

Roger W. Sperry:  
From Neuro-Science to Neuro-Philosophy

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## Introduction: The Uniqueness of Roger Sperry

A book on the history of neuropsychology should include biographies of luminaries in the field. However, the choice as to which ones should be included is a difficult task. The purpose of this chapter is to provide the background, explanation, and justification as to why Roger W. Sperry belongs in a book of this type.

Presumably, one could simply argue that Sperry is the only person with a graduate degree in psychology to have received a Nobel Prize. Maybe it would be worthwhile to highlight the over 300 articles in the most rigorous scientific journals published, often as single author. Of course, even the lay public knows about his discovery of left and right brain. Although his work is well known to psychologists, he also established groundbreaking work in the areas of both neuroscience and neuro-philosophy. It is also important to note that his own training was unique and that he provided training to almost 100 other visiting scientists, graduate students, and post-doctoral fellows from 12 different foreign countries and several different disciplines, ranging from medicine to philosophy. Also, as discussed in more detail later, historians of psychology consider Sperry one of the major figures in the discipline's century old pursuit of the scientific understanding of the mind and behavior.

Sperry might represent as an excellent a model to the spirit of the history of psychology (Puente, 1996). Wilhelm Wundt was a physiologist working in a Faculty of Psychology when he established the first laboratory of psychology over a century ago. For many historians of psychology, Wundt represents the beginning of psychology in large part due to the development of the first and still functional scientific laboratory devoted exclusively to the study of psychological principles, originally the focus was

introspection. He merged scientific methodology to study mental processes with philosophical questions, resulting in the discipline of psychology. Sperry represents this historical foundation of psychology. His scientific methodology was as rigorous and elegant as any in the twentieth century yet his questions were the same ones found in William James' Psychology (1909); what is consciousness and what is the origin of behavior?

Undeniably these reasons alone should be in and of themselves sufficient to justify the inclusion of Sperry in a book of this sort. However, it is what is not commonly known about Sperry that places him in a particularly unique position in the history of neuropsychology. The following reasons are provided to illustrate his position in the field: 1). His commitment to neuropsychology as early as an adolescent, a span of 65 years. 2). His unwavering and relentless focus on simplicity and elegance in methodology. 3). The understanding of historical and philosophical questions in psychology. 4). His discomfort with much of society's situation. 5). The role of psychology in solving societal predicaments. 6). The uniqueness of his personality and life, both personal and professional.

To develop a better understanding, the chapter will address each of these areas within the context of three separate sections followed by summary and directions. The first section will focus on background including personal and professional information. The origin of his ideas will be traced from his early years reading James' Psychology to the relationship with his mentors, students, and collaborators. The four turnarounds, as Sperry called them, of his career will be then considered. Finally, Sperry's concerns for

society and the implications of his research and ideas to the solution of societal problems will be outlined.

#### Background: Biographical and Scientific

As a young teenager, Sperry's father brought home from the public library William James's book, *Psychology*. Although his father was a banker, reading and scholarly achievement were valued in the Sperry home. After a chance reading of James' book, Sperry was to come in contact again with these ideas in his Introduction to Psychology course by Raymond Stetson at Oberlin College. These two events were defining in that his entire career was devoted to asking the questions posed by James and presented by Stetson; what is consciousness and what is the role of nature and nurture in the development of behavior (and, presumably, consciousness).

It would have been almost impossible to predict that Sperry as a student would have chosen a career of research. His interests appeared to be focused on sports. He was apparently quite popular with his peers. His early experiences revolved around the typical things a boy might do in a rural setting. One thing that seemed unusual was the trapping of wild animals and keeping them in cages. The untimely death of his father and the eventual effect on the family's income resulted in the family moving to East Hartford, Connecticut where he continued his interests in sports. So much was this interest that in his application for college, the primary goal was listed as coaching athletics. As a second choice, he indicated medical research. He and his brother were admitted to Oberlin College, a highly selective liberal arts college in Ohio. Again, he continued with his interests in sports, lettering in baseball, basketball, and track. While his brother pursued chemistry, Sperry drifted initially towards English. Although he went on to receive his

undergraduate degree in English, his interests began to move towards psychology near the end of his undergraduate career.

Sperry was particularly impressed with Raymond Stetson. Stetson had gone to Harvard to obtain his Ph.D. with James. Unfortunately, by the time of his arrival James had drifted towards religion and Stetson studied with others including Munsterberg. Nevertheless, the indirect impact of James' ideas prevailed. Stetson secured a position at Oberlin College, remaining there for his entire career. He was not a particularly prolific researcher although it is known that he was well liked as a professor. Stetson's field was speech therapy and his publications were for the most part published in European journals where he considered his ideas to be better received. In many respects, Oberlin and Stetson may have had the greatest impact on Sperry relative to his training. This is evidenced partially by two facts; 1) Sperry's notes on the first day of Introduction to Psychology (by Stetson) served as the foundation for his research program, and 2) Sperry left his papers to Oberlin. The admiration appears to have been mutual, the neuroscience building on campus is named after Sperry and he received an Honorary Doctorate degree from Oberlin.

After completing his Masters degree with Stetson, Sperry wanted to pursue additional training. Clearly the focus was on attempting to answer the ubiquitous nature vs. nurture question- quite ambitious for a graduate student. He went to the University of Chicago and studied with Paul Weiss, a prominent scientist working in the Department of Zoology. Weiss' research was prolific and well cited during the first part of the century. The basic premise amounted to the fact that the nervous system was plastic. However, it is important to note that Weiss was known not only for his resonance principle but for his

other work in related fields. This focus set the foundation for Sperry's first turnaround of research. Working under the direction of Weiss, Sperry set out to test the resonance principle. Challenging the intellectual status quo, whether it was his graduate advisor or the intellectual zeitgeist of the day, became a pattern for Sperry. In addition, Sperry was particularly good at seeing ways to test other people's ideas and experiments.

His time at Chicago was prosperous for Sperry. He published his first article (Sperry, 1939) in a non-psychological journal, the Anatomical Record since the research was more appropriate for an anatomical journal than a psychological one. The article was published (as well as later ones) because he was in the Department of Zoology and later Anatomy. Further, he was refuting ideas that had been published in those journals. He received a post-doctoral fellowship at Harvard with Karl Lashley, another prominent scientist around the middle of the 1900s. Weiss and Lashley had both suggested to Sperry that he apply for a fellowship. Lashley, like Sperry, was formed as a zoologist but had migrated over time to study the brain and its relation to behavior. Lashley was appointed as director of the Yerkes Primate Research Center in 1941. Robert Yerkes, from Harvard, had originally established the research center but due to the inclement weather in Boston, it was eventually moved to a suburb of Jacksonville, Florida, Orange Park. There Lashley worked with other prominent (e.g., Nissen) as well as promising (e.g., Pribram) scientists of that time. Others there with Sperry included Hebb, Riesen, Young, Semmes, Clark, and Birch. The focus was on behavior but the conduit to its understanding was the nervous system. Again, Sperry went on to challenge his advisor's thinking resulting in his second "turnaround" of research. Both at Yerkes and later back at Chicago, Sperry developed simple experiments that were to challenge Lashley's equipotentiality theory.

After the completion of his post-doctoral training at Yerkes, Sperry secured a tenure-track position in the Department of Anatomy at the University of Chicago. For reasons that are not clearly understood, despite Sperry's productivity, he was denied tenure at Chicago. He obtained an appointment as Section Chief in the Division of Neurological Diseases and Blindness, under Seymour Kety, at the newly-formed National Institutes of Health. His appointment there was 1952 to 1953. However, Sperry never resided in Bethesda, Maryland, the eventual home of this agency. Diagnosed with tuberculosis in 1949, probably contacted while posting monkeys for material for nerve grafts, most likely at Harvard. He was given a one year sabbatical for the treatment. During this convalescence, Sperry began to contemplate more seriously the role of consciousness in brain function. Indeed the last section of the article "Neurology and the Mind-Brain Problem" (1952) provides a glimpse of his research and writing focus for the next 40 years. This signaled the beginning of the third turnaround in his thinking.

He forged ahead with his theories and writing. After a particularly well-received symposium talk, Sperry was invited to the California Institute of Technology (Caltech) by Norman Horowitz to present a lecture. That lecture so impressed the faculty that Sperry was offered a tenured position as the first Hixon Chair of Psychobiology, a position he held until his retirement in 1984. The Division of Biology was looking to appoint an endowed Hixon professorship and needed a "hard" research scientist with interest in human behavior. Nevertheless, Caltech was an odd place for Sperry. There was no question that he felt right at home with the likes of other world-class scientists and students. The Division of Biology not only was extremely well funded and productive but was on the cutting edge of a then emerging field, microbiology. In contrast, Sperry was

the only one of four behavioral scientists on the faculty at Caltech. This isolation remained until his death. Hence, he was surrounded by the best of science and scientists but worked in geographical isolation from the colleagues he most wished to affect, psychologists and neuropsychologists. He often shared the fact that he felt that neither, Caltech nor the field of psychology, truly appreciated his work.

While at Caltech Sperry became as productive as anytime in his 50-year research career. By the peak of his productivity during the 1960s, Sperry had up to 10 different scientists and/or graduate students working on a variety of projects. Originally, the laboratory was housed in Kerckhoff, then Alles, and finally Church. All during this time, he kept a relatively low profile, opting to stay in his office, often with his feet on the desk, “thinking”. Sperry’s research program was an intellectual factory. Nevertheless, he was a daunting supervisor. Meetings with him were often prefaced with questions such as “is this important...will your ideas make a difference”. Unprepared contacts with Sperry were highly inadvisable. In fact, superficially he could across as cold, distant, aloof. In reality, Sperry was quite shy and preferred to avoid much public contact. Simultaneously, Sperry was highly driven. He challenged his students and colleagues, but never more than he did himself. For example, his writings were always reviewed a number of times, not only by himself but colleagues as well as his spouse. Sperry rewrote his manuscripts and edited them numerous times. Only those with theoretical sections were sent to anyone not in the laboratory and then primarily the philosophical ones to see if any flaws could be found in his thinking. It was also not unusual to read the papers at his laboratory seminars. This approach to science resulted in extremely high levels of productivity and

excellence from the laboratory as well as constant funding from a variety of sources, primarily the National Science Foundation, for the entire length of his career.

Sperry retired in 1984, meaning no new students. However, he continued to collect data and formulate ideas for his philosophical papers to the end. As Sperry became increasingly affected by a neurological disease (PLS), he began to focus almost exclusively on the fourth turnaround. It was during this time that Sperry's writings were primarily philosophical in nature. He had stopped giving lectures by 1980 because of slowed and labored speech with the presentations being delivered by his colleagues or students. He opted to stay out of the public eye choosing instead to split his time between his office at Caltech and his home where he furthered his ideas by publishing in a variety of journals both in the US and abroad. In fact, at the time of his death Sperry was still working on the revision of at least one manuscript.

#### Origin of Ideas: People and Trends

As previously noted, Sperry's research program owes its roots to William James and Raymond Stetson. As a student Stetson had gone to Harvard to study with James but by this point James had migrated towards other disciplines, including religion. Stetson never did actually study with James but was highly influenced by his ideas, primarily through the use of James' textbooks as well as the lingering conceptual framework left for James' successors. Stetson obtained his primary position, which he held until his retirement, at Oberlin College in Ohio. There a psychological laboratory was established and a range of courses was offered.

In his first psychology class, Introduction to Psychology, Sperry wrote on the first page of his notes two questions; 1) where does behavior come from, and 2) what is

consciousness. These two questions, which arose from James' view of psychology, formulated the foundation for Sperry's half a century of research. While he ended up obtaining his undergraduate degree in English, Sperry often shared with me that Stetson may have had the greatest impact on his intellectual development.

Hence, it should not be surprising to note that his research program follows a systematic road of attempting to answer these two provocative and central questions to the history of psychology. Nevertheless, he saw a challenge in the work of Weiss. His new doctoral supervisor provided both techniques and a theoretical framework from which to attempt to answer the questions of nature versus nurture. Weiss had postulated that the nervous system was plastic and, indirectly, had provided support to the then emerging theory of behaviorism. Sperry proceeded to embark on a research program lasting approximately two decades in which convincingly the resonance ideas of Weiss were rebutted and the idea of chemoaffinity was advanced (Sperry, 1945).

A similar strategy was pursued while working with his next supervisor, Karl Lashley. Again this supervisor provided techniques and theory. Shifting his work to the Yerkes' Primate Research Laboratory in Orange Park, Florida Sperry developed relatively simple experiments to test Lashley's theory of equipotentiality. What is particularly interesting is that Sperry was able to understand Lashley's concepts in simple behavioral terms that, in turn, were translated into experimental paradigms. These manipulations allowed Sperry to directly challenge this idea of Lashley (Sperry, Miner, & Myers, 1955).

There was little question that Sperry became more directly interested in the brain, in contrast to his earlier work that focused almost exclusively on the peripheral nervous

system. Although he was interested in the brain from the beginning one needed to know how it functioned to draw any conclusions about higher order activities. Behavior is dependent on how the structure and the physiology of the nervous system are organized and operate. Further, I believe he wanted to challenge his own ideas by focusing on both the brain and higher-order mammals. His return to the University of Chicago during the mid-1940s signaled the beginning of a shift in his focus towards the brain, monkeys, and eventually humans. It was during this time that he became involved with a wide variety of young scientists, some of whom became lifelong colleagues. Robert Doty, now at the University of Rochester, included Sperry as part of his doctoral thesis committee in 1950. He worked also with several other graduate students, including Nancy Miner and Ronald Myers.

Norman Horowitz was instrumental in recruiting Sperry to Caltech and provided a life-long friendship and support for Sperry's behavioral research (but not of his philosophical ideas) at the Institute's molecular-based Division of Biology. His work started much in the same direction as Chicago, doing nerve-regeneration. However, by the late 1950s he had shifted focus towards examining the split-brain phenomena, initially in cats (1956), later in monkeys (1958), and finally in humans. (1962). While the split-brain work began in Chicago, it expanded substantially at Caltech. For example, Miner came from Chicago with Sperry as a postdoctoral fellow while Myers came to Caltech to complete work on his thesis on split-brain in cats. Sperry work on cats was primarily carried out in collaboration with Nancy Miner, John Stamm, Ronald Myers, A. M. Schrier, and T. S. Voneida. His work with the monkeys involved Mitchell Glickstein, Colwyn Trevarthen, Richard Mark, Evelyn Lee-Teng, and Charles Hamilton. When his

corpus callosum work shifted towards humans another set of young scientists collaborated. These included; Joseph Bogen, Michael Gazzaniga, Jerre Levy, Harold Gordon, Richard Nebes, Eran Zaidel, Dahlia Zaidel, Leah Ellenberg, G. Plourde, and R. Saul. His work on consciousness and neuro-philosophy was almost exclusively done alone.

At his peak, Sperry's work at Caltech resembled more of an intellectual and research factory than a standard scientific laboratory. For example, in 1976 Sperry had numerous individuals in a variety of positions working in his laboratory. These included: Research Associate was Charles R. Hamilton; Visiting Associates included Evelyin Lee-Teng, Colwyn B. Trevarthen; Research Fellows were Laura Franco-Testa, Ronald L. Meyer, and Eran Zaidel; Graduate Students included Sheila Gillard Crewther, Karen E. Gaston, Karen F. Greif, David S. Isenberg, Larry E. Johnson, Margaret Y. Scott, and Betty A. Vermeire. In addition to these there was one student assistant and 10 research staff members including Lois E. MacBird, long-time secretary and technician, Dahlia Zaidel, a long-standing collaborator, assistant, and technician, and Erika Erdmann, library research assistant.

While these individuals are well recognized in their own right as well as published with Sperry, others have played a role in Sperry's professional development. These include: Robert Galambos (classmate at Oberlin), Emeritus Professor of Neuroscience at the University of California School of Medicine; William Burbank (graduate student at Chicago); Emeritus Professor of Biology at Emory University; Jerry Kollros (roommate at Chicago), Emeritus Professor of Zoology at the University of Iowa; and, Kao Liang Chow (colleague from Yerkes), Emeritus Professor of Neurology at the

Stanford University School of Medicine. There is little question that Sperry interacted both with his students and with colleagues around the country. This collaboration was largely intellectual as he relied on people he considered highly-qualified for feedback on the development of his concepts.

His articles have been published and/or translated into several languages including Russian, Chinese, Japanese and Spanish. A large percentage of his articles are single-authored although I believe he was generous in many instances by placing himself as second or even last author despite the fact that the research design, etc was generated by Sperry (e.g., Gazzaniga, Bogen, & Sperry, 1962). Several of his articles, especially those involving the human-split brain work, have been reprinted in numerous journals and readings in books. However, it is interesting to note that several books, such as Forty Studies that Changed Psychology, the work that is often cited is that of Sperry's student, Gazzaniga. This could reflect the ongoing publications of more contemporary neuroscientists and neuropsychologists, the misunderstood role of Gazzaniga in the laboratory (as a student), or a misunderstanding of the role of Sperry and his prior work with cats and monkeys prior to pursuing human split-brain research.

What is curious is that while a particular line of research evolved, its focus would fade slowly. For example, Sperry published his first article on nerve-regeneration in 1939 and his last one in 1975 although his major focus in this area lasted about 20 years. Also, there are specific periods of times for each of the four major areas. The first one began in 1937 and ended in 1975. The second one was rather short, 1952-1955. The third phase began in 1950 and lasted until 1985. The fourth and final phase probably began with a lecture at Caltech in the spring of 1962 and continued until his death in 1994.

### Research: Four Turnarounds

Sperry believed that his 50 plus year research program could be divided into four phases or “turnarounds”, as he called them. The purpose of the four phases was to specifically address the questions from his introduction to psychology class. There is little question that the research was systematic and that each phase evolved into the next one. There are several pieces of evidence supporting this contention; 1) he repeatedly indicated this to myself as well as to others verbally, 2) he kept a scientific diary for a number of years that also indicated the flow of his research, and 3) his most recent writings, especially those during the 1990s allude to this fact, although not often in straightforward terms.

The four phases, which were previously mentioned, were as follows;

1. Nerve regeneration & chemo-affinity studies
2. Studies involving equi-potentiality
3. Split-brain studies
4. Consciousness and values

The following is a breakdown of each of the phases according to the years in which that particular research was carried out and the number of articles produced in that particular area. It is important to note that it is almost impossible to be very specific about these estimates. For example, in some review articles, Sperry addressed research that involved more than one of the turnarounds. Also, in some rare instances the empirical research did involve two areas simultaneously. However, the following estimates are good approximations;

<b>Phase</b>	<b>Years</b>	<b>Number of Articles Published</b>
Nerve Regeneration	1939-65	75
Equipotentiality	1952-55	5
Split-brain	1955-85	80
Consciousness	1952-present	70

There are several issues that need some clarification. Sperry always kept a small portion of his research allocated to areas that were no longer central to his interests. Hence, Even though the peak of his nerve regeneration research occurred during the 1940s and early 1950s (but continued into the 1960s), he and a small number of his students continued doing research in this area for another 10-15 years. Secondly, it appears that he devoted equal time in terms of publications for the three areas that were most important to him. I believe he felt that Lashley's theory of equipotentiality was well -answered by the five of so studies devoted to this topic. Indeed, I questioned him on the validity of including this as a turnaround in his research program. He considered this phase of his research quite important since it disproved the electrical field theory and confirmed Lorento de No's views of vertical organization within the cerebral cortex. Fourth, the consciousness research spans the longest time, almost half a century. The first article, published in the American Scientist (Sperry, 1952), contains in the summary section a blue-print of what was to come from his research program for the next 30-40 years- an unbelievably clear and well-laid out plan for attacking the questions of his introduction to psychology course. There was little question that he was interested in

using science to answer age-old philosophical questions. In fact, I believe that he considered this last phase of his research to be potentially the most important of all the turnarounds.

In reviewing his publication record, there is no question that he preferred to publish empirical articles in rigorous scientific journals. In fact, his first review article was published only after 37 empirical articles had been published. And, it was not until his 45<sup>th</sup> article that psychological issues creep into his discussions and even then briefly. However, by the 1960s it was clear that his ideas were starting to have an international impact, since his research began to be translated and published in other languages. Also, it is worth noting that it was not until 1955 that Sperry published articles in psychological journals, namely the Journal of Comparative and Physiological Psychology and the British Journal of Animal Behavior. This is interesting in light of the fact that historically and vocationally Sperry considered himself much more of a psychologist than a zoologist or even a biologist.

Each of these turnarounds was well funded, mostly by governmental agencies. He received his first research grant in 1940 and his last one in 1993. Further, his research was continuously funded for his entire career. Most of his research funding came from federal agencies, ranging from the National Institutes of Health to the Public Health Service. In addition, he received support from various sources including the Penrose Fund (American Philosophical Society), Eli Lilly and Company, and the Hixson Fund from the California Institute of Technology. Additional information is contained in Table 1.

Table 1. Main Funding Activity by Source of Funding, Date, and Type of Research

<b>Source</b>	<b>Date</b>	<b>Type of Research</b>
Penrose Fund	1940	Muscle Transposition
National Institutes of Health	1955	Visual Pattern Perception
Public Health Service	1955	Visual Pattern Perception
Southern California Society for Mental Hygiene	1955	Visual Pattern Perception
National Science Foundation	1956	Perceptual Integration
Mental Health Foundation	1956	Perceptual Integration
Eli Lilly & Company	1957	Myotopic Respecification
National Science Foundation	1960	Split-brain Rhesus Monkeys
Commonwealth Fund	1961	Central Nervous Pathways
Hixson Fund	1968	Hemispheric Disconnection
Public Health Service	1970	Neocortical Studies
Institutes of Health	1971	Developing Brain
Public Health Service	1973	Interhemispheric Interaction
Public Health Service	1977	Hemispheric Lateralization
Public Health Service	1980	Lateralized Functions

In the first turnaround, nerve regeneration, Sperry was interested in addressing the nerve growth issues and developing the chemoaffinity theory which addressed the nature vs. nurture question (Sperry, 1945). His overall goal was to determine whether Weiss' theory of neural plasticity was correct. In other words, is the peripheral nervous system malleable enough that nerves can be interchanged and function remain intact. In order to achieve an answer to this question, Sperry began a series of studies involving muscle transplantation in rats. He then added nerve crossings. After coming to the conclusion that little plasticity was evident with these nerves and muscles, Sperry proceeded to work on sensory functions, including vision and olfaction, and expanded from rats to other species including amphibians, monkeys, and fish. By the early 1950s Sperry was convinced that plasticity was limited in scope in motor and sensory activities in a wide variety of animals.

His post-doctoral years with Lashley resulted in adding to his research program the question of equipotentiality. By using dielectric plates (mica) and later subpial slicing and tantalum wire implants in the visual cortex, the spread of nerve impulses that was hypothesized by Lashley did not occur (Sperry, Miner & Myers, 1955). The experiments were simple, elegant, and methodologically robust allowing Sperry to conclude after 3-4 years of work in this area that it was probably time to move on to more complex issues.

This next phase of his research is what Sperry is best known for and, unfortunately, what is most misunderstood about his ideas as well. A survey of over 25 Introduction to Psychology textbooks reveals that every one makes reference to the split-brain research of Sperry. Interestingly, some give more credit to his student, Gazzaniga, than to Sperry himself. Almost all of the books provide a cursory analysis and none

explicate the issues beyond the role of the cerebral hemispheres. Yet clearly the concept of right and left-brain has become widespread both in psychology and in western culture. However, Sperry did not necessarily believe, for example, that the left brain was dominant nor did he believe that people could be classified as left or right brained. What Sperry did suggest is borne out by the close to 100 studies that he and his students and colleagues at Chicago and Caltech performed using cats, monkeys, and humans. The original study on humans by Gazzaniga, Sperry, and Bogen (1962) provided a template for the research that was to continue for another 25 years. Clearly the left hemisphere appears more analytical than the right and, in contrast, the right is more appreciative of gestalt and emotional behavior. It is also very important to note that the split-brain research involved cats, monkeys, and eventually humans. The elegant and simple approach to understanding hemispheric functioning and the function of the corpus callosum across the three species may have been the singular most important scientific accomplishment resulting in the Nobel Prize in 1981 (Sperry, 1981).

What is also not well understood about Sperry's split-brain studies is both the origins for such studies and the development of his thinking for those studies. Lashley had suggested that the corpus callosum's primary function was perhaps to hold the cerebral hemispheres together. And, the previous work of Akelaitis on the corpus callosum had not yielded an understanding of the role of this large structure. Sperry was interested in not only discovering the role of the corpus callosum and "replicating" Akelaitis' work, but was interested in determining whether the findings of the nerve regeneration (peripheral nervous system) could be generalized to the brain (Sperry, 1961). Was the brain plastic (malleable)? If indeed the brain were plastic, then the

findings from his prior studies on nerve regeneration would not be generalizable to the central nervous system. If, however, the brain was as “hardwired” as the peripheral nervous system appeared, then significant conclusions regarding the plasticity of the entire nervous system could be drawn and the question of nature Vs. nurture could be more easily addressed.

After almost 50 published studies on nerve regeneration, Sperry began to work not only on the transfer of information from one side to the other of the periphery (e.g., visual information) but from one side to the other inside the brain (i.e., across hemispheres). His first few studies focused on cats, initially with visual information, then tactile information, then with memory of visual information. This phase was initiated in Chicago and continued at Caltech with the first publication on this topic occurring in 1953 and the last one in 1959. By the mid 1950s, his split-brain work started including monkeys with the first publication in 1958 and the last one being published in 1966. His initial studies involved somesthetic discrimination and later included inter-manual transfer of learned information. Sperry and colleagues worked using a small number of subjects to determine the transferability of information after sectioning of the corpus callosum. By 1960, his work was focusing more on monkeys although cat split-brain studies were still ongoing. His first presentation to psychologists on split-brain was at the 1960 convention of the American Psychological Association and his first publication on this topic in a psychological journal, Journal of Comparative and Physiological Psychology, was also in 1960. . Hence, by the time he had initiated his studies with humans, a significant body of literature on the split brains spanning over a dozen years, using cats and monkeys, had emerged from Sperry’s laboratories.

In 1961, he published “Cerebral Organization and Behavior” in Science (Sperry, 1961). The byline provides a glimpse of his past, current, and future research; “The split-brain behaves in many respects like two separate brains, providing new research possibilities”. This is particularly interesting in that prior to 1961 his research had been carried out almost exclusively with non-humans. Hence, even without information derived from language-based studies, the conclusion regarding the isolated functional capacity of the two hemispheres had been already reached.

However, the question remained would these results, of the lack of transferability of information across the corpus callosum, be also found in humans. The assumption was that humans were more likely than non-human animals to develop new learning systems that would compensate for the destruction of an existing fiber connecting system. In other words, plasticity would be more prevalent not only in the central nervous system but in humans and, thus, if plasticity would occur in the nervous system it would do so under these circumstances. Together with his eventual life-long colleague, Joseph Bogen, and a graduate student, Michael Gazzaniga, a research program was launched which spawned an entire way of thinking for psychology and a psychological concept which eventually became part of popular culture. Working initially with a war veteran with intractable epilepsy and slowly expanding the program to include another dozen research volunteers with similar epileptic conditions, Sperry and colleagues worked on understanding the corpus callosum and the two cerebral hemispheres. After numerous studies, the research has concluded that both hemispheres have quite different functional specialization. Further, and possibly more importantly, when the two hemispheres are disconnected, the person functions with two separate consciousness (Sperry, 1966).

The first human study (Gazzaniga, Bogen, & Sperry, 1962) documented the initial findings of independent hemispheric functioning. The article, which was published in the journal Neuropsychologia, focused on transfer of somesthetic information across the corpus callosum. Soon thereafter, Sperry and colleagues began exploring language (initially in the “dominant” hemisphere) after bisectioning of the brain. This study was followed by studies on visual perception, praxia, dichotic information, visual and geometric perception, temperature, part-whole relations, memory, intelligence/problem solving, and conscious awareness. It was clear that the disconnection of the two hemispheres produced essentially two separate minds that worked independently from each other and, at times, acted as rivals for attention. Personal identity, according to Sperry, could only occur when both hemispheres were intact and interacting (through the corpus callosum). His Nobel lecture (1981), “Some effects of disconnecting the cerebral hemispheres”, was the culmination of approximately 30 years of research using three different species and a variety of methodologies and dependent variables.

The fourth and final phase of his research involved consciousness. This phase could probably be further subdivided into two sections. Consciousness is given form from a unified interaction of both hemispheres in the intact normal individual. In a split-brain individual, one can demonstrate a separate consciousness for each hemisphere. One hemisphere alone, while producing significant consciousness in its own right, does not produce as purposeful and goal-directed behavior as if both hemispheres work in unison. Consciousness emerges from brain activity and, in turn, that consciousness has a unique downward causation controlling and directing the brain activity. The second section of this phase of research involves the application of a value system (Sperry, 1972). The

focus of consciousness results in invoking a value system that allows for such thoughts to emerge. Then comes the issue of which value system is most correct. Sperry believed in two major sources for consciousness; 1) a system of thinking in which scientific methodology was applied to the development of values, and 2) nature and time are ultimately the deciders of which values are most useful to the species. The question of the origins of behavior was addressed but as the program of investigation progressed, the question shifted. Specifically, his interest evolved more into the remaining question from his introduction to psychology class, “what is consciousness”.

#### Future Directions: Neuropsychology and Society

There is little question in my mind that Sperry believed that his work was misunderstood. For example, historically he believed that Caltech focused too much on molecular biology and that his work, at the level of behavior and mind, was considered too soft, especially for the “hard” science focus of Caltech. He believed that the split-brain work was over-interpreted, especially by non-scientists. In addition, his work on nerve-regeneration was best appreciated by neuroscientists but largely ignored by psychologists. Sperry’s ideas on consciousness were considered by some, especially those not appreciative of his long and carefully crafted research program, to be misguided efforts at philosophy. And, finally, I believe Sperry considered himself to be a psychologist and felt very strongly that a consciousness revolution began in the 1960s. That revolution could be considered as critical as that of the Copernican revolutionary ideas and could be (best) furthered by psychology. Again, both of these beliefs have yet to be fully appreciated by scientists, including psychologists.

However, it is similarly important to note that his work is only partially misunderstood and has had a significant impact in both psychology and in society. In psychology, continuing surveys about historical figures in psychology include Sperry (see Korn, Davis, & Davis, 1991). In society, the work of Sperry has produced ripple effects such as the development of the Declaration of Human Responsibilities by a group of distinguished scientists from around the world. The document is being considered by the United Nations as the step following the 50<sup>th</sup> anniversary of the Declaration of Human Rights. Both a more accurate understanding of his research and the acknowledgement of his work as seminal in the development of a consciousness revolution were critical to Sperry. And, in turn, such an understanding could serve as the foundation for the solution of modern-day problems. The integration of science and mind combined with a focus on consciousness and brain function will serve as the legacy of Roger Sperry.

### Reference Notes

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