, cats, and horses as pets see Lederer, "Political Animals," p. 64; Ritvo, *Animal Estate* (cit. n. 88), pp. 35–37; and French, *Antivivisection and Medical Science* (cit. n. 88), p. 374. On the neglect of rats by the antivivisection movement see entry for 20 June 1912, minutes of the executive council of the Animal Defence and Anti Vivisection Society: "taking steps for the framing & introduction of a Bill for the exemption of the higher animals (horses, mules, monkeys, dogs & cats) from vivisection." Animal Defence and Anti Vivisection Society, GC/52, Wellcome Institute for the History of Medicine, London. Bonnie Clause has found no evidence for antivivisection activity targeting the use of rats at the Wistar Institute; I thank her for sharing this work.

[93] See note 59, above.

[94] I thank Tilli Tansey for suggesting this point to me. If these preparatory manipulations of the animal were definable as an "experiment" according to the 1876 act, then the physiologist could face various restrictions. For a discussion of the 1876 act and the complex negotiations surrounding the definition of what counts as an experiment see E. M. Tansey, "The Wellcome Physiological Research Laboratories, 1894–1904: The Home Office, Pharmaceutical Firms, and Animal Experiments," *Medical History,* 1989, *33*:1–41, esp. pp. 5–9.

downplaying the physiological rationale behind their particular concerns with suffering.[95]

An alternative perspective on the possible contributions of the antivivisection movement to these developments in physiology goes beyond rhetoric and public relations. Cannon's work as head of the Committee on the Protection of Scientific Research of the AMA began several years before his extensive research on emotions. Perhaps his involvement with that committee contributed to his heightened physiological awareness of the experiences of laboratory animals. The tenor of the informal set of guidelines he created, which addressed the welfare of laboratory animals by focusing on changing the interactions between humans and animals, matches the tone of reports of his physiological practices in the laboratory after 1910.[96]

CONCLUSION

The turn to emotions created a seeming paradox at the heart of physiology: it introduced a pervasive focus on individual organisms and their emotions in the midst of investigations intended to be objective, impersonal, and repeatable; and it established universal physiological knowledge on the basis of unique (affective) interactions and subjective evaluations.

Emotion was understood in early twentieth-century physiological laboratories as, first and foremost, a local intrusive event, a moment of loss of control—over the body, over the protocol, or over the encounter. When the organism escaped, in a sense, from the grasp of the structured scientific protocol, when it deviated from the prescribed and controlled path of the experiment, or when it failed to follow the narrative of the experimental laboratory (e.g., when it failed to produce the same results under the same circumstances on different occasions), then it was often defined as emotional—"nervous," "angry," "apprehensive," "excited," and so forth.

This identification of emotion with disorder was widespread. Physiologists of the early twentieth century targeted a broad class of disruptive moments—"emotions"—and eliminated these events from their laboratories. By purging emotions they controlled their laboratories and protocols.

The organism that these physiologists manipulated held a new intermediate position between what Richard French has defined as "two world-views." It accommodated both nineteenth-century representations of animals as "interchangeable biological systems" on

[95] Cannon's guidelines were designed to convince the public that medical researchers were taking an active role in self-regulation. They were circulated among the deans of seventy-nine medical schools and included significant protection for dogs and cats, but not for rats. See Lederer, "Controversy over Animal Experimentation" (cit. n. 49), p. 250. For the guidelines see Walter B. Cannon, "Medical Control of Vivisection," *North American Review,* 1910, *191*:814–821, on p. 817. There was a profound irony in that (male) physiologists took over emotion, managing and "rationalizing" emotion in animals, while at the same time they castigated (female) antivivisectionists for their emotional investment in animals. I thank one of the anonymous referees for the suggestion and succinct rendering of this point. See Turner, *Reckoning with the Beast* (cit. n. 88), pp. 96–121; and Lederer, "Controversy over Animal Experimentation," p. 246.

[96] The creation of "the modern pet" and the construction of a "culture of pets" during the Victorian era were important developments that contributed to the emphasis on animal emotions, particularly in cats and dogs. This transformation was echoed in literature, art, and even in the English language (the word "brute" disappeared by the end of the nineteenth century). Thus, in conjunction with the emergence of physiological concerns with animal emotions, a flourishing popular literature that portrayed the psychology and consciousness of various animals emerged in the United Kingdom. See Turner, *Reckoning with the Beast,* pp. 71–121; Ritvo, *Animal Estate* (cit. n. 88), pp. 125–166; French, *Antivivisection and Medical Science* (cit. n. 88), pp. 373–391; and Rouse, "Gendered Reflexions on the Laboratory in Medicine" (cit. n. 88).

which the experimenter carried out "mechanistically conceived experiments" and antivivisectionist representations of animals as "unique individuals" with "mental . . . and spiritual qualities."[97] The turn to emotions merged elements from the "materialistic, scientific world" with elements from its late nineteenth-century detractors, represented by the antivivisectionists.

This new model of the organism undermined the animal-as-machine. Its energy expenditure, the pressure of its hydraulic systems, the fatigue of its striated muscles, the availability of its energy stores (glucose, fats), and its configuration were all modified in important ways by emotion. And emotion was, by definition, an accidental event that was often unpredictable—even in the sanctuary of the laboratory. Emotion signified the collapse of the laboratory's ideal of the animal-machine, of reliable control, predictability, replicability, and standardization.

This challenge to the mechanistic view was achieved not by the introduction of vitalistic, phenomenological, or holistic models but by a radical approach that even mechanized emotion. This mechanization of emotion introduced an affective dimension into the heart of the organism-as-machine.[98] It transformed the predictable and controlled body into an idiosyncratic, unpredictable, and local machine.

I would suggest that these developments in physiology reflected and contributed to a broader late nineteenth-century crisis in knowledge. The physiologists that I have considered forged their own unique route to knowledge, integrating various contradictory elements into a new synthesis. They shared with Ernst Mach and Karl Pearson the concern with "sources of controversy" and strove to "enhance objectivity in the sense of intersubjectivity," but they rejected the radical descriptionism and the "retreat from belief in objects" that these philosophers promulgated for physics. They founded consensus by explicitly "contracting nature" and eliminating the multiple possibilities of biological forms, but they did not express the "crisis of anxiety and denial" that such choices, with their "invitations to subjectivity," entailed for the contemporary community of late nineteenth-century atlas makers.[99] By maintaining these tensions, physiologists subdued and interpreted numerous physiological facts and artifacts, promulgated alternative forms of knowledge-making, privileged new knowledge claims, and diffused mounting political pressures.

[97] French, *Antivivisection and Medical Science,* p. 383.

[98] Recent historiography has tended to project an image of animals as machines or tools. But as the discussion of these physiologists shows, animals—at least mammalian species of cats, rabbits, dogs, and rats—were not perceived or handled as tools or instruments for the job.

[99] Theodore M. Porter, "The Death of the Object: *Fin de siècle* Philosophy of Physics," in *Modernist Impulses in the Human Sciences, 1870–1930,* ed. Dorothy Ross (Baltimore: Johns Hopkins Univ. Press, 1994), pp. 128–151, on p. 130; and Lorraine Daston and Peter Galison, "The Image of Objectivity," *Representations,* 1992, *40*:81–128, on pp. 86–87. For additional important developments see Otniel E. Dror, "Modernity and the Scientific Study of Emotions, 1880–1950" (Ph.D. diss., Princeton Univ., 1998).