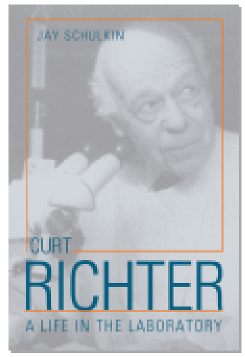
Curt Richter



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CHAPTER 5

Neurobiological Investigations and Clinical Applications

LESSONS LEARNED IN PANAMA

As noted in previous chapters, Curt Richter's orientation to the brain and the organization of behavior was influenced greatly by Adolf Meyer, a neurologist by training and a student of the great nineteenth-century neurologist Hughlings Jackson (1884/1958). Jackson, among others, suggested that the evolution of the brain mirrored the evolution of a species: the more advanced the species, the more corticalized the brain; the dissolution of the nervous system was the breakdown of function, the converse of the evolutionary trend (Critchley and Critchley 1998).

Richter was interested in behavioral adaptation, the idea that, as James put it, "all nervous centers have then in the first instance one essential function, that of intelligent action" (James 1890/1952, p. 79). Predominant in this view was that the organization of action was dependent on the forebrain and that the basic reflexes were mediated by the brain stem. This theme in neurological research today remains a viable hypothesis about the organization of behavior and the levels of neural integration (Grill and Norgren 1978). As Richter began his studies on the sloth during his trip to Panama, neurological inquiry would play a fundamental role, as would the idea of levels of neural function. These would remain important aspects of Richter's research throughout his career.

Two Hopkins figures, Meyer and Watson, influenced Richter's travel to and work in Panama. Meyer provided the resources for Richter to travel to that country to study the neurological basis of behavior. The grasp reflex Richter would focus on there was of paramount importance to Watson (1919; see Boakes 1984), and Richter inherited this interest.

FIG. 5.1. Newborn infant hanging from apparatus designed to test the grasp reflex. *Source:* Richter 1934c

The grasp reflex had already been identified in newborns. Watson described this phenomenon in print and in his promotional films about behaviorism and reflexes. Richter wrote, "I have attempted to carry this work a step farther along the line of Watson's original experiments: first by putting it on an objective basis, with a method for measuring the strength of the reflex" (Richter 1934c, p. 327). Note the comment about the contrast to Watson—an "objective basis."

Richter began this exploration with a set of experimental objectives that he would continue to pursue throughout his career. They were (1) to study the grasp reflex from a distinctively neurological and physiological orientation, (2) to measure skin resistance (a clinical technique that he inherited from Meyer), and (3) to investigate broad-based neurological phenomena by combining neurological, behavioral, and clinical scientific perspectives. Richter always had an eye toward the patient; because he worked in a hospital clinic, his experiments had clinical applications. His neurological investigations were perhaps most important clinically.

TROPICAL FORESTS IN PANAMA

The Panama Canal was completed in 1914. Its building necessitated the deliberate flooding of areas of tropical forest. The high ground of Barro Colorado ("Red Clay") Island came into being due to that flooding. By 1923, the island had become a research bastion for a number of scientists, a small tropical forest rich with animal life. One major figure at the newly formed island was the naturalist Thomas Barbour (1943), who helped shape it into a research institute (Leigh 1999).

Barro Colorado research station was originally funded by foundations and universities, under the direction of the National Research Council, to foster biological research. It has now become part of the Smithsonian Tropical Research Institute. The island is home to many mammalian species, birds, reptiles, and amphibians (see Leigh 1999) (fig. 5.2).

A report by Thomas Barbour, chair of the Executive Committee for the Institute for Research in Tropical America, identified Adolf Meyer as the sponsor of Richter's sojourn to the research island. The Johns Hopkins University (at Meyer's suggestion) contributed $300. Richter was listed in notes on the island's visitations as follows: "Dr Curt Richter, Johns Hopkins Medical School, Baltimore, MD, experimental physiologist: studied the sloth principally, but used monkeys and some other mammals as well. Plan to return with two associates to continue research next summer" (Annual Report of the Barro Colorado Island Biological Station, March 7, 1925). Judging by the descriptions, either conditions were minimal or Richter was very frugal: an entry dated August 8 lists $30.35 spent on "subsistence," and one dated September 16 lists $16.65 for subsistence and $1.20 for supplies.

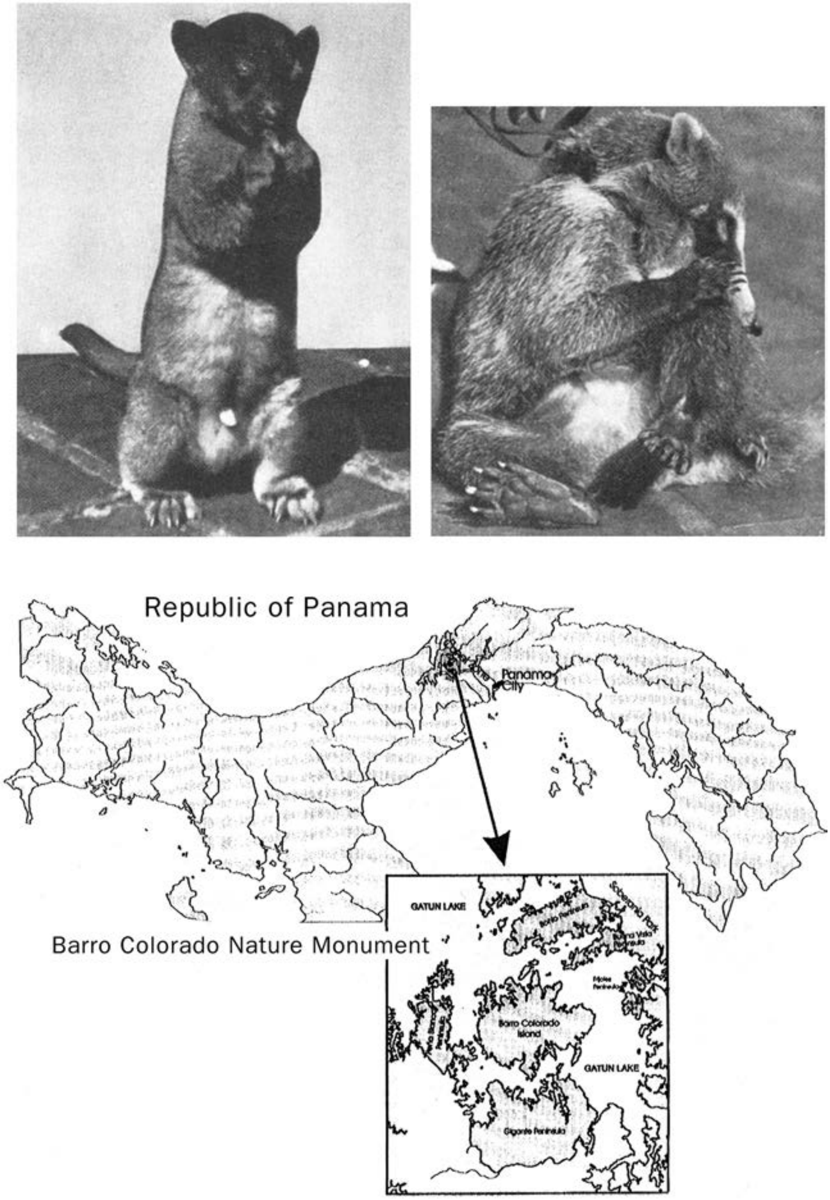

FIG. 5.2. *Top:* Two of the animals Richter worked with on his sojourn to Panama: *left,* a coatimundi; *right,* a kinkajou. *Bottom:* A map of Barro Colorado. *Source:* Richter 1925; Barro Colorado, Republic of Panama

For Richter's second and final trip to the Institute, the visitation log reads, "Dr Curt P. Richter, Johns Hopkins Hospital, Baltimore, MD, continued his studies begun at the island last year in experimental physiology using as subjects the sloths and monkeys" (Annual Report of the Barro Colorado Island Biological Station, March 7, 1925).

Richter's trips to Panama were rare sojourns into a naturalistic paradise for a scientist rooted in the laboratory. One of the papers he published based on those excursions was entitled "Some Observations of the Self-Stimulation Habits of Young Wild Animals" (Richter 1925). Richter noted how human self-stimulation, "thumb and finger sucking and erotic habits," would serve our understanding "from a more biological point of view" (Blass 1976, p. 148). The following are his anecdotal observations.

Richter began the article by noting that "during the past summer in Panama I had opportunity to make a few observations on several forms of self-stimulation habits of three wild animals: a coatimundi, a kinkajou, and a spider monkey" (Blass 1976, p. 148). He observed the behavior of a young female coatimundi on a colleague's patio. He noted that the animal had a habit of sucking and chewing on her knee. This was a common occurrence, but when given other behavioral options, the animal ceased this behavior.

The second animal Richter observed, a young male kinkajou, had been raised by a physician. The kinkajou had a habit of "autofellatio so firmly fixed that the physician was unable to break it" (Blass 1976, p. 150).

A spider monkey was the third subject of his observations. It, too, was raised in the home of a colleague, who took it in after its mother was shot. It was treated as a member of the family, eating and sleeping with other family members. Richter observed that the monkey sucked its finger and displayed childlike behaviors.

Richter noted in the same paper that "in all three animals the self-stimulation activity was suckling" (Blass 1976, p. 151). Richter speculated that the suckling behavior originated in utero, was a source of comfort throughout the animals' development, and was expressed in a variety of mammals. In making this observation, he was neither observing nor reporting on the animal in the wild terrain of Panama. Instead, the animals were observed on front porches.

Richter's behavioral observations were in line with the earlier approaches to developmental observation reported by Lashley and Watson (1913), who described one or more animals over a period of weeks. Their work too was supported by Meyer.

BEHAVIORAL/NEUROLOGICAL STUDIES

STUDIES ON THE GRASP REFLEX

Richter's major study in Panama was a neurological examination of the effects of decerebration in the sloth on sensory motor rigidity (Richter and Bartemeier 1926).

Richter would acknowledge in his paper on the sloth:

> The experimental part of this work was done by Dr. Richter, with the aid and suggestions of Dr. George B. Wislocki, in Panama at the Institute for Research in Tropical America. Dr. Richter wishes to express his indebtedness to the Institute for the assistance and facilities offered for carrying on this and other work during the summer months of 1924 and 1925. Thanks are due especially to Mr. James Zetek, custodian of the laboratory, and to Dr. Ignanzio Molino, assistant custodian, for their tireless efforts in helping to procure the necessary materials and animals. The histological work was done in the Neurological Laboratory of the Phipps Clinic by Dr. Bartemeier. The work both in Panama and in Baltimore was greatly aided by the interest and encouragement of Dr. Adolf Meyer. (Blass 1976, p. 245)

Richter would study the neurological basis of behavior, and in particular the grasp reflex, for many years. He described his method for studying the grasp reflex in humans as follows:

> The technique of measuring the reflex was similar to that employed in the experiments on the new-born monkeys. The apparatus consisted of two round, parallel brass rods, 1/4 inch (0.6 cm.) in diameter and 5 inches (12.7 cm.) apart, firmly supported 2-1/2 feet (76.3 cm.) above a mattress on a small table. In order to give the infant a firm gripping surface, two short pieces of tight-fitting, thin rubber tubing were placed in the middle of the rods. The infant was held down by the experimenter, just beneath the parallel bars, while an assistant brought the palms of the hands into contact with the bars. As soon as the baby gave any indication of grasping, its body was lowered quickly and it was permitted to hang unsupported. The hanging time recorded with a stopwatch served to measure the strength of the reflex. This method, whereby the infant hangs by both hands rather than by one, has the advantage of eliminating considerable strain, but the hanging time does not seem to be any longer than when the entire weight is supported by one hand. (Richter 1934c, pp. 328–29)

Though Richter noted individual differences and cyclic daily patterns in the grasp reflex, he concluded that it was important for helping newborns cling to their mothers during the neonatal period. He also suggested that the grasp reflex appeared less prominent in humans than in monkeys (Richter 1931a). The method he used with monkeys was different from that used with human newborns, however, so his comparison was misleading. Nonetheless, Richter built on the common evolutionary theme that the grasp reflex was stronger in monkeys than in humans.

Richter chose the sloth for his study of the neural basis of the grasp reflex because the sloth spends most of its time hanging upside down from tree branches (Richter and Bartemeier 1926). Richter's paper described the two- and three-toed sloth (fig. 5.3).

For this study, Richter chose a decerebration method commonly in use at the time (e.g., Bazett and Penfield 1922) to decerebrate a number of sloths. He would later perform the same procedure on other species (e.g., cats, monkeys, beavers).

The decerebrated animal had to be tube-fed to keep it alive, and thermal regulation, like most bodily functions, was compromised. Richter, interested in the organization of posture and of the hanging reflex in particular, noted the compensatory responses that resulted from decerebration-induced motor rigidity. For example, in contrast to decerebration in the cat, which results in extensor rigidity, decerebration in the sloth resulted in flexor rigidity. This was because of the posture of the sloth, in contrast to that of the cat.

Thus Richter predicted, and found evidence, that decerebration leads to exaggerated activity in the antigravity muscles. The rigidity induced by decerebration results from a set of postural reflexes. Richter further noted that tactile stimulation to the head region of the sloth resulted in dissolution of the decerebration-induced flexor rigidity. Richter sought to understand the effects of the decerebration in order to understand the rigidity of limbs in brain-damaged humans. In the case of the sloth, however, decerebration revealed flexor rigidity. In other words, extension rigidity is really antigravity rigidity.

A particular issue with regard to the degree of decerebration-induced rigidity was the role played by the red nucleus (in the brain stem), which had been understood to be essential for posture flexibility. Richter and Bartemeier (1926) noted that their results were consistent with what others had found (e.g., Bazett and Penfield 1922); eleven sloths with transections at the level of the red nucleus showed diminished motor rigidity. The results Richter

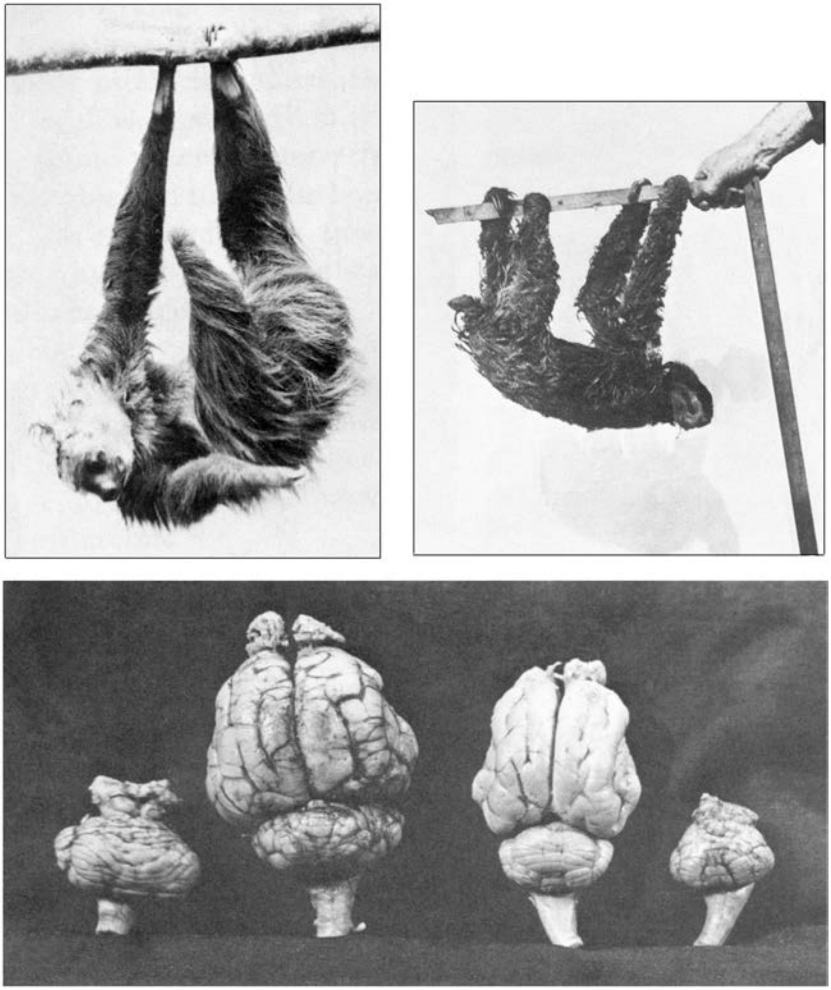

FIG. 5.3. *Top:* Hanging posture of the sloth: *left,* the two-toed sloth; *right,* the three-toed sloth. *Bottom:* The kinds of decerebration performed on each species. *Source:* Richter and Bartemeier 1926

reported also resembled those of Liddell and Sherrington (1924). Richter and Bartemeier (1926) found that the motor rigidity varied with the level of decerebration; if decerebration was above the red nucleus in the brain stem, the rigidity was less pronounced.

Richter was interested in the organization of movement and action. Under the influence of Sherrington, Head, Adrian, Denny-Brown, and other leading neuroscientists of his day, he set out to determine the organization of voluntary and reflex actions, of which the grasp reflex was one. His technique involved using the electromyogram (EMG) to study lesions of the central nervous system.

EMG tests showed that as part of the grasp reflex the flexor muscle of the forearm underwent from five to sixty-five contractions per second, with other wave forms between 180 and 250 per second (Richter 1927b). Richter then inferred that the impulse generators were linked to the wave forms he uncovered in the grasp reflex.

Richter investigated various forms of motor control over behavior, continuing his Jacksonian interest in determining the level of function responsible for the organization of motor control. For example, he looked at the role of motor cortex in decerebrated beavers (Langworthy and Richter 1938). In this electrophysiological study, the researchers recorded responsive neurons in the motor cortex of the beaver and found that stimulation of the frontal cortical areas resulted in movement. This study would again demonstrate one major effect of decerebration, namely, motor rigidity. In this case, the beaver's forelegs were frozen in rigidity.

Richter would continue work on the grasp reflex by observing its physiological and pharmacological basis in a simple study inducing catalepsy by bulbocapnine (Richter and Paterson 1931). It was well known that this agent reduces activity and facilitates catalepsy, causing a great reduction in what Richter and others called "spontaneous movement." He used the drug in macaques, measuring the time an animal could hang with one arm (its other arm and its feet were tied) until it fell to a net. He noted individual differences in response to the injected drug, but the underlying hypothesis was confirmed: the induced catalepsy enhanced the grasp reflex, and the younger the animal, the greater the effect of the drug on the duration of the grasp reflex. The hanging reflex disappeared in adulthood but could be brought on during this drug-induced cataleptic response.

Richter and Paterson looked at the effects on the grasp reflex of injecting various compounds into systemic circulation. In adult macaques, they experimented with over fifteen compounds. The authors found that several of the compounds elicited a grasp reflex in these adults. At high doses, many of these compounds were thought to suppress cerebral activation, especially that related to normal inhibitory input from the motor frontal cortex to the brain stem. In a further study, Richter and Hines showed that frontal lobe lesions in macaques could invoke exaggerated grasplike reflexes in adults (Richter and Hines 1932a).

THE USE OF ELECTRICAL RESISTANCE TO UNDERSTAND NEUROLOGICAL FUNCTION

The very first paper of which Richter was an author reported on a formal technique in which an equilateral triangle was used to predict the electrical patterns of the heart (Carter, Richter, and Greene 1919). The idea of measuring electrical activity was nothing new at this point in physiological inquiry, and Richter would make great use of these electrophysiological techniques for the next fifty years.

Richter next used the EMG to monitor the disruption of voluntary motor control. This avenue of research focused on the amplitude and expression of the EMG wave form in muscles of patients with a diverse range of neurological disorders (e.g., motor horn cell syringomyelia, muscular dystrophy). Richter noted that these diseases often resulted in a reduction or alteration of the wave forms.

In "New Methods of Obtaining Electromyogram and Electrocardiogram from the Intact Body," Richter described his method:

> To obtain records of the action currents from voluntary and reflex contractions of the muscles of the human body, we have devised an electrode that is considerably simpler in construction and manipulation than any of the others commonly employed today. It consists of a sheet of pure zinc about 1 inch square, held in contact with the skin by means of a paste made of kaolin and saturated zinc sulphate solution. This paste alone is sufficient to hold the electrode in place on almost any part of the body; where there is much violent movement of muscles, a large rubber band may also be applied. This electrode has the following advantages: 1) it is nonpolarizable; 2) it is quickly and easily prepared; 3) it can be attached over any part of the body, however irregular and inaccessible to other electrodes, and 4) it makes an intimate, moist contact with the skin without producing any irritation or injury even when left in place for several hours. (Richter 1926a, p. 1300)

Richter envisioned the measurement of skin resistance as a basic, broad-based clinical and research tool. He used this method early in his career to measure electrical resistance in skin during sleep (Richter 1926a). At this time, the study of sleep and biological rhythmicity were already a prominent part of Richter's neurological research program. He would attach electrodes to the hand or to other parts of the body, depending on the experiment. In one experiment characterizing the skin resistance of subjects (both humans and macaques) during sleep, he showed that the depth of sleep patterns was correlated with skin resistance in, for instance, the palms of the hands; as the individual began to wake up, the resistance increased.

PSYCHOGALVANIC REFLEXES AND THE AUTONOMIC NERVOUS SYSTEM

Richter's instrumentalist nature again took form in his adaptation of a new tool to measure skin resistance. Meyer had purchased a galvanometer, but the instrument was not being used. Meyer did not like waste. Richter knew that the galvanometer could measure electrical conductivity. He thought surely he could find some use for it, and he did (fig. 5.4).

Interest in measuring skin conductance dated back to the students of Fechner, the father of psychophysics (Richter 1926a). Richter first used the galvanometer to measure skin resistance, which he inferred was an index of the activation of sweat glands in the skin. He then used the device to understand neurological innervations, to detect clinical syndromes, and to determine normal regulatory mechanisms.

Following up on some of the observations Head and his colleagues made of World War I soldiers, Richter sought to reveal the mechanisms of the neural control of sweating. Skin responsiveness and sweating as measures of spinal damage figured significantly in his work over the next two decades, particularly during World War II. The effect of spinal cord transection on the skin galvanic response would lead to an important experimental venture, the rudiments of which were already present in the first part of Richter's neurological investigations (Richter and Shaw 1930).

In one experiment, Richter induced sweating by the simple method of the hot-air bath or by injections of pilocarpine. He also injected atropine into subjects' adrenal glands. He measured sweating from both hands over several months in a patient who had what Richter thought was a unilateral lesion of the sympathetic nervous system (the clinical diagnosis included small pupils and greater-than-normal skin resistance). Measuring what he called the "psychogalvanic reflex" and electrical skin resistance under a variety of conditions, Richter compared the normal side of the body with the damaged side. Atropine produced no effect on the damaged side, but the psychogalvanic reflex was eliminated or altered on the side with damage. Richter took this as proof of the role of the sympathetic nervous system in this response (Richter 1927c).

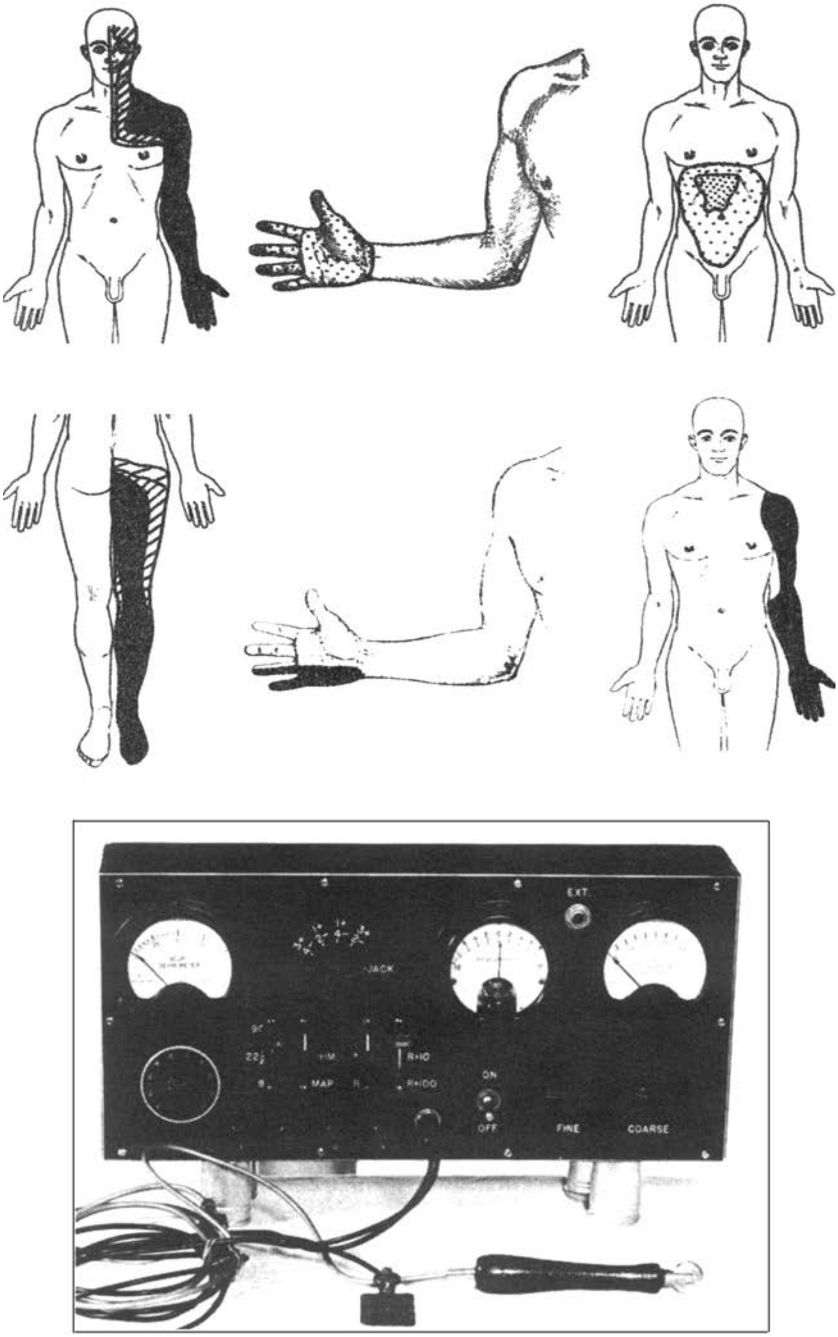

FIG. 5.4. *Top*: Skin conductance as a measure of nerve injury. *Bottom*: A dermometer. *Source:* Richter 1947; Riley and Richter 1975

Richter and his neurological colleagues almost always provided a fairly detailed depiction of the patients in their experiments. Each pathological group usually consisted of one or two subjects. The researchers' methods resembled a clinical case study more than a true experimental design, and the results were typically presented as case vignettes with an experimental bent.

In further studies, Richter continued to look at the relationship between neuromuscular damage and various reflexes. This research emphasized the relationship between the brain and peripheral systemic regulation. Richter and Ford used the EMG to determine wave forms and their link to muscular activity. They found a reduction in primary wave forms among patients with hypothesized lesions of the motor horn, syringomyelia, muscular atrophy, and poliomyelitis, although the amplitude was still large despite the atrophied musculature (Richter and Ford 1928).

In an experiment with macaques and cats, Richter cut various nerves to determine the effect on skin resistance. For example, he cut the somatic nerves, leaving intact what he thought was the sympathetic system in three monkeys and five cats. This resulted in changes in skin resistance. In another experiment, Richter surgically removed the abdominal sympathetic nervous system, leaving the somatic nerves intact (Richter 1929b). Because he provided no histologic data, it is difficult to determine the accuracy of his procedures. He did report that he performed a histological examination, however. The effect of the sympathectomy was to initiate an increase in conductivity in the porous regions of the skin, which then gradually decreased over time. Richter articulated the view that the sympathetic ganglia regulated skin conductivity and that reciprocal innervations of sympathetic and parasympathetic systems regulated systemic physiological end-organ systems.

Richter went on to examine the relationship between sleep and electrical skin resistance, again looking at the hand. He found that average skin resistance was higher in patients with muscular pathology than in normal control subjects and that there was wider variation in resistance in patients with damaged spinal cords. Comparing these results with those from several other clinically pathological states, such as schizophrenic stupor, he found his results to be most similar to those in narcoleptic patients. He speculated that the disruption of sleep patterns in narcolepsy might reflect an "encephalitic process" (Richter 1929c).

The sympathetic nervous system and the recovery response would be a constant neurological interest of Richter's (Tower and Richter 1932a, 1932b).

Richter and his colleagues examined patient populations with sympathetic damage at the Johns Hopkins Hospital (Richter and Levine 1937). They performed cervical sympathectomies at different levels among four patient populations (those with migraine, neuralgia, Hirschsprung disease, and Raynaud disease). In each case, after the sympathectomy, skin resistance was increased.

CLINICAL ASSESSMENT OF WAR WOUNDS IN WORLD WAR II SOLDIERS

During World War II, Richter found himself with a useful technique for monitoring neurological damage in soldiers. As noted earlier, he had inherited the galvanometer from Meyer, and now he developed and expanded its use, devising a smaller version of this tool that would facilitate his collaboration with several colleagues in the field of neurology (e.g., Tower, Levine, and Katz) and allow him to embark on new neurological studies.

Richter's laboratory state of mind led him to take advantage of an opportunity to use his new instrument with World War II soldiers. Richter, the scavenger-scientist, always made the most of whatever was available, inventing simple tools and using simple measuring techniques to great effect. He epitomized the tenacity of the scientist by continuing to apply and extend his methods to determine their full usefulness.

Richter noted early on that some forms of bodily damage altered skin conductance, and he continued to develop methods to determine the relationship between sensory processing and sympathetic damage (Richter 1926a). One common theme in this research was the link between high resistance in electrical conductivity and diminished sweat (Richter and Woodruff 1941).

Having developed a small, portable galvanometer they called a "dermometer," Richter and his colleagues measured skin resistance (Whelan and Richter 1943; Richter 1946b) and extended the dermometer's use to determine peripheral bodily damage (Richter and Whelan 1949). Identifying areas in the hand and foot with differences in electrical skin resistance, Richter, Woodruff, and Eaton (1943) further explored the link between skin resistance and sweating.

In the *Journal of the American Medical Association* at the height of World War II, Richter and Katz, in their most publicized statement, described their line of research as having three primary goals: (1) to determine anatomically the areas innervated by peripheral nerves, (2) to discern damaged areas, and (3) to note neural regeneration and recovery. In one experiment, they found increased electrical skin resistance after injections of procaine were used to block the nerve in question. They asserted: "The simplicity, accuracy and speed of the method make it useful for the exact examination of all types of peripheral nerve lesions" (Richter and Katz 1943, p. 651).

Further studies by Richter and his colleagues in the immediate postwar period further helped to ascertain the mechanisms of sweating and skin resistance. The researchers labored under the influence of Langley and Sherrington in determining which sympathetic fibers were important for the response. Richter collaborated on studies in monkeys (Bruesch and Richter 1946) and humans (Richter and Otenasek 1946), looking at different regions of the body under various experimental conditions after different kinds of sympathectomies. The results, on the whole, tended to reflect greater electrical skin resistance in patients with denervated regions.

Richter's work in this area was supported by colleagues, mostly clinical medical doctors (e.g., Maurice Levine). They hoped he could parlay the use of the galvanic instrument into a broadly useful clinical instrument, one that could be supported by the military in the war effort (Bump 1996).

So it was that during the war Richter and his colleagues continued to look at a number of clinical populations with the portable dermometer. He continued to note great variations in skin resistance in the populations he studied (Richter and Otenasek 1946). Richter and his students and colleagues were on the offensive to persuade the military of the usefulness of his technique to detect peripheral pathology (Bump 1996). Richter would, in fact, effectively promote his instruments and his methodology in some cases; for example, Surling at Walter Reed Army Medical Center was persuaded of the clinical utility of the tool. Although Richter secured military contracts for his research, military physicians were divided in their opinions of the method. With variation in results and diminished prospects for its utility as a general tool, use of the dermometer began to wane (Bump 1996).

Nonetheless, Richter and his colleagues continued to publish papers on the use of electrical skin resistance as a measure of peripheral neurological damage. Into the 1960s, he would think of the skin resistance method as a way to detect pathology (see Fries and Richter 1964).

TENACITY

Richter always looked for ways to extend the use of a method or tool to other applications and areas of study. In the early 1930s he extended his study of electrical skin resistance to the study of mental illness. Looking at electrical resistance of the skin "in catatonic and depressive stupors and similar conditions . . . to determine whether it is possible to separate these conditions on the basis of skin resistance," Richter inquired into "experimental catatonia" (Meyer files, Chesney Archives). He became interested in "measuring the postural changes characteristic of catatonia," using this measure to understand "the grasping reflex," and using high and low electrical resistance to discern catatonia's neurological basis in sympathetic and peripheral damage (Richter 1946b; Richter, Woodruff, and Eaton 1943).

Some fifty years after his first publication on the use of the electrode to measure skin resistance, and with long periods in which this experimental issue was not at the forefront of his laboratory or clinical concerns, Richter returned to the topic. Never one to leave something behind, he summarized in a paper what he took to be the underlying principles of his technique:

> The neurological and physiological principles underlying use of this method were worked out 1924–1934 on cats, monkeys, and human subjects: 1. Passage of a direct electrical current through the body is localized practically entirely in the skin. 2. Electrical skin resistance reflects activity of the sweat glands, but not of actual amounts of sweat. 3. Heat lowers the electrical resistance of the skin; cold increases it. 4. Sectioning of peripheral nerves increases skin resis-tance; irritation of peripheral nerves decreases it. 5. Sympathectomy increases skin resistance; hyperactivity of sympathetic nerves decreases it. 6. Depression increases; emotional excitement increases it. (Riley and Richter 1975, pp. 59–60)

In the 1970s, Richter was still applying this method, in collaboration with clinicians, to determine whether skin electrical resistance was associated with pain in the neck and upper extremities (Richter 1972; Riley and Richter 1975).

CONCLUSION

Richter was an adventurous spirit; he grew up in the outdoors. It was not surprising that early in his career he would make a sojourn to Central America. Following the naturalists of the nineteenth and early twentieth centuries, he embarked on a brief excursion to study animals near their natural habitat. He still investigated with a laboratory state of mind; he just did it closer to, and sometimes in, the animals' natural environment.

The influence of Theodore Roosevelt pervaded the Panama Canal, which he was responsible for having built. F. M. Chapman, a leading figure from the American Museum of Natural History who spent time on Barro Colorado

Island, commented, “Always in the background stands the figure of Theodore Roosevelt, who whether on the Zone or in the White House, was the inspiring, understanding leader” (Chapman 1938, p. 4). Roosevelt was a naturalist, founder of the Museum of Natural History, and a conservationist. He revered nature and science and brought great projects to fruition. Perhaps Richter embraced the idea of President Roosevelt, a rugged individual with an appreciation of natural resources, a can-do attitude, a lot of muscle, and little fear.

Richter inherited his interest in the grasp reflex from Watson and studied it primarily to understand the neurology and the pharmacology that made it possible. Richter remained rooted in a neurological tradition in which evolution permeated the conception of the brain. The hierarchical conception of the nervous system was, and still is, a common intellectual framework for understanding the brain. Richter inherited this perspective and used it creatively in his own investigations. This research also demonstrated his long-term focus on core issues and the development and pragmatic use of research tools.

With increasing age and prestige, Richter never seemed to discard the old tools but continued to expand their application. Though not atheoretical, Richter engaged first and foremost with experiments, inventions, and the practical meanings of science. Richter retained pervasive interests in the neurological techniques and data he generated and in the methods he used. As in the case of the clinical dermometer, he constantly returned to and revised his methods.