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Sperry, Roger

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0457.001 Roger Wolcott Sperry (1913–1994), who received a Nobel Prize for Physiology and Medicine in 1981 for his research on brain science, devoted his scientific work to a search for the neural circuits of action and consciousness. From an undergraduate psychology project at Oberlin College with R. H. Stetson (an expert on timing in speech and music), to appointment as Hixon Professor of Psychobiology at the California Institute of Technology and fame as a neuropsychologist who discovered new ways to reveal the mental functions of the cerebral hemispheres, Sperry was a meticulous experimenter on the growth and functions of neural systems. A quiet-spoken, taciturn man, he seemed to have the skill of a magician in making basic laws of brain activity apparent in a new form. He was also a plain-speaking thinker about the power of consciousness in guiding what we do, and he wrote passionately about the nature of human values. As a young man he had accepted the doctrine of the philosopher John Dewey that thought is a form of conduct, with corresponding responsibilities, and this belief remained with him throughout his life.

0457.002 Sperry's first experiment, the results of which were published when he was 26 years old, used electromyography (recording the electrical signals of contracting muscles) to demonstrate the infinitely varied yet coherent neural instructions for a simple human movement, namely making a circle in the air in different planes with an extended arm. The results led to a concept of the 'motor image', which anticipated the classical work on the 'Coordination and Regulation of Movement' of the Russian physiologist Nicholas Bernstein, and to the following statement of Sperry's concept of the role of movement in generation of awareness:

An objective psychologist, hoping to get at the physiological side of behaviour, is apt to plunge immediately into neurology, trying to correlate brain activity with modes of experience. The result in many cases only accentuates the gap between the total experience as studied by the psychologist and neural activity as analysed by the neurologist. But the experience of the organism is integrated, organised, and has its meaning in terms of coordinated movement. (Sperry, 1939, p. 295)

A contemporary behavioral scientist may feel that this text ought to be displayed as a caution in all experimental psychology laboratories and functional magnetic resonance imaging (fMRI) units, where immobile subjects ponder prefabricated thoughts and are excited to have named emotions.

Sperry's graduate research, undertaken with Paul Weiss at Chicago, initiated a series of experiments on plasticity of nerve-muscle systems and regrowth of motor nerves in rats and monkeys. Subsequently, his studies of the patterning of connections from eye to brain and from brain to muscles in fish and amphibia proved that chemical markers of some kind were guiding nerve axons to form the right connections. Experiments on the growth of eye-to-brain connections in fish and newts after surgical rotation of the eyes made Sperry world famous before he was 40 years of age (Figure 2a). They confirmed that the chemical markers would rebuild visual connections by inherent mapping principles, even when rearranged eye-to-body relationships produced totally non-functional reactions to stimuli. Visual areas map out the space for action in terms of body form automatically, without teaching from stimulation. This cast doubt on prevailing theories of the construction of functional brain circuits by learning. Sperry's 'chemoaffinity' principle is now accepted as being a primary factor in the early growth of nerve-cell connections. This is despite revolutionary advances in molecular biology and new models to explain order emerging in complex nonlinear dynamic systems of nerve cells, axonal and dendritic branches, and synapses, and selective retention of elements under the validation of environmental input. Emergent order and selection do create new functions and transform sensory and motor maps, but these maps retain a basic functional design of 'behavior space' – a product of a cell-to-cell communication that is set up in the embryo before the sensory nerves are connected to the brain.

Throughout his career, Sperry constantly tried to explain the creativity of 'experience', in the true sense of that word – that is, how conscious minds in active bodies 'try' to know. Cognitive psychology now favors analysis of human consciousness

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in terms of the data-transforming powers of intelligence – the processing and storage of information for mind work. Sperry had a deep conviction about and respect for the vitality and complexity of whole living organisms, and he emphasized the services of motor action to cognition. He attempted to determine how brains seek and generate information – not just logically processing what comes in, but how they create a useful sense of stimuli and how sensory information is taken in to monitor and guide intended movements. This interest led him to examine pathways within the visual cortex, and from visual areas to motor output. For every question Sperry found revolutionary answers. Step by step, he presented clear data on the living structure of cerebral pathways.

0457.006 Mapping of skin or retina to the brain in a fish, a frog or a newt makes it possible for the animal to anticipate what will happen when it moves. Sperry's nerve regrowth experiments that were designed to determine how the maps are made are simple and elegant. The surgical skill necessary to operate under a binocular microscope on the nerves of animals only a few centimeters in length gave Sperry the means to conduct a brilliant study of the cortical mechanisms of vision in a mammal. He sliced through loop connections just beneath the gray matter of the visual cortex, making the incisions with tiny specially shaped knives through holes in the blood-vessel-rich membrane that covers the cerebral cortex. By showing that operated cats could perform difficult visual discriminations with little loss after this surgery, he disproved a theory of 'psychoneural isomorphism', that integration of perceptions was by local linking of features to make a neural analog of a photographic image. He found that visual pattern recognition was mediated by deep cortico-cortical loops which the surface surgery left intact. This was one demonstration in a series that he designed to highlight the involvement of longer connections and separate brain parts in the unity of sight. A visual 'image' in the brain is not like a photograph or movie – it is more like a rumour spread by telephone calls between distant points.

0457.007 Sperry's research on coordination of movements and awareness led him to investigate how intentions relate to consciousness in cats, monkeys and humans. The 'split-brain' studies which eventually earned him his Nobel Prize were started in Chicago, and continued at the California Institute of Technology after Sperry moved there in 1954. They germinated from an idea that was implanted in Sperry's mind in the 1940s while he was working with Karl Lashley at Yerkes Laboratory of Primate

Biology in Florida. The aim was to find out how consciousness could be related to brain pathways. As Lashley interpreted his own extensive experiments, there was no clear location of learning and no function for the millions of fibers that bridge the gap between the two halves of the cortex in the corpus callosum, the largest single fiber tract in the brain. In Sperry's attack on this question, visual input to the cortices of the two cerebral hemispheres was divided by cutting the half of optic fibers that cross the midline under the brain in the optic chiasm (Figure 2b). Ronald Myers and Sperry showed that visual learning in a cat could be doubled by transecting both the optic chiasm and the corpus callosum, thereby producing the 'split brain'. A major advance in understanding how brain connections serve in awareness, and how the cerebral cortex works with brainstem structures that were not divided by the surgery, was made possible. Eventually it led Sperry to direct inventive testing of the effects of the operation, by dividing the corpus callosum in human patients, tests that demonstrated the different consciousness of the two human hemispheres (Figure 2c).

In 1960, the neurosurgeon Joseph Bogen suggested to Sperry that an improved understanding of the human mind could be obtained by methods based on those that had been perfected at the California Institute of Technology in the late 1950s for elucidating visual and touch learning in split-brain monkeys. The equivalent human operation, known as commissurotomy, had been used by neurosurgeons to prevent the interhemispheric spread of intractable epilepsy, but no effects on consciousness were reported. Most probably the tests had been inappropriate, or the surgery was incomplete. A new series of operations was medically justified for individuals with severe seizures, and better-controlled testing, like that developed for the studies on animals, could aid the post-surgical care of these patients. The first paper on surgically divided awareness in humans was published by Bogen and Sperry with Michael Gazzaniga in 1962, nine years after Myers and Sperry's first report on split-brain learning in cats. There followed a rich series of tests of the differences and interactions between images and memories, feelings and intentions in the left and right cerebral cortices of a small and devoted group of patients who were grateful for the improvement in their lives, and for the attention that they received in collaboration with Sperry's team. Apart from firmly linking aspects of consciousness to identified parts of the brain, the results of experiments by researchers who joined Sperry at the California Institute of Technology clarified the

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functions of the brain areas involved in language and thinking. They proved that intentional 'mind sets' (anticipating the type of strategy that would be needed for the subject to a conscious act of any kind to a successful conclusion) were allocating particular territories of the cerebral cortex, directing attention and the information-processing of perception, and preparing the body to move in precisely directed ways, using intention, memory and emotions to generate a receptive consciousness. The California Institute of Technology commissurotomy studies stimulated a new era in neuropsychology of the hemispheres, and accelerated the testing of left-brain and right-brain mental functions in normal individuals. In Sperry's mind the findings generated a new line of philosophical inquiry and a new teaching venture that kept him hard at work until his death in April 1994. He believed that the 'cognitive revolution' of the 1970s was inspired by the research on consciousness in commissurotomy patients, and he continued to spare no effort in explaining his thinking, despite increasing disability due to a serious central motor disorder that weakened him and progressively restricted his freedom of action and participation in academic meetings. This infirmity in no way diminished the acuteness of his thought or the fluency of its expression.

0457.009 Roger Sperry's thoughts on the causal potency of consciousness were developed after 1965 in a series of philosophical papers on 'Mind, Brain and Humanist Values'. His scientific colleagues, many of whom were still persuaded that consciousness must be a notion beyond the reach of rigorous science, were puzzled. Was he becoming mystical? Surely he was being philosophically naive. However, anyone who had crossed logical swords with Roger Sperry knew the danger of assuming that he could be naive. He was too thorough and tenacious to miss a weakness in his own or another's argument. On the other hand, he was stubborn, and the notion of consciousness and its innate values as a causal force in nature, as a director of human experience and knowledge, was consistent with his original phenomenological beliefs, and it did become an abiding conviction. Now, of course, his message seems far less deluded, and more a prophetic realization of how universal 'autopoietic' or self-creative emergent principles must apply (and with great force) in the consciously monitored activities of the human brain and mind, directing not only the elementary physiology of the neurons in patterned arrays, but also the culturally contrived mechanisms of society in harmony with ancient requirements for human life on earth. And it is

not so odd, in the twenty-first century, to say that if we do not find lasting values to guide our collective actions, things may go badly for our societies and for the world that coexists with our dangerously increasing numbers. In that context, Sperry's thinking on global causality and the place of the human mind and human conscience in the making of a liveable future has increased validity.

New notions of causality propounded by physicists with regard to the origins of the cosmos and the evolution of matter give scientific authority to the nonreductive psychology that Sperry had developed as a biologist who was aware of the special creativity of neural systems. However, physics can provide only the most general, abstract enlightenment about psychological processes. What Sperry set out to do was to challenge the powerful orthodoxy of psychometrics, experimental psychology and reductive brain science that seeks linear explanations for the construction of behavior and consciousness, all deriving from the input of information from sources that have no intrinsic values and no moral force. As he challenged behavioristic notions of learning with his demonstrations of innate forces in the growth of nerve connections to form functional networks, and as he insisted that surgical operations could locate motives for learning in animals and show the real anatomy of human consciousness and its creative subdivisions, so he concluded that human values are not just convenient fictions with short-term validity. Rather, he believed that they are rooted in inherited psychobiological principles for acting in harmony with the physical and social world in which humans have evolved.

Sperry's writings are lucid, not least when his ideas challenge accepted theory. His later writings are motivated by strongly formed personal beliefs, but they remain a clearly articulated call for new scientific thinking. He always advocated keeping 'the big picture' in mind.

Further Reading

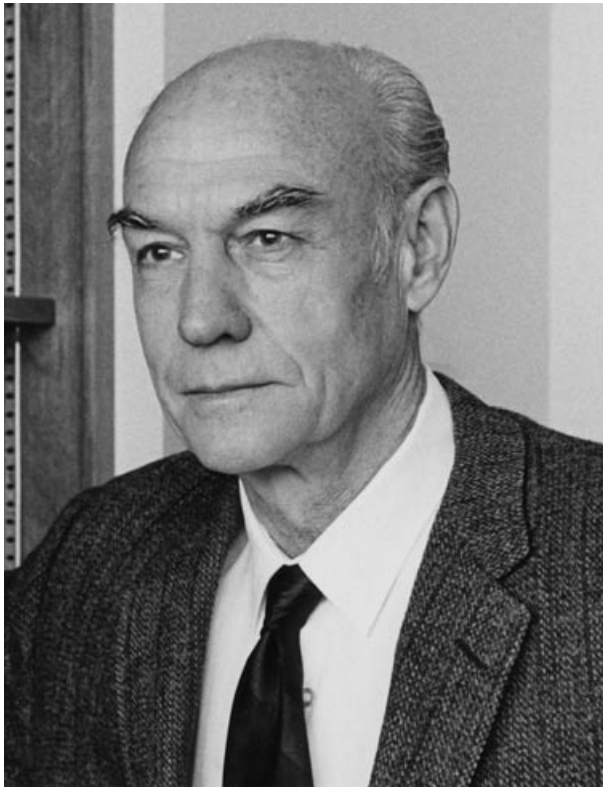
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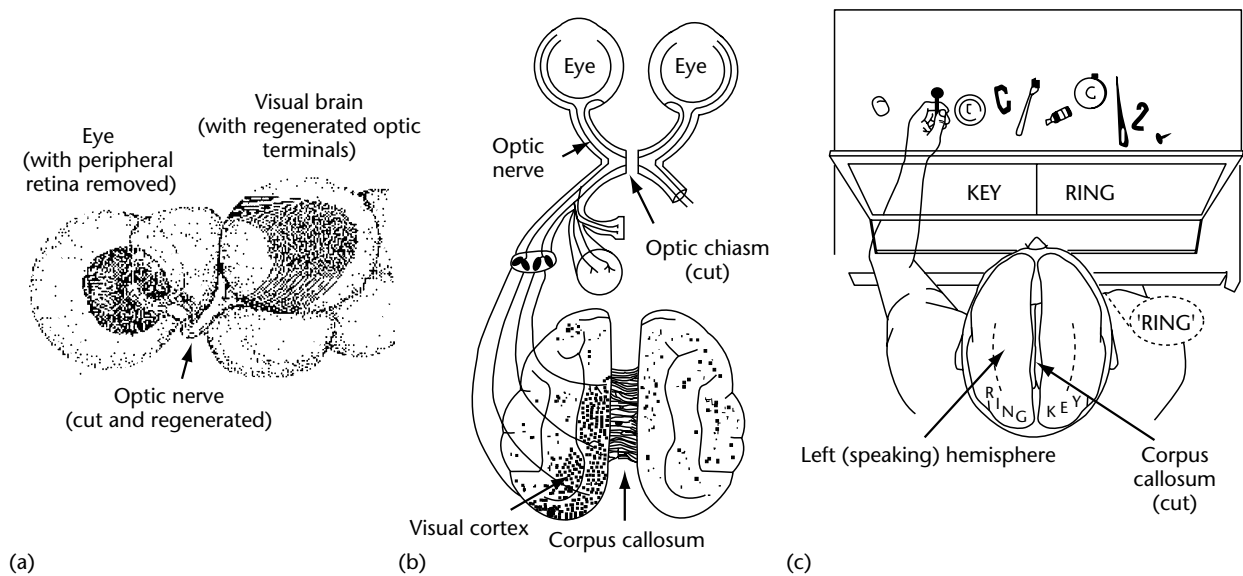
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Keywords:



0457f001 **Figure 1.** Portrait of Roger W. Sperry.



0457f002 **Figure 2.** Drawings by Sperry showing three important experiments in the study of brain growth and function. (a) Growth of eye-to-brain connections after surgical rotation of the eye in fish. (b) Division of visual input to the cortices of the two cerebral hemispheres in cat brain. (c) Division of the corpus callosum in a human patient.

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