NATIONAL ACADEMY OF SCIENCES

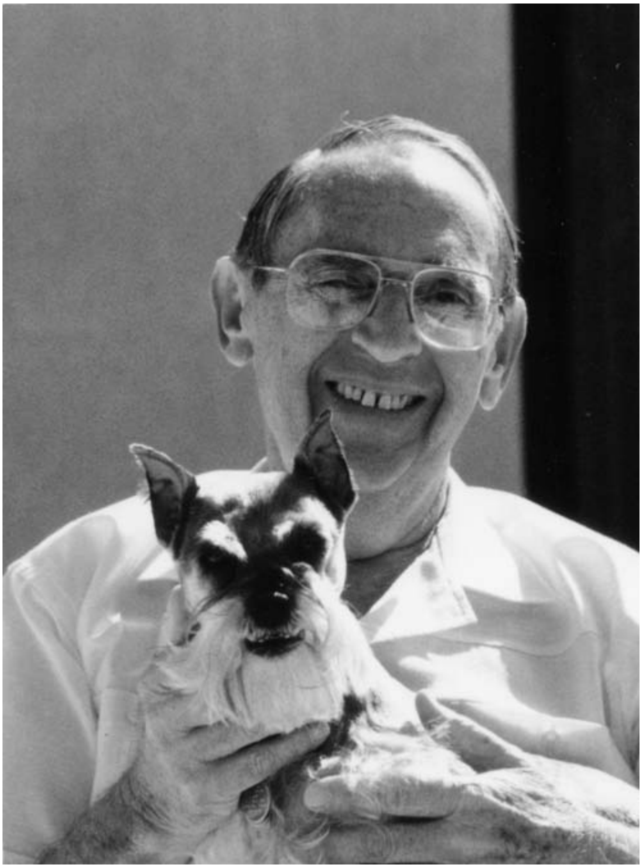
JOHN I. LACEY
1915–2004

A Biographical Memoir by

J. RICHARD JENNINGS
AND
MICHAEL G. H. COLES

Biographical Memoirs, VOLUME 88

PUBLISHED 2006
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C.



John I. Lacey

JOHN I. LACEY

April 11, 1915—June 27, 2004

BY J. RICHARD JENNINGS AND
MICHAEL G. H. COLES

FOR APPROXIMATELY 30 YEARS John I. Lacey defined the field of psychophysiology. His pioneering work relating physiological measures in humans to their psychological function subsequently influenced the fields of behavioral medicine and neuroscience. He died on June 27, 2004, at age 89. His wife and coworker, Beatrice C. Lacey, had died earlier, on November 9, 2000. They retired from academic roles and their collaborative research in the early 1980s. Both worked for over 30 years at Fels Research Institute in Yellow Springs, Ohio, and continued to live there prior to retiring to Rancho Mirage, California.

We first encountered John Lacey when he was in the middle of his career. At that time John and Bea's research was becoming a dominant force in psychophysiology, and we were both drawn to them because of their enthusiasm and because of the novelty of their ideas. In their early careers the Laceys adopted the contemporary view, embodied in general arousal theory, that the reticular activating system was the neural substrate of a central arousal system. Central arousal, as a regulator of both neural and psychological function, was then viewed as a key concept for both psychology and neuroscience. However, empirical data collected by the Laceys failed to demonstrate the generality of arousal across brain and bodily systems. Furthermore, their data suggested that homeostatic regulatory systems of the body appeared to influence the brain. Brain and body were engaged in a two-way communication that had implications for human performance.

The excitement of this period did not arise by chance but was a result of a combination of elements that ultimately defined the field of psychophysiology. The field was defined by an alliance of psychology, physiology, medicine, and engineering. The inclusion of medicine and engineering requires some explanation. The Laceys' work on individual and situational differences in autonomic response patterns opened applications to medicine. Why do some individuals become ill and others not when exposed to similar pathogens and situations? Why are some individuals more or less resilient to the effects of psychological stress? And why does the pattern of responsivity among different autonomic systems vary as a function of the situation? This work on what they called "individual response stereotypy" and "situational stereotypy" provided an alternative scientific basis for the medical field of psychosomatic medicine, which was becoming disillusioned with strictly psychoanalytic approaches. The assessment of human physiological responses also required engineering. Sensitive biological amplifiers that were resistant to electrical interference were not readily available. Instruments that transduced the biological signals of relevance were also not routinely manufactured. Investigators who wished to study sweating palms due to stress typically built their own electrodes and bridge circuits to derive the galvanic skin response measures.

John fit the field well with interests in all four members of the alliance. His biographers (*American Psychologist,* 1977, 1985) tell us of his initial study of engineering at Cornell and that his reading during recovery from a fencing team injury might have turned John away from a career in engineering and toward biology and psychology. His Cornell degree trained him thoroughly in experimental psychology, but World War II added further skills. He became familiar with research on individual differences and associated statistical techniques in the Army Air Force's Psychological Testing and Classification Program. All of these skills (many of which Bea shared) made John an ideal choice for research investigator at Fels. They built a laboratory at Fels using his engineering skills, and started a research program designed to examine individual differences and normal development using carefully designed experiments.

John's early work, which was continued during the initial years at the Fels Institute, focused on defining meaningful characteristics of individuals that would then predict subsequent health and performance. Conceptually many investigators at the time thought it likely that individuals would differ in peripheral physiological levels and responses; these differences, if consistent over time, would then define a psychophysiological personality type. Later commentators noted that this seemed to harken back to medieval classifications based on different bodily humors, such as the *sangwyn franklin* and the *colerik reve* in Chaucer's *Canterbury Tales.* John and Bea's approach was hardly medieval, however. Armed with their knowledge of statistics and methodology growing from their World War II experience, they set out to determine empirically whether individuals would show consistent levels of activity in physiological systems controlled by the autonomic nervous system and whether they would respond consistently in these systems to different stimuli. If reliable psychophysiological types could be identified, then the origins and development of these types could be studied, their sensitivity to life experiences assessed, and the relationship to both psychiatric and physical disease examined. Difficult problems had to be overcome first. Each of the physiological measures studied had different characteristics; heart rate was assessed as beats per minute, palm sweating as electrical resistance, brain waves as voltage changes. The Laceys (e.g., Lacey and Lacey, 1962) developed a method for a combining measure based on the mean and variability of the measure.

In the case of responses to stimuli the Laceys addressed another issue. The amplitude of the response to a stimulus frequently appeared to depend on the level of activity in the measure just prior to stimulation. This correlation between initial level and response amplitude had to be considered if responsivity was to be isolated. They introduced a regression approach to this problem, variants of which are still being employed. Using their methods, the Laceys were able to show that autonomic patterns were to some degree a consistent characteristic of an individual. Their work also showed them that the nature of the stimulus as well as individual characteristics determined the exact pattern of change across a set of autonomically controlled physiological responses. The stage was then set to see if these autonomic patterns characterizing individuals related to other individual characteristics, such as personality types, motivational styles, or proneness to disease. For example, if a person was characterized by strong blood pressure responses to a psychological challenge, would that person be more likely to develop hypertension than a person responding primarily with sweaty palms? The contemporary field of behavioral medicine is finding support for this last conjecture in that cardiovascular reactivity now appears to be a risk factor for hypertension and coronary heart disease (e.g., Schneiderman et al., 2005; Jennings et al., 2004). The notion of stereotyped responses to situations has also been incorporated into behavioral medicine. Using ambulatory physiological and behavioral recordings, investigators now attempt to determine whether individuals reactive to laboratory stressors do or do not encounter stressful situations that alter their physiology during their normal work day. Presumably, risk for cardiovascular disease will be greatest for those with the combination of an environment with situations that elicit cardiovascular reactivity and an individual tendency to show large cardiovascular responses.

Although their early work had substantial influence on the fields we now term behavioral medicine and psychosomatic medicine, the careers of the Laceys were taken in a somewhat different direction by their testing of the concept of general arousal. Physiological investigations, most particularly of the reticular activating system of the brain, had suggested that daily events and personal characteristics led to a level of activity in the brainstem that then had critical modulating influences on the rest of the brain and thus on behavior. These central effects were presumed to be mirrored rather directly in neural outflow within the autonomic nervous system, known also to have control centers within the brain stem. Levels of arousal assessed from autonomically controlled variables would presumably predict an individual's affective state and performance capabilities. The concept of general arousal suggested that a degree of activation would be observed to be consistent across output systems—creating a simpler theory of psychophysiology type than envisaged in the Laceys' earlier work. The Laceys set out to define general arousal given that their approach and measures were so suitable to this then-popular new concept. However, the concept of general arousal was quickly challenged by the Laceys' results. They developed an innovative scale in which different situations were used to elicit responses in a variety of autonomic systems measured concurrently. The results failed to show general arousal. There were dissociations among different autonomic measures such that different person-environment interactions induced different patterns of physiological response. One of the most striking findings was that heart rate decreased during active attention to environmental stimuli.

Their research questioning general arousal theory coincided with a number of related developments that enhanced the value of their empirical critique and the development of their alternative view. Questions about the necessity of the reticular activating system for cortical function were being raised in the physiological psychology and neuroscience communities. The general arousal concept did not fit neatly with the results from new research with such measures as the electroencephalogram and cortical evoked potential and with theoretical approaches to the physiology of cognition and emotion. More specifically related to the Laceys' work, Sokolov's (1958) view that a panoply of physiological responses were evoked while orienting to novel and significant events was becoming well known in the then-Western-World. Graham and Clifton (1966) published an influential article describing how heart rate slowed during orienting. We, in particular, were drawn to the idea that shifts in information processing from orienting or attention to internal processing could be detected in the direction of brief heart rate response to events (e.g., Coles and Duncan-Johnson, 1975; Jennings and Hall, 1980). In short, the Laceys led a change in thinking away from a solely arousal view to a view that both central and peripheral physiological responses could be meaningfully related to cognition as well as affect.

The Laceys moved forward by developing a bold neurophysiological theory for their results and creating precise experimental paradigms to study the patterning of autonomic responses during information processing. Their theory suggested that the activation of the baroreceptors reduced cortical integration of perceptual-motor events such that baroreceptor activation would interfere with performance, and deactivation (such as when heart rate slowed) would facilitate performance. Characteristically, this hypothesis was based on a combination of results from the neurophysiological literature and a detailed examination of a series of experiments from their Fels laboratory. Baroreceptors, which are buried in the wall of arteries in the carotid sinus and aortic arch, respond to the rate of change of pressure by sending signals with this information to the brain. As pressure rises in the arteries during the heartbeat, volleys of afferent information about pressure are sent to the brain. The neurophysiological literature suggested that enhanced signals from the baroreceptors reduced the amplitude of neural responses in the cortex. The results of the Laceys suggested that perceptual motor performance in humans was less efficient when the baroreceptors were most active during cardiac contraction. Their hypothesis met with variable empirical success; only some studies were able to replicate the influence of baroreceptor discharge on performance. On the positive side it engendered a hypothesis by others (e.g., Dworkin et al., 1979) that suggested that high blood pressure might be learned and maintained by the pain reduction reinforcement initiated by blood pressure increases (and consequent baroreceptor stimulation). The interrelationships of pain, blood pressure, hypertensions, and baroreceptor activation continues to be actively investigated. More importantly, by proposing an influence on sensory information processing by the body on the brain, the Laceys provoked a reconsideration of the importance of interoceptive information for our basic biology. Indeed, the vagal branch of the autonomic nervous system, a key component in the Laceys' thinking, is now being actively investigated because of its central role in carrying information about the body to the brain.

The Lacey hypothesis also brought a controversy that may not have been pleasant for the participants, but which nevertheless altered the field of psychophysiology. At a meeting in Denver in 1967 a former postdoctoral student of John Lacey, Paul Obrist, proposed what he considered an alternative formulation to explain why heart rate slowed during attention to environmental events. Based on animal conditioning experiments Obrist (1976) suggested that peripheral motor inhibition was the cause of the heart rate slowing, due to the intrinsic coupling between somatic and cardiovascular systems. He considered this a basic and simple biological explanation and initiated a heated discussion by suggesting that the Lacey hypothesis was less biological. Obrist elaborated on his ideas of the importance of cardiosomatic coupling and initiated a research program that ended up addressing the causes for hypertension and, as such, influencing the emerging field of behavioral medicine. The Laceys pursued their neurophysiological views, with both the Laceys and Obrist attracting adherents who ended up discussing the controversy more than the primary antagonists. The empirical data suggested that aspects of both their views were correct. A partial reconciliation of the individuals occurred at a Festschrift honoring the Laceys in 1982 (Coles et al., 1984).

John enjoyed meetings and interactions with his colleagues. He vacillated, however, from being totally engrossed and asking piercing questions during presentations to skipping sessions so he could tell stories to colleagues in the hallways. He reputedly advocated certain varieties of bass plugs—even to the extent once of having a number of colleagues pass one along under the table at a society banquet.

Over the course of his career John became increasingly involved in a number of scientific societies. He was active in the American Psychological Association, and equally active in societies related to psychophysiology, such as the American Psychosomatic Society and, of course, the Society for Psychophysiological Research. He played an important role in the formation of the now burgeoning Society for Neuroscience. He attempted to promote a continued interest in human as well as animal model work within the neuroscience community. Undoubtedly, he would be pleased by the reentry of human work into the Society for Neuroscience occasioned by the development of neuroimaging. He was also an active participant on several National Institute of Mental Health committees injecting a psychophysiological approach into their deliberations.

John was elected to the National Academy of Sciences in 1980. Prior to that, Beatrice and John together received the 1976 Distinguished Scientific Contribution Award from the American Psychological Association. A portion of the citation for that award is worth repeating:

> Arguing the inadequacy of traditional views of a unitary activational system, they have described a system with central feedback and dissociable subsystems. With superb technology and meticulous experiments, they have demonstrated that complex patterns of autonomic response are a measurable, characteristic of individuals, stable across years, and predictive of individual-environment transactions.

The interested reader is further referred to the thorough biography of Beatrice and John that follows this citation (*American Psychologist,* 1977). A similar (but at points, tongue in cheek) tribute to the Laceys also accompanied the earlier Distinguished Contribution to Psychophysiology Award from the Society of Psychophysiological Research (Stern, 1971). Beatrice and John also received the Psychological Science Gold Medal Award from the American Psychological Foundation in 1985. Again the citation and biography related to this award are informative (*American Psychologist,* 1985). Just prior to this, in 1982, Beatrice and John were honored at a Festschrift during which a dozen colleagues who had been strongly influenced by their work presented papers (Coles et al., 1984).

Despite an intention to retire, John was busy learning new techniques in his later career. In a visit to Yellow Springs around 1980 to talk to Bea and John about cardiac measures, we heard instead about John's new work with cortical evoked potentials. Few laboratories were using this measure, but John developed it in his laboratory at Fels based on information gained from visits in the laboratories of Grey W. Walter, Vahe E. Amassian, Karl H. Pribram, and Horace W. Magoun (during a Commonwealth Fund Fellowship). This work, published in 1980 together with Bea, described the concordance between cardiac and brain responses. Later during our visit, John entered his animal laboratory and demonstrated the success of an implanted device that stimulated the baroreceptors with varying acceleration to peak pressure. He planned to evaluate the precise sensitivity of the baroreceptors to this stimulation. At the end of the visit he did speak of retirement but only to say that computers had begun to fascinate him and that he wanted to build one from component parts.

Bea and John retired gracefully into private lives, attending to the families of their two children. They had visited the Palm Springs area of California at earlier times in their lives and became more attracted to it during retirement. John particularly was drawn to the warmth and the scenery of mountains and desert. John did woodworking and Bea gardened and they both enjoyed listening to jazz. Misfortune came soon, however. Two years after buying a home in Rancho Mirage, Bea became ill and was unable to continue to enjoy the home. After a period in special care, she died in 2000. Given the closeness of the couple, John's survival was a concern to all their friends and family. He proved resilient, however—even learning some Spanish to speak with a Guatemalan housekeeper that he employed. This resilience was challenged beyond measure, however, by the death of their daughter, Carolyn, in 2002 from leukemia. John also faced physical struggles with heart failure and then a broken foot. This occasioned a visit by his son, Robert, in 2004. The visit went well, but a few weeks later Robert died unexpectedly from a myocardial infarction. Four months later John passed on after tragically surviving his spouse and both children. He did leave behind, however, two successful families with grandchildren. Both his children's spouses, Karen Lacey and David Turner, spoke fondly of Bea and John and appreciated the chance to help create this memoir that would let their children appreciate the legacy of their grandparents.

The passing of John I. Lacey reminds us again of both how our science is built on conceptual and methodological developments and how these developments become such a part of scientific training and of the empirical corpus that their origins are forgotten. John (and Beatrice) established instruments, statistical techniques, integrative alliances, and basic concepts that can be identified today in the fields of psychophysiology, behavioral medicine, neuroscience, and psychology. The work truly turned us toward understanding the two-way communication between body and brain. This communication is now being emphasized in areas as seemingly discrepant as immunological theories of the cause of heart disease and the experience of different emotional qualities. We have lost one of our key integrative scientists, but his legacy continues to enrich us.

REFERENCES

American Psychologist. 1977. Distinguished scientific contribution awards for 1976. *Am. Psychol.* 32:54-59.

American Psychologist. 1985. American Psychological Foundation awards for 1985. *Am. Psychol.* 41:409-411.

Coles, M. G. H., and C. C. Duncan-Johnson. 1975. Cardiac activity and information processing: The effects of stimulus significance, and detection and response requirements. *J. Exp. Psychol. Human* 1(4):418-428.

Coles, M. G. H., J. R. Jennings, and J. A. Stern. 1984. *Psychophysiological Perspectives: Festschrift for Beatrice and John Lacey.* New York: Van Nostrand Reinhold.

Dworkin, B. R., R. J. Filewich, N. E. Miller, N. Craigmyle, and T. G. Pickering. 1979. Baroreceptor activation reduces reactivity to noxious stimulation: Implications for hypertension. *Science* 205:1299-1301.

Graham, F. K., and R. K. Clifton. 1966. Heart-rate change as a component of the orienting response. *Psychol. Bull.* 65:305-320.

Jennings, J. R., and S. W. Hall Jr. 1980. Recall, recognition, and rate: Memory and the heart. *Psychophysiology* 17:37-47.

Jennings J. R., T. W. Kamarck, S. A. Everson-Rose, G. A. Kaplan, S. B. Manuck, and J. T. Salonen. 2004. Exaggerated blood pressure responses during mental stress are prospectively related to enhanced carotid atherosclerosis in middle-aged Finnish men. *Circulation* 110(15):2198-2203.

Lacey, B. C., and J. I. Lacey. 1978. Two-way communication between the heart and the brain. Significance of time within the cardiac cycle. Am. Psychol. *33:99-113.*

Lacey, B. C., and J. I. Lacey. 1980. Cognitive modulation in time-dependent primary bradycardia. *Psychophysiology* 17:209-221.

Lacey, J. I., and B. C. Lacey. 1962. The law of initial value in the longitudinal study of autonomic constitution: Reproducibility of autonomic responses and response patterns over a four-year interval. *Ann. N. Y. Acad. Sci.* 98(4):1257-1290.

Obrist, P. A. 1976. The cardiovascular-behavioral interaction: As it appears today. *Psychophysiology* 13:95-107.

Schneiderman, N., G. Ironson, and S. D. Siegel. 2005. Stress and health: Psychological, behavioral, and biological determinants. Annu. Rev. Clin. Psychol. *1:607-628.*

Sokolov, E. N. 1958. *Perception and the Conditioned Reflex*. Oxford, U.K.: Publishing House, Moscow University.

Stern, J. A. 1971. Award presentation to J. I. and B. C. Lacey. *Psychophysiology* 8:241-242.

SELECTED BIBLIOGRAPHY

1939

With K. M. Dallenbach. Minor studies from the Psychological Laboratory of Cornell University. LXXXVIII. Acquisition by children of the cause-effect relationship. *Am. J. Psychol.* 52:103-110.

1941

Changes in cardiac and respiratory activity in states of frustration. *Psychol. Bull.* 38:581-582.

With B. C. Lacey and K. M. Dallenbach. Areal and temporal variations in pain sensitivity. *Am. J. Psychol.* 54:413-417.

1947

Sex differences in somatic reactions to stress. *Am. Psychol. 2:*343.

1948

Individual differences in somatic response patterns. *Am. Psychol.* 3:254-255.

1949

Consistency of patterns of somatic response to stress. *Am. Psychol.* 4:232-233.

1950

Individual differences in somatic response patterns. *J. Comp. Physiol. Psychol.* 43:338-350.

1952

With D. E. Bateman and R. Van Lehn. Autonomic response specificity and Rorschach color responses. *Psychosom. Med.* 14:256-260.

With R. Van Lehn. Differential emphasis in somatic response to stress. *Psychosom. Med.* 14:71-81.

1953

With D. E. Bateman and R. Van Lehn. Autonomic response specificity: An experimental study. *Psychosom. Med.* 15:71-82.

1954

With R. L. Smith. Conditioning and generalization of unconscious anxiety. *Science* 120:1045-1052.

1955

With R. L. Smith and A. Green. Use of conditioned autonomic responses in the study of anxiety. *Psychosom. Med.* 17:208-217.

Conditioned autonomic responses in the experimental study of anxiety. *Acta Psychol.* 11:137-138.

1958

With B. C. Lacey. The relationship of resting autonomic activity to motor impulsivity. *Res. Publ. Assoc. Res. N.* 36:144-209.

With B. C. Lacey. Verification and extension of the principle of autonomic response-stereotypy. *Am. J. Psychol.* 71:50-73.

1959

Psychophysiological approaches to the evaluation of psychotherapeutic process and outcome. In *Research in Psychotherapy,* eds. E. A. Rubinstein and M. B. Parloff, pp. 160-208. Washington, D.C.: American Psychological Association.

1962

With B. C. Lacey. The law of initial value in the longitudinal study of autonomic constitution: Reproducibility of autonomic responses and response patterns over a four-year interval. *Ann. N. Y. Acad. Sci.* 98(4):1257-1290, 1322-1326.

1969

Proceedings of the seventy-seventh annual meeting of the American Psychological Association, August 31-September 4, 1969, Washington, D.C. *Am. Psychol.* 24(12):1119-1172.

1974

With B. C. Lacey. On heart rate responses and behavior: A reply to Elliott. *J. Pers. Soc. Psychol.* 30(1):1-18.

1976

Psychophysiology of the autonomic nervous system. *Cat. Sel. Doc. Psychol.* 69:2.

1977

With B. C. Lacey. Change in heart period: A function of sensorimotor event timing within the cardiac cycle. *Physiol. Psychol.* 5(3):83-93.

1978

With B. C. Lacey. Two-way communication between the heart and the brain: Significance of time within the cardiac cycle. *Am. Psychol.* 33(2):99-113.

1979

Somatopsychic effects of interoception. In *Research in the Psychobiology of Human Behavior,* eds. E. Meyer III and J. V. Brady, pp. 59-73. Baltimore: Johns Hopkins University Press.

1980

With B. C. Lacey. Cognitive modulation of time-dependent primary bradycardia. *Psychophysiology* 317:209-221.

1985

The visceral systems in psychology. In *A Century of Psychology as Science*, eds. S. Koch and D. E. Leary, pp. 721-736. Washington, D.C.: American Psychological Association.