NATIONAL ACADEMY OF SCIENCES

RENÉ JULES DUBOS

1901—1982

A Biographical Memoir by

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Lawrence Moberg

René Dubos

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February 20, 1901–February 20, 1982

BY JAMES G. HIRSCH AND CAROL L. MOBERG

RENÉ JULES DUBOS, microbiologist and humanist-philosopher, was professor emeritus at The Rockefeller University at the time of his death in New York City on his 81st birthday, February 20, 1982. His name calls to mind a tall, vigorous, rosy-cheeked man, with durable white wisps on a balding head, intense blue eyes behind thick glass lenses, a shy yet broad smile, and beautiful large hands that enthusiastically punctuated every sentence. He was a spellbinding speaker and a prolific author. His charming French accent and his perfect command of English made any contact with him memorable. Whether it was a private conversation or a public lecture, he always spoke with the knowledge of a scientist, the eloquence of a poet, and the wisdom of a philosopher.

René was born in Saint-Brice-sous-Forêt, France, on February 20, 1901, and grew up in Hénonville, another small Île-de-France farming village north of Paris. His parents, Georges André Dubos and Adéline De Bloëdt, ran a butcher shop in each of these villages. René attended a one-room school where discipline was strict and students taught one another. He was a husky boy, fascinated by sports, especially bicycle racing and tennis, but at age eight he suffered a severe

attack of rheumatic fever that incapacitated him for more than a year and left him with damaged heart valves. Early in his youth he was also found to be severely near-sighted, a condition that required thick corrective lenses. These afflictions instilled in him a fear of possible blindness and of a shortened lifespan, a fear that he never showed but that nonetheless caused him to live with special intensity and purpose. In place of typical childhood activities, René developed traits that would dominate the rest of his life. He walked and explored the countryside, a pastime that helped him cultivate a meditative mood—what he called the beginning of his freelance spirit. He also read avidly in history and literature, finding his earliest heroes in French translations of stories about Buffalo Bill and Nick Carter.

The family moved to Paris when René was thirteen years old. Within months, his father was called to World War I. Shortly after his return in 1918, he fell ill and in 1919, died. The raising of three children (René, his brother Francis, and sister Madeleine) and the management of the family shop were left to his mother. René helped run the butcher shop while continuing his schooling at the Collège Chaptal. At fourteen, he read Hippolyte Taine's essay on La Fontaine and was introduced to the concept of the environment as a molding force on historical events, particularly on the human psyche.

At age eighteen he applied to the École de Physique et Chimie, but another attack of rheumatic fever caused him to miss the entrance examination. After recovering he took the next test that came up, in economics, and was pleasantly surprised that he did well, ranking fourth out of 400. He was admitted to the Institut National Agronomique and excelled in all courses except microbiology—an intensely boring course, he later recalled, that dealt solely with taxonomy. He neither enjoyed nor excelled in chemistry and told his

mother that this was certainly the last time he would walk into a laboratory. In his third year he won a scholarship sponsored by the government of Indochina for studies of agriculture and technology in the École d'Agriculture Coloniale in Paris with a required period of service in Southeast Asia, but was later disqualified because of his rheumatic heart disease.

In 1922, René obtained a position in Rome on the staff of the International Institute of Agriculture, a branch of the League of Nations. For two years, as associate editor of the *International Review of the Science and Practice of Agriculture* for the Bureau of Agricultural Intelligence and Plant Diseases, he abstracted journal and agricultural reports from all over the world. He now spoke Italian and English as well as French and German. René recalled his days in Rome as very pleasant. He was a handsome young man with a bushy head of hair who was particularly attracted to English girls, ostensibly to improve his language skills. At this time he was undecided about career goals, considering occupations as divergent as journalist and scientist.

In the course of his translation duties René encountered an article that he considered the major influence in his life. While sitting in the Palatine Gardens on a warm May day, instead of reading about fertilizers in a semipopular journal, he turned to an article by the famous Russian soil microbiologist Serge Winogradsky, then at the Pasteur Institute in Paris. In it Winogradsky stated that microorganisms should be studied not in a pure laboratory culture but in their own environment in competition with other bacteria. He emphasized interactions of organisms under natural conditions and the significance of the role played by the environment in these interactions. René said his scholarly life began with these ideas—ideas he restated in many forms throughout his life. (Although the two men never met, Winogradsky pre-

sented René's paper, based on his Rutgers thesis research, at the Académie des Sciences in Paris in 1927.)

This experience played a major role in his decision to become a bacteriologist. But René did not know how to begin until he met the American delegate to the International Institute of Agriculture, Asher Hobson, a professor of economics from the University of Wisconsin. Hobson urged Dubos to emigrate to America and even offered to lend him money. René took a course in bacteriology at the University of Rome, earning extra money to pay for his passage to America by translating books on forestry and agriculture into French. In 1924, at a conference on soil science in Rome, Hobson introduced Dubos to Dr. Selman Waksman, who was then a distinguished bacteriologist at Rutgers University. René's duties as technical assistant during the Congress included showing Dr. and Mrs. Waksman around Rome. Fate intervened a few weeks later when René set sail for America and found that the Waksmans were fellow passengers on the steamship, *Rochambeau.* They had plenty of time to talk during the crossing; Waksman was delighted to hear of Dubos's ambitions and, learning René had no definite plans, offered him a small fellowship as one of his graduate students at Rutgers.

René arrived in America and went to New Brunswick with the Waksmans that same evening. Three years later he completed his doctor of philosophy degree, doing thesis research on the decomposition of cellulose by soil bacteria. He credited Waksman with helping him develop an ecological concept of microbiology through an understanding of the relation between biochemical and biological processes. Dubos earned extra money working part time as an animal caretaker at nearby Johnson & Johnson, tutoring the research director's children, washing laboratory glassware on holidays, and translating papers on poultry pathology for a young professor.

It was just about this time that René, a budding scientist with an abstract humanist education, read Lewis Mumford's *Sticks and Stones.* René said this American author influenced his social philosophy by making him realize that institutions exist not to foster political or economic power, but to serve human needs and thereby broaden the quality of human life. Moreover, Mumford wrote about subjects related to sciences and humanities in earthy terms that described sensory experiences of daily life. Mumford's writing had a lifelong effect on this impressionable young European trying to understand American ways and to express himself in English.

René had no special plans after graduation, except for wanting to move from the field of soil science to deal with more fundamental biochemical problems. His application for a National Research Council Fellowship was rejected because he was not a citizen. The secretary who sent the rejection letter penned a note at the bottom recommending that he consult with a fellow Frenchman, Alexis Carrel, at The Rockefeller Institute in New York. This chance event led René to The Rockefeller, where he was destined to spend some fifty years of his life. Carrel was kind and considerate but had no special advice. He took him to lunch and there, whether by chance or prearrangement, René was seated next to Oswald Avery. Dubos and Avery liked each other immediately, spending not only the lunch hour but most of the afternoon discussing René's experiences with soil enrichment as a technique for recovering microbes that could do almost anything and Avery's preoccupation with the capsule of the pneumococcus and its role in virulence. René brashly stated that it should be easy to find an organism that could make a capsule-destroying enzyme, a statement that impressed Avery.

In the summer of 1927, without a job or definite plans, René was France's official delegate at the First International

Congress of Soil Science in Washington, D.C. Along with 275 soil scientists from all over the world, he traveled throughout the United States and Canada in a chartered train to visit agricultural experiment stations and to examine different soil formations. He was offered at least two jobs that summer, one at the Experiment Station in Fargo, North Dakota, and the other at The Rockefeller with Avery—at half the Fargo salary—which he readily accepted. A series of accidental events had finally led him to a place where he could immerse himself in activities favorable to the development of his remarkable career.

Dubos's laboratory career can be divided into three general phases. The microbiology period, from 1927 to 1944, was devoted to demonstrating that bacteria nourished in the proper environment can produce enzymes specific to those bacteria and to showing that bacteria have genetic mechanisms. During the tuberculosis and experimental pathology period from 1944 to 1960, certain products of bacteria were shown to stimulate immunity, and environmental factors were found to influence susceptibility to disease. The environmental period, from 1961 to 1971, was dedicated to showing that various environmental stresses affect the development of the whole organism.

At no time was there a gap or significant change in the direction of his career. The fourth and final phase of his life, from his official retirement in 1971 until his death in 1982, was spent writing and lecturing on environmental and social determinants of health and disease. As he evolved into an environmentalist, he applied his earlier concerns to broader fields. His interests progressed from studies of pneumonia and tuberculosis to the whole pattern of disease and, finally, to the quality of human life on earth. The unifying thread in this seeming diversity was his perception that any living or-

ganism, whether microbe, man, or society, can be understood only in the context of the entire web of relationships it forms with everything else. A brief review of his major accomplishments in each of these phases reveals his continuous search for those factors in health that he believed are determined more by surroundings than by the mere presence or absence of microbes.

The microbiology period began with Dubos working alone in a small laboratory on the sixth floor of The Rockefeller Institute Hospital. Within three years, he succeeded in fulfilling the promise he had made to Avery: He recovered a microorganism that decomposed the capsule of Type III pneumococcus. He then proceeded to extract and purify the enzyme responsible for this activity, and finally he demonstrated that administration of the enzyme would protect rabbits or monkeys against usually fatal experimental pneumococcal infection. These impressive laboratory findings were described in several papers between 1930 and 1934. The enzyme might well have been further purified and then used to treat certain cases of pneumococcal pneumonia in humans, but the sulfa drugs had just become available for the treatment of this disease. The capsule-destroying enzyme did not achieve fame as a specific therapeutic agent, but the research on this material was nevertheless an auspicious beginning of Dubos's microbiological work.

In his search for a capsule-destroying microbe, René used the soil enrichment technique and added the capsular material to various soil samples. When he had isolated a suitable organism and maintained it in pure culture in the laboratory, he made the arresting discovery that the organism produced the capsule-destroying enzyme only if the capsular material were included as the sole source of carbohydrate in the culture medium. He called this phenomenon adaptive, or in-

duced, enzyme formation, which demonstrated that a cell has multiple potentialities that become manifest only when placed in an environment where it is compelled to use them.

René often referred to this discovery as the greatest intellectual satisfaction of his research career. The techniques in biochemistry and genetics to inquire further into this phenomenon were not yet available, but were later used by his friends Jacques Monod, François Jacob, and André Lwoff, who received the Nobel Prize for their work on this topic.

In the mid-1930s René and colleagues used the soil enrichment technique to isolate bacterial enzymes that destroyed creatinine and enzymes that converted creatine into creatinine. These materials were used to develop methods for measuring creatinine in the blood and urine, which had not been possible up to that time. In 1937 and 1938 he published papers on the recovery and partial purification of the enzyme that degraded one type of nucleic acid, and he named the enzyme ribonuclease. He did no further work with the enzyme, but it served as the basis for research by a number of scientists at The Rockefeller. Moses Kunitz further purified ribonuclease and obtained crystals of this protein. Stanford Moore and William H. Stein used the highly purified ribonuclease as material for their work on amino acid analysis of proteins, and Bruce Merrifield used ribonuclease in his first synthesis of an enzyme—discoveries for which these three men were awarded Nobel Prizes in chemistry.

Dubos's best known and most remarkable achievement during his microbiology period was the discovery of gramicidin and tyrocidin—the first antibiotics systematically cultivated from bacteria and produced commercially. Based on his several successes using soil as a source of special organisms, he searched for a microbe that would produce a substance capable of destroying intact bacteria. His search culminated in the isolation of *Bacillus brevis,* from which he

extracted the active soluble principle he called tyrothricin that contains two substances that attack gram-positive organisms. Tyrocidin kills bacteria in vitro but not in vivo and is toxic to animals; gramicidin is active both in the test tube and in animals but is limited to external use (superficial wounds, bovine mastitis) because it causes hemolysis. Papers on these substances published between 1939 and 1941 established their structure, antibacterial activity, and clinical efficacy.

In this way, Dubos provided methods through which other antibiotics came to be discovered. His work stimulated Howard Florey and Ernst Chain to look further into Alexander Fleming's penicillin, which was found in 1928 but neither purified nor obtained in large enough quantities for testing. It also stimulated Waksman, René's former teacher, to undertake a search that led to streptomycin. Fleming, Florey, Chain, and Waksman subsequently received Nobel Prizes for their discoveries. Dubos's antibiotics are not the ones widely used for the treatment of bacterial infections, yet he was a true pioneer in the development of antibiotics—the most momentous development in the history of medical science.

By 1941, when René was barely forty, the publicity surrounding his discovery of tyrothricin had made him a famous man. In that year, he reached the highest rank, full member, at The Rockefeller Institute and was one of fifteen members elected to the National Academy of Sciences. He was not, however, carried away by the notion that antibiotics were wonder drugs that would eliminate all disease. In a 1942 article in the *Annual Review of Biochemistry,* he predicted that bacteria would adapt themselves to these drugs and that new strains would become resistant. Having opened the pathway for the discovery of antibiotics, he no longer found it intellectually challenging nor was he interested in devoting his life to finding more of them. He felt this type of research was more suitable for pharmaceutical laboratories.

The fifteen years of this microbiology period were, for the most part, happy and successful. In 1934 he married Marie-Louise Bonnet, a French teacher and pianist, and in 1938 he became an American citizen. He suffered a third episode of rheumatic fever, however, following a severe streptococcal infection. In 1940—under the stress of family problems related to world War II—his wife developed pulmonary tuberculosis, a reactivation of a childhood infection. Her condition grew progressively worse, and René, hoping that she would benefit from a change of environment, accepted a professorship at Harvard Medical School. But Marie-Louise died in the spring of 1942, and René went to Boston suffering from the severe emotional shock of her death.

As George Fabyan Professor of Comparative Pathology and Tropical Medicine at Harvard from 1942 to 1944, René had minimal teaching and administrative responsibilities and could concentrate on research. His letter of acceptance stated his wish to study the physiology and immunology of the tubercle bacillus and tuberculosis infection—an investigation stimulated by the illness and death of his wife. The critical wartime need for tropical medicine research, however, led René to work on the problem of bacillary dysentery.

While in Boston, the Lowell Institute invited him to deliver a series of public lectures on science. The lectures were published as his first book, *The Bacterial Cell in Its Relation to Problems of Virulence, Immunity, and Chemotherapy* (1945). Written in a somewhat philosophical manner (perhaps a reflection of the intellectual atmosphere at Harvard), this classic text reviewed the biochemistry and variability of bacteria and analyzed the mechanisms of pathogenesis in terms of individual components of the bacterial cell.

Despite many invigorating friendships and pleasant social occasions, René was lonely, and Boston became linked in his mind with the loss of his wife. When Thomas Rivers and

Herbert Gasser asked him to return to The Rockefeller in 1944 to head his own laboratory once again, he readily accepted and came back to begin work on tuberculosis.

Dubos's work during his tuberculosis period was not limited to microbiology but included experimental pathology and even clinical studies. René began with the conviction that tuberculosis became an important social disease only under certain social conditions, and he decided to work both on the chemical nature of the virulence of the organism and the social determinants of the disease. Between 1945 and 1960, several outstanding junior and senior colleagues did notable work in the Dubos laboratory. One colleague deserves special mention—Jean Porter, the technician who returned with his staff from Harvard and became his wife in 1946.*

The first major advance in the Dubos lab was a technical one—the introduction of nontoxic wetting agents into the culture medium to enable diffuse growth of tubercle bacilli. Previous research in the field had been hampered by the fact that these organisms were very slow-growing and could be cultured only as a surface pellicle, making quantitation impossible. The new technique brought about a renaissance in tuberculosis laboratory research. Several of Dubos's papers describe the use of these wetting agents (specifically the detergent Tween) and other factors—such as albumin and fatty acids—that led to vigorous, dispersed growth of tubercle bacilli. This advance in culture method enabled researchers to make accurate, quantitative studies of various strains of tubercle bacilli and of their virulence and pathogenic properties, for the first time. The Dubos laboratory could then investigate both host and microbe responses to a number of variables that constituted stresses. They produced an impressive stream of publications between 1948 and 1955 on

* Mrs. Jean Dubos died on August 6, 1988.

such topics as the virulence and immunizing properties of various attenuated BCG strains, the effect of diet on the course of experimental tuberculosis in laboratory animals, and the nature of some tissue substances that inhibited the growth of tubercle bacilli.

In the mid-1950s, Dubos's laboratory work in tuberculosis was supplemented to include human clinical studies done in a special unit of The Rockefeller Institute Hospital. By this time, effective chemotherapy for tuberculosis was available, and the clinical studies were designed to determine whether or not traditional treatment, with prolonged bed rest, was still necessary in patients receiving optimal medications. The findings indicated that prolonged bed rest was not needed. While the tuberculosis clinicians initially were reluctant to accept this result, it was confirmed—and led to the closing of tuberculosis sanitaria, marking the end of an era in the annals of medicine.

This period of clinical studies was particularly exciting for René, who had a special respect for physicians. He was at times a frustrated Ph.D. among the many M.D.s at The Rockefeller. With the tuberculosis project, however, he helped physicians read chest X rays and plan protocols for tuberculosis patients. Most of all, he enjoyed putting on a white coat and joining rounds on the ward to show concern for "his patients."

It was during this period that René began the transition from laboratory scientist to environmentalist. His reference book for physicians and medical students, *Bacterial and Mycotic Infections of Man* (1948), hinted at this shift, stressing as it did the *process* of infectious diseases. In his biography of Louis Pasteur (1950), he turned toward the social and historical study of disease, analyzing his hero's contributions to microbiology in the context of nineteenth century scientific thought—an intellectual life that, in many ways, paralleled

his own. This book was written during his wife Jean's convalescence from tuberculosis. After her recovery, they collaborated on a multidimensional study of this disease, *The White Plague—Tuberculosis, Man, and Society* (1952). Extrapolating from their laboratory studies and using illustrations from medical, social, and literary history, they enlarged the theory that susceptibility to infection was closely related to environmental disturbances.

The key book resulting from Dubos's thoughts about illness, and his most popular work, was *Mirage of Health* (1959). Embodied in its title is his ecological view that man will never be free from disease because he must continuously adapt to environments in flux: Disease results from the dynamic process of life. In *Dreams of Reason* (1961), he questioned overconfidence in science's ability to eliminate disease, advocating, instead, using the means and knowledge of science to determine the kind of health society wants. A more explicit, scientific statement of his views on environmental biomedicine appeared a few years later in *Man Adapting* (1965), which emphasized that states of health or disease are organisms' adaptive responses to environmental challenges. Public response to these writings ensured Dubos a continuous flow of invitations to lecture all over the country on environmental aspects of health and disease.

The last ten years of René's laboratory activity in environmental biomedicine was an outgrowth of the tuberculosis work that incorporated some of his emerging convictions about what causes disease. He conducted studies on the influence of metabolic factors, nutrition, and environmental stresses on host resistance to various infectious diseases. Further bacteriological studies focused on the effects of environmental factors on the composition of normal gastrointestinal flora and its consequences on the host's development and resistance to disease. A final series of papers described lasting

biological effects in newborn mice of early influences on their subsequent development, health, and longevity.

René's "official" retirement years were active ones. In the late 1960s, his prominent role in studying social and environmental effects on health brought him into the mainstream of the environmental movement. His highly publicized view that every part of life is interconnected made him a spokesman for those disturbed about the effects of a rapidly expanding technology on human life. René's eloquence in speaking and writing, coupled with his stature as a scientist, enabled him to bring these issues to the attention of a wide public audience. The well-deserved fame of his final years resulted from his passionate involvement in serving as the "conscience of the environment."

René presented his initial warnings on the health of the earth in *So Human an Animal* (1968), for which he received the Pulitzer Prize. He cautioned that humans are so well adjusted to their surroundings that they no longer mind the stench of automobile exhausts, ugly urban sprawl, "starless skies, treeless avenues, shapeless buildings, tasteless bread, joyless celebrations." He further warned that man's ability to adapt unconsciously to environmental threats means that basic human values will inevitably be destroyed. The book inspired concerned citizens with ideas and motivations for intelligent social action to combat environmental problems. René soon recognized, however, that the movement's zeal was misplaced, turning into a negativism that emphasized desecration and extinction. He changed his approach from provoking awareness of environmental perils to helping the movement develop what he believed they needed to survive: a philosophy of man in his environment.

In many lectures, articles, and books, René created this philosophy, using earthy terms and experiences of daily life to show that humans can act to shape their own destiny

through their manipulations of the environment. This philosophy was based on his conviction that environments and institutions can never be better or worse than the individuals who shape them. *A God Within* (1972) emphasized the importance of developing the distinctive genius of each place, person, and social group, which in turn gives rise to richness and diversity in life. A complementary global attitude appeared simultaneously in *Only One Earth* (1972), written with economist and political scientist Barbara Ward, which served as the unofficial scientific and social guidelines for the First United Nations Conference on the Human Environment.

Beast or Angel? (1974) focused on the difficult choices and creative interventions into nature that humans must make to shape their ways of life, environments, and ultimately their civilizations. *The Wooing of Earth* (1980) presented a balanced primer: Man can improve on nature and even remove environmental degradation through deliberate social action, and the responsible use of scientific knowledge and technology are invaluable to these pursuits. His "Think globally and act locally" became the slogan of environmental activists and is still frequently quoted. His final book, *Celebrations of Life* (1981), amplified his equally well-known dictum that "wherever human beings are involved, trend is not destiny."

René's human-centered views, considerate of both liberals and conservatives in the environmental movement, continue to point the way to policies and solutions acceptable to all. His contributions to a philosophy of the environment can best be summed up in the title he gave himself and his regular column in *The American Scholar* (1970–1980). As a "Despairing Optimist," he lamented the deterioration of human and natural values; nevertheless he persisted in robust expressions of faith in the resiliency of nature and what he called the "creative adaptations" of mankind.

René Dubos achieved worldwide fame as a microbiologist,

experimental pathologist, author, lecturer, and environmentalist—any one of which would have sufficed as a successful career. Despite the unfavorable prognoses of his childhood illnesses, he lived a long and productive life, remaining vigorous until his death at eighty-one. He was endowed with many intellectual talents, great sensitivity, originality, and rigorous self-discipline. His contagious enthusiasm for new ventures and his endless curiosity and wonder about life were especially important for achieving so many goals.

Those of us who knew René as a friend recall personal habits and strengths the public man did not reveal. The outward manifestations of his life were plain and simple, sheltering an intense dedication to his work. Every day, just before 9 A.M., he walked the few blocks from his New York apartment to the laboratory at 66th Street and York Avenue. As soon as he reached his office, he shed his suit jacket for a beige laboratory coat. During the active years he went directly to the lab bench, eager to record overnight results, review protocols, and begin the day's experiments. When he no longer had the pressure of a lab, and writing and lecturing were important activities, he would sit down at his desk and begin to recopy and revise the innumerable pages he had written into the late hours of the preceding night. Writing did not come easily to him, and every manuscript went through many handwritten drafts.

He took numerous rests from his reading and writing throughout the day and would engage one of us in long, involved conversations. These exchanges played a deliberate role in his work, for he used them to reformulate ideas he was struggling with on paper or he indulged in hypotheses, sometimes intentionally extravagant, about ideas he had just read. As we participated in his exacting disciplines of learning, thinking, and writing, we in turn gleaned much from his insights and observations.

Sharing a Rockefeller lunchroom table with René was an exciting and unpredictable experience. There he led discussions on the latest scientific news or, more ardently, on the unusual profusion of interests he had outside the lab. Whether it was growing truffles in the laboratory, infections that produced beautiful variegated tulips, or why water does not freeze in fire hydrants in the winter, he enlivened every meal with remarks and stories that made his company a delight. René also served as editor of *The Journal of Experimental Medicine* from 1946 to 1972 and participated in journal club and lecture activities at The Rockefeller. He did not indulge in sports, clubs, hobbies, or other extracurricular activities, but could be the life of a party on the infrequent occasions when he allowed himself to participate. Like Avery, he avoided much of the busy-ness of science, spending countless hours in thinking and debating what he felt was really important about the countless things that could be done.

Outside the laboratory, René's most enjoyable moments were spent quietly with Jean. In the later years, he would leave The Rockefeller promptly at 5 P.M. and walk briskly home where more discussions, reading, and writing continued late into the night. His travels and lectures were arranged so that he and Jean could spend weekends on their Hudson Highland property in Garrison, New York. René was particularly fond of planting and pruning trees, clearing brush to make trails through hemlock groves, observing the resident frogs and turtles, or tending a small vegetable garden—all the while meditating on his own interventions into nature. It is no surprise that his best writing took shape in these invigorating surroundings.

René Dubos was a scientist in his respect for facts and his exacting requirements for evidence. He was drawn naturally to humanism through his tireless efforts to reconcile man's biological uniformity with his social diversity. His emphasis

on the interplay between living things and their environment made him conceptualize an area of medical science that is only now beginning to grow. He contributed to a philosophy of scientific humanism by perceiving that all forms of life on earth are integrated components. René will be remembered for formulating broad questions affecting human life, many of which are not yet ripe for solution. Fortunately, his extensive legacy of books and essays will continue to provide perceptive counsel for generations to come.

HONORS AND DISTINCTIONS

AWARDS AND MEMBERSHIPS

1940 John Phillips Memorial Award, American College of Physicians
1941 E. Mead Johnson Award, American Academy of Pediatrics
1945 Member, National Academy of Sciences
1945 Member, The Century Association
1946 Gordon Wilson Medal, American Clinical and Climatological Association
1948 Lasker Award, American Public Health Association
1948 Member, Practitioners' Society, New York City
1950 Member, Academia de Ciencias Fisicas, Matematicas, y Naturales, *Venezuela*
1951 Trudeau Medal, National Tuberculosis Association
1954 Member, American Philosophical Society
1958 Howard Taylor Ricketts Prize, University of Chicago
1960 Fellow, American Academy of Arts and Sciences
1960 Passano Foundation Award
1960 Robert Koch Medal, Robert Koch Foundation, Berlin
1963 Phi Beta Kappa Award in Science for *The Unseen World*
1965 Phi Beta Kappa Award in Science for *Man Adapting*
1966 Arches of Science Award, Pacific Science Center
1968 Two Cultures Award, Flushing High School, New York City
1969 Pulitzer Prize for Nonfiction for *So Human an Animal*
1969 Benjamin Franklin Fellow, Royal Society of Arts
1970 Harold Terry Clark Medal, Cleveland Museum of Natural History
1972 Frances K. Hutchinson Medal, Garden Club of America
1972 Prix de l'Institut de la Vie, Paris
1973 Bradford Washburn Award, Boston Museum of Science
1975 Cullum Geographical Medal, American Geographic Society
1976 Tyler Ecology Award, Pepperdine University
1979 Wilder Penfield Award, Vanier Institute of the Family
1979 Member, American Academy and Institute of Arts and Letters

HONORARY DEGREES

Forty-one honorary degrees, including three honorary doctorates of medicine, from thirty American and eleven foreign institutions, 1941 through 1981

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1929

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1930

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1931

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1932

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1935

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1936

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1937

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1938

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With Robert H. S. Thompson. The isolation of nucleic acid and nucleoprotein fractions from pneumococci. J. Biol. Chem., 125:65–74.

1939

Studies on a bactericidal agent extracted from a soil bacillus. J. Exp. Med., 70:1–17.

1940

The adaptive production of enzymes by bacteria. Bact. Rev., 4: 1–16.

The effect of specific agents extracted from soil microorganisms upon experimental bacterial infections. Ann. Intern Med., 13:2025–37.

1941

With Rollin D. Hotchkiss. The production of bactericidal substances by aerobic sporulating bacilli. J. Exp. Med., 73:629–40.

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1943

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1945

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