NATIONAL ACADEMY OF SCIENCES

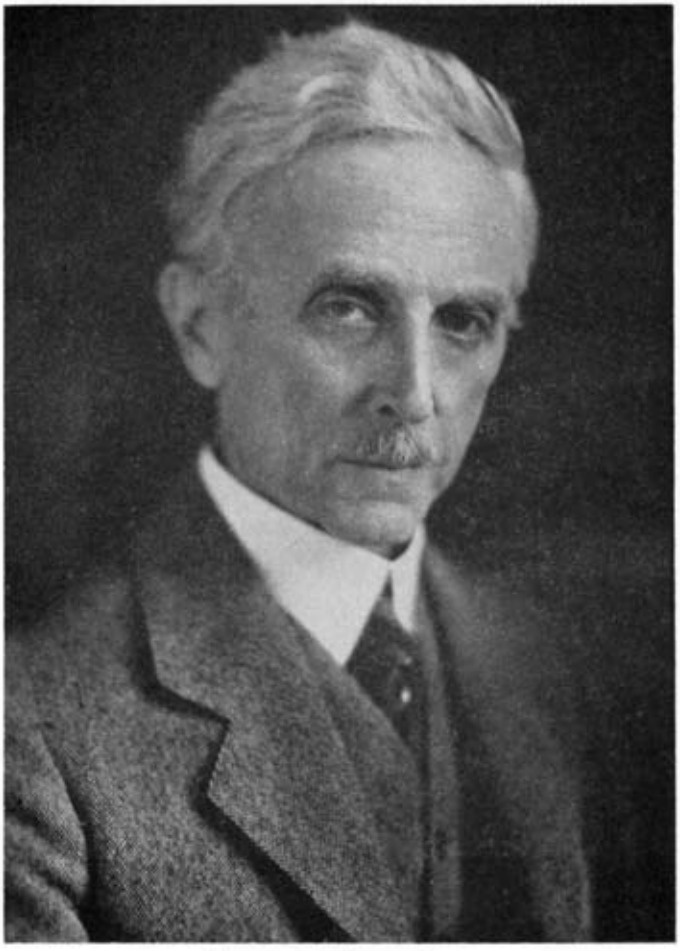
LEO LOEB

1869—1959

A Biographical Memoir by

ERNEST W. GOODPASTURE

Biographical Memoir



Leo Loeb

LEO LOEB

September 21, 1869–December 28, 1959

BY ERNEST W. GOODPASTURE

LEO LOEB was born on September 21, 1869, at Mayen, a little town in Germany, near the junction of the Mosel River and the Rhine. He became an orphan at the age of six but remained in his homeland with relatives to receive his early education. Later, however, he preferred to pursue his medical studies in Switzerland, where in 1897 he earned a degree of Doctor of Medicine at the University of Zürich. In the same year he immigrated to America, and he became a citizen of the United States in 1902. After a distinguished academic career in pathology, characterized by exceptional productiveness in research and teaching, he died at his home in St. Louis on December 28, 1959, in his ninety-first year.

Many honors came to Dr. Loeb, including election to the National Academy of Sciences in 1937. He retained active membership until his death and left with the Academy an interesting and informative biographical sketch and an almost complete bibliography, both of which have been of valuable assistance in the preparation of this Memoir. In 1958 his Autobiographical Notes were published in the second volume of *Perspectives in Biology and Medicine*. These notes made readily available many details of his life and work which need not be repeated here.

Nearing the end of a long life and burdened with infirmities of age notwithstanding, Leo Loeb in his final years was working on the preparation of two books. The subjects had occupied his thoughts

for a long time. One manuscript was to consider the causes and nature of cancer; the other would deal, probably quasi-scientifically, with the broad topic of human relations. He was deeply absorbed in these projects and hoped to complete the manuscripts in due course, but at times his failing eyesight and general infirmity made the task seem too much for him.

The two groups of problems which thus concerned him in his declining years seem on first glance to be wide apart, but the Autobiographical Notes published about a year before his death perhaps forecast to some extent a relationship which he had in mind in preparing them simultaneously. In his autobiographical sketch he considered two aspects of his life which, though different, were interdependent; namely, his life of scientific endeavor and his reflections upon socio-psychical problems and experiences as manifestations of individuality. Whether he intended to emphasize the interrelationship or not, one may see that his treatment of the problems of cancer would have served to present the method and preoccupation of science, to some extent, with improvement of human welfare. This sort of progress of science would condition the reserved optimism of his conclusions concerning the outcome of human socio-psychical experience. Finally, the two books with such a message of optimism would serve as his valedictory.

In a few sentences of his autobiography, Leo Loeb left a glimpse of his kindly spirit and his conditioned optimism. In concluding a consideration of some general problems of human experience he offers his opinion that a diminution of cruelties in the life of individuals, groups, and nations is possible. Amongst a few other orderly suggestions for the accomplishment of this worthy objective, he bids us to "give simple psychical goods—kindness, understanding, appreciation, and affection—as much as possible to others. Thus, with patience and good will, we may hope that the values of life will increase and its acerbities will diminish." Science, he thought, by discovering means that make possible a relatively healthy development of body and mind, and by serving as a basis of ethics through

enabling individuals to recognize themselves in others and others in themselves, can justify a degree of optimism concerning improvement of the human condition.

Those who may be interested will find in his Autobiographical Notes the story of many phases of his career, such as: a brief account of his early life and education in Germany; his dissatisfaction with the contemporary emphasis on formal linguistic problems in the educational program of the Gymnasia there, to the neglect in his opinion of literary aspects and of science; his disapproval of the growing nationalism and militarism in his native land in the Nineties, which sent him eventually to democratic Switzerland for a medical education; his visits to the United States to join his brother Jacques at Woods Hole; his final immigration to this country to become a citizen of a democracy which he admired and desired to serve; his adoption of the discipline of pathology as a framework for a career of research and teaching; his early professional associations and final move to St. Louis, eventually to occupy the Chair of Pathology at Washington University; his marriage to Dr. Georgiana Sands and their happy life together until the end. In addition to an autobiographical sketch, Dr. Loeb left with the National Academy of Sciences an almost complete bibliography of over 400 titles extending from 1896 through 1953. The present Memoir will be concerned only with the development and fruition of some programs of research which these reports in the scientific literature record.

There was a consistency, coherence and continuity in the core of Dr. Loeb's scientific work which permit one to follow successive stages in the progress of his studies and to observe their relation to contemporary advances in the general fields of his interest. The continuity starts from the beginning of his scientific career and this emphasizes the importance of the circumstances of his initial environment, for it is evident that they made a lasting impression upon the direction and thread of his thought, inquiry and developing insight.

Having finished the final years of clinical training at the Uni-

versity of Zürich, he passed the Swiss state examination which permitted him to practice there, but he chose to stay on at the University to complete a thesis as prerequisite for the degree of Doctor of Medicine. For this purpose he undertook experimental investigations in the Pathological Institute of Hugo Ribbert, Professor of Pathology. Loeb makes no comment as to reasons for working with Ribbert, but in retrospect one might be permitted to make certain surmises concerning circumstances which possibly influenced him to some extent to do so, and perhaps helped also to create an atmosphere and environment that appealed to his imagination and interested him in choosing a scientific career in experimental biology and pathology.

Hugo Ribbert (1855–1920) was not only a distinguished pathologist of morphology, but an experimental scientist as well. He was no doubt favorably known as a teacher and investigator not only to Leo who had studied medicine at Zürich, but also to his brother Jacques, ten years Leo's senior, who had worked at Zürich after his return to Europe from the United States in 1900. Leo, while a student at Zürich, had visited his brother at Woods Hole on two occasions; and one may suppose he had become well acquainted with the group of biologists who gathered there and the scientific interests which drew them together. Two influences were thus brought to bear upon him as he approached the critical decision as to what graduate work he would undertake and what career really beckoned him. These influences were the Institutes of the Medical School at Zürich and his associations at Woods Hole. Hugo Ribbert seemed to bring the two together congenially.

When Wilhelm Roux proposed in 1894 the founding of a new journal, the *Archiv für Entwicklungsmechanik der Organismen,* a number of distinguished scientists, especially of Germany, the United States of America and Italy, gave the project their endorsement. Among those whose support Roux acknowledged were Jacques Loeb of Chicago (lately of Bryn Mawr College), Thomas Hunt Morgan of Bryn Mawr, and Hugo Ribbert of Zürich. The first contribution

to the new journal, following one by Roux himself, was by Hugo Ribbert, and in the first volume was a paper by Jacques Loeb. Thus the developmental mechanics or causal morphology of organisms which the journal was designed to promote served as a focus of interest for both Ribbert and the group at Woods Hole, and it served, understandably, as the outlet for Leo Loeb's first publications. In volume six (1898), the first paper is the product of his work on his thesis with Ribbert.

In this paper he states that Herr Professor Ribbert assigned to him the problem of the outcome of transplanting white skin of guinea pigs into black skin and vice versa. Ribbert's interest at the time in the general subject of tissue transplantation is indicated by his paper on changes in transplanted tissues; this appeared in the same volume. Likewise, in the same volume a little later appeared Leo's extensive study of regeneration of epithelium which occupied 63 pages, and was accompanied by eight pages of colored illustrations. This study was based upon observations which he made during his first inquiry, and it indicates his intellectual maturity and early ability to undertake independent investigations, to interpret his own observations and to correlate them with available literature. In the numerous references accompanying this thorough study, occasion was found to refer to several publications by Jacques Loeb, which suggests the importance at this early period of his visits to Woods Hole. In his studies of transplantation of skin and of regenerating epithelium, Leo Loeb observed a phenomenon which led him to the brink of modern tissue culture in artificial media.

By the time his first publication of experimental research appeared (1898), he was already established in Chicago where he went to be near his brother, no doubt, when he arrived in this country for good in 1897. There he continued his investigations, in part at least, in a private laboratory, which he outfitted and supplied with experimental animals. This was in a room he rented back of a drug store. For a while he undertook to practice medicine too, having obtained an

Illinois license. But it was no use; he was after all a scientist, and it suited him better to join the staff of an institution which later became the Medical School of the University of Illinois.

Here he continued to carry out experiments concerning the processes of wound healing in the skin of guinea pigs, and became especially interested in the mode of ingrowth of regenerating epithelium into blood clots. He observed that tongues of epithelium could divide and become separate and distinct masses of cells. These could penetrate into the clot and there separate into new strands. This appeared to him to be a form of tissue growth which could sustain itself indefinitely presumably, provided temperature and nourishment were suitable. To vary the environment he placed slivers of agar and of coagulated serum (Loeffler's medium) into the wounds, and into these media also the epithelial buds and separate cellular masses would penetrate, independent of connective tissue, blood vessels, and nervous influences. He described also the implantation of bits of epithelium, obtained sterilely from fetuses of guinea pigs, embedded in slivers of agar and coagulated serum. In these artificial media the bits of epithelium grew without the accompaniment of connective tissue or any other tissue. He thought such a method might be applied to the study of independent growth of other tissues suitable for the purpose, and substances might be mixed with the agar or serum or be introduced into the surrounding tissue fluid to study the reaction of the growing tissue to irritants of one sort or another. Although Loeb did not perfect *in vitro* culture of cells, he conceptually paved the way. Later on his comment on these early (1898–1902) studies was as follows: "To our knowledge in these our earlier experiments for the first time the attempt was recorded in the literature to grow tissues of higher animals under artificial environments that differ from those found in the body under natural conditions; to separate experimentally growing epithelium from connective tissue cells."

These early studies of tissue growth and transplantation were soon followed by others, including the transplantation of tissue from

tumors of animals into the bearing host and into other animals of the same and different species. Through the years reactions to transplanted tissues were to expand into studies and analyses which extended throughout his investigative career and led to such syntheses as his integration of biological characteristics of individuality.

Dr. Loeb was one of the first to succeed in the serial transplantation of tumors, and the use of this method contributed much to knowledge of experimental neoplasms. It is still widely used in studies of the origin and behavior of cancer cells.

In early studies of cancer, a subject which soon became a major interest, Dr. Loeb, assisted by Miss A. E. C. Lathrop, demonstrated the influence of hereditary factors in the origin and incidence of certain cancers, particularly those occurring in the mammary glands of female mice. As a result of these studies, he discovered that hormonal factors in the environment acting upon tissues sensitized by heredity could bring about cancerous transformation, and that suppression of certain hormones could reduce the incidence of mammary cancers in mice.

The problems of cancer occupied much of Dr. Loeb's thought and work and the development of this interest constituted an important aspect of his scientific career. His initial experiments on transplantation of skin in guinea pigs and his observations upon the regeneration of epithelium in the wounds directed his attention to similarities in the appearance of growing strands of epithelium and the invasion of cancer. Soon he was engaged in the study of transplanted cancer and the phenomena of resistance to transplants in general in some animals of the same and in practically all hosts of different species. His studies of resistance to transplants impressed upon him the importance of the lymphocytic reaction long before evidence of the formation of antibodies by cells of this series was available. He was interested also in genetic differences of hosts in reactions to transplants, both normal and cancerous.

By means of large-scale experiments, begun early in his career sometime between 1903 and 1910 with Miss A. E. C. Lathrop, the

relation of hereditary genetic factors to the incidence of mammary cancer in different strains of mice was investigated. These studies continued with Miss Lathrop until her death in 1920, then with other associates. Separate families and strains of mice were bred in the same environment and the rate of cancer incidence in successive generations was determined. It was discovered that while certain strains had a rate approaching zero, in others it was 80 per cent or more. In successive generations these differences remained quite constant for the respective strains. It was Loeb's opinion that hereditary genetic factors may cooperate with stimulating factors in inducing cancer. In general the former are limited to a specific organ or tissue and the mechanism of the hereditary transmission of cancer in a certain organ may differ from that in another. Different tumors consequently are genetically independent of one another.

In pursuing this concept, Dr. Loeb made a discovery which constituted an important contribution to the science of oncology and had practical applicability as well. This was his observation that in the case of mammary gland carcinoma of mice differences in the expression of hereditary tendency to these neoplasms correspond in the main to the graded ability of the gland tissue to respond to the action of ovarian hormones by growth. This fact is of no less importance because Bittner discovered later that a virus transmitted by the milk of the mother participates in the production of these cancers.

In breeding experiments he established the fact that, in addition to heredity, functional activity of the sex organs played a significant part, not only in the origin of mammary cancers in mice, but in its prevention or suppression. If he prevented breeding the rate of these tumors receded, and castration of female mice was an even greater deterrent. The earlier the ovaries were removed the greater the reduction in cancer rate. Hence arose his interpretation that heredity serves to sensitize a tissue for growth if stimulated by hormones or other irritants.

These studies led to the discovery of the effect of estrogen on the origin of mammary cancer in mice acting in conjunction with he-

reditary factors and, as now known, with the virus-like milk factor of Bittner.

Other extensive investigations in the field of experimental endocrinology demonstrated the stimulating, hyperplastic effect of anterior pituitary extract on the thyroid gland, and the associated changes and symptoms simulating those of Graves disease. His earlier work on transplantation of thyroid tissue had demonstrated in guinea pigs that successful grafting was not, as Halstead supposed, dependent upon a deficiency of this tissue.

An inverse relation seemed to him to exist between the intensity of stimulating factors and the strength of the genetic factors needed for the transformation of normal into malignant tissue. Either of these two sets of factors however, acting alone, could be effective in certain cases. Loeb expressed this relation by the equation: H (hereditary constitution) $\times$ S (stimulus) $=$ C (cancer).

The demonstration of the influence of ovarian hormones, particularly estrogen, in the occurrence of mammary cancers came about through an unrelated set of investigations in which Dr. Loeb became interested in the functions of the ovary and in the phenomena of the sexual cycle. He studied the significance of the corpus luteum throughout the duration of that cycle, and analysed its specific effects. In these studies he established the fact that the transitory neoplasms of the uterine mucosa, deciduomas and placentomas, could be caused mainly by two factors: first, a sensitization of the uterine mucosa by the hormone of the corpus luteum, followed secondarily by the application of mechanical stimuli, such as a wound or the introduction of a foreign body into the uterine lumen.

In 1903 Loeb spent a year with Professor Adami in Montreal, and then accepted a position in the department of pathology at the University of Pennsylvania with Professor A. J. Smith. When he left the latter position in 1910 to accept the directorship of cancer research at the Barnard Skin and Cancer Hospital in St. Louis, he made it clear that he would devote his investigations mainly to fundamental problems in this field. This he did during the five years

of his tenure and continued to do when he then accepted the professorship of comparative pathology at Washington University in 1915. Nine years later he was still a fundamentalist in research when he succeeded Dr. Eugene Opie as head of the department of pathology there.

Because much of his work concerned tumor growth and cancer, it is of interest to observe the changes in Dr. Loeb's concepts of the etiology of cancer at different periods of his investigations. It seems evident that, when he began his serial transplantations of tumors in Chicago, he was seriously considering the possibility of an infectious etiology, although he did not consider an extracellular cancerogenic microorganism as probable. At the outset of his investigation in this field he, with Dr. G. Jobson, showed that carcinoma of the eyes of cattle was frequent in the United States. Without success he attempted transplantation of this tumor and then transmission of it by means of filtered press-juice, to test for the presence of ferments or other agents in or between the cells which might cause the growth. Even with Berkefeld filtrates the results were negative. This was in 1899, and constituted his first attempts at tumor transplantation. He succeeded later in transplanting a tumor of the thyroid gland of rats by inoculation, but only under conditions which seemed very likely to transmit live tumor cells with the inoculum. It is of interest that the rat bearing this tumor was given to him by his Chicago colleague, Dr. Maximilian Herzog, who was also investigating the etiology of cancer while working in the laboratory of pathology of the Chicago Polyclinic. Dr. Herzog was trying to induce a tumor by means of a cell-free substance derived from a cancer of rats (apparently the same tumor which he gave to Dr. Loeb). Bacteria-fast Pasteur filters were used.

Filtration studies at this time were based on the fact that Loeffler and Frosch (1898) had filtered the virus of foot-and-mouth disease, Walter Reed the virus of yellow fever (1900), Nicolle and Adil Bey the virus of cattle plague and Marx and Sticker the virus of epithelioma contagiosum, thus proving that certain infectious agents, too

small to be seen with the light microscopic, can pass through the pores of a bacteria-fast filter.

Loeb's filtration experiments as well as those of Herzog were negative, but the latter made at this early date the following astute and perhaps prophetic statement: "I have also in these and other experiments considered the possibility that ultramicroscopic organisms, which might be the cause of malignant tumors, might be so strictly parasitic that they cannot exist outside of living cells." It was years later (1910) that Peyton Rous filtered the agent of a chicken sarcoma which pioneered the present-day exploration of the relation of viruses to cancer.

Thus early (1899–1902) Loeb was alert to the possibility of an agent separable from cells as the cause of cancer though doubtful of an infectious etiology. After about thirty years of subsequent research he published a review of the contemporary status of knowledge concerning the cause of cancer. In the meantime he and E. E. Tyzzer had made the suggestion that cancerous growth might profitably be conceived to be due to a somatic mutation, which signifies "a change in the gene constitution of a few localized cells; this mutation would explain the persistence of the characteristics which tissue cells assume when they become transformed into tumor cells." Somatic mutation is to be distinguished from a germinal mutation which, by affecting the germ cells, is responsible for hereditary changes in organisms as a whole. It did not seem probable to him, from what was known at that time concerning the role of extraneous growth substances (in which group he placed the Rous agent) and of internal secretions, interacting with heritable factors in the etiology of cancer, that microorganisms could be the essential cause, thereby making cancer a peculiar type of infectious process—a view having much favor at the present time. He considered somatic mutation to be the most likely cause, assuming at the same time that the proneness to undergo this change would depend largely upon the genetic constitution which these somatic cells received from the germ cells.

As time went on, doubts continued to arise in his mind as to the adequacy of this explanation of cancer, and in his book *The Biological Basis of Individuality* (1944) he gives it as his view that serious objections to the somatic mutation theory render this explanation probably erroneous. The view that viruses are the essential cause, he realized, has difficulties of application to many cancerous states, although he considered it unwise to rule this possibility out altogether. In his opinion at this time the most likely general explanation of the cancerous process was his own theory that step-by-step increases in growth momentum of tissues, stimulated in various ways, lead to intermediate stages of sensitization, and ultimately to irreversible cancerous proliferation, perhaps through the mediation of an autocatalytic growth substance. This explanation is more diffuse than the other two and seems to indicate a postponement of judgment as to the most productive experimental hypothesis.

Finally in his discussion of *The Causes of Cancer* in 1947, there was a tendency to unify or at least to correlate the concepts of somatic mutation, viral activity, and his own view of an autocatalytic growth stimulating substance which gradually developed and became permanent in cancer cells. Objections to the application of the term "somatic mutation," he thought, hold good only if we use this term in the strict genetic sense. If we should extend the definition to include not only changes in genes and chromosomes, but also a series of steadily increasing cytoplasmic changes, then the origin of cancer might be attributed to somatic mutations; and he himself had used the term in this wider sense. Thus interpreted, however, somatic mutation would really be synonymous with a developed autocatalytic growth-stimulating agent. Loeb believed that the autocatalytic growth factor proposed by his theory might be separated from cancer cells and transmitted to related hosts to induce other cancerous growths. If so, it would act like or be essentially a virus, although one of immediate endogenous origin. Thus, he would bring together somatic mutations, viruses, and autocatalytic growth substances into harmony and possibly unity as concepts of the cause of cancer. The

resolution of such problems he conceded, however, must be left to future investigations, which might make more definite the lines of demarcation between those tumors in which true viruses are involved and others which are caused by autocatalytically propagating, intracellular growth substances.

In the midst of continuous studies of growth and differentiation of tissues, which persisted throughout his scientific career as the unbroken thread of his interest, Dr. Loeb found time to divert his attention now and then to a number of other problems of pathology with interesting results. Through his early sojourns and associations at Woods Hole he undertook comparative inquiries into the coagulation of blood of invertebrates. Among other discoveries in this diversion he found that specific adaptations exist between the genetic constitution of tissue coagulins and the types of blood whose clotting would be induced by these substances respectively. Studies of blood coagulation led to the demonstration, with A. J. Smith, that the anterior portion of the parasite *Anchylostomum caninum* contains a strong anticoagulant. This discovery, applied by others to the similar parasites of man, helped explain the anemia which is such a prominent result of heavy intestinal infestation with these worms.

Still other studies, particularly with associates, were concerned with such pathological phenomena as thrombosis, edema, myocarditis, and hepatic necrosis, but they did not long divert his thought and inquiries from the subject of growth and, later particularly, of the specificity of tissues as studied by the method of transplantation. The analysis of specific qualities of individual tissues of an individual animal or of a species, was the subject of numerous papers by Loeb and his associates, and finally led him to a synthesis which was the subject of his book, published in 1944 as *The Biological Basis of Individuality*.

At the onset of the twentieth century, very little was known about the compatibility reactions of hosts toward transplanted tissues of the same and different species. In general, it was known that blood and other fluids of one species of animal were injurious when trans-

fused into individuals of another species. Even surgeons, acquainted especially through the investigations of Reverdin and Thierch with the fact that grafting could be used for therapeutic purposes, laid little stress upon differences between individuals of the same species in respect to successful takes. It was during the first decades of the present century that distinctions existing between tissues of different individuals of the same species received serious attention. Amongst the pioneers who opened up this field of research and cultivated its scientific aspects with great success was Leo Loeb, whose experimental investigations began with study of the behavior of transplanted skin of guinea pigs as the subject of a thesis for the degree of Doctor of Medicine under Ribbert. His attention soon turned to the transplantation of tumors. In these studies he found that while autotransplanted pieces of tissue continued to live, and in some cases proliferated, homoiotransplanted tissue died.

Continuing research on transplantation showed that some tumors of laboratory animals can be homoiotransplanted in series, whereas this does not succeed with normal tissues, nor in fact with a majority of tumors.

His experiments supported the conclusion that in principle the host reacts in a similar way against normal tissues and against tumors, but certain modifications may occur in the case of the latter because of their different growth energy and their ability of adaptation.

Loeb's histological studies of the fate of transplanted tissue, both normal and tumorous, were probably the first, certainly the most detailed, investigations of this kind. With his associates he noted and carefully evaluated the significance of the lymphocytic infiltration about and into grafts. This became such a decisive tool in his hands that with it he was able to determine quantitatively the degree of compatibility between host and implant and, together with reactions of connective tissue and blood vessels, their genetic relationship.

As his experience with such a delicate method increased, Loeb realized more and more that he was concerned in this field with fundamental and far-reaching biological phenomena—the phenom-

ena of specific differentiation which exist not only in all classes of living things, but also within the tissues of an individual body. From the facts which he observed experimentally, he developed a theory of organismal differentials in which he assumed that all or almost all the tissues of an individual within a certain species have in common certain chemical characteristics which may be designated as individuality differentials; in a similar way all the tissues have organismal differentials. These differentials determine the reactions between donor grafts and host. In the inadequate environment of a near relative of the donor or into an unrelated individual of the same or a different species the individuality differentials assume properties manifesting themselves as specific toxins against which the host reacts. The lymphocytes are attracted, the vascular supply is diminished and fibroblasts are stimulated to greater activity.

Through the mosaic pattern of genetic and organismal differentials which he observed and quantitated in terms of host response, Dr. Loeb arrived at his concepts of individuality. In concluding his comprehensive study as presented in *The Biological Basis of Individuality,* he considered it to be these relations between the individuality and the surrounding world, including both physical and psychological manifestations, which constitute the main problems philosophy has dealt with throughout its history. It is probable that he was concerned with the characteristics of individuality, as expressed in the psychical-social relation, in the preparation of one of his proposed books at the time of his death.

In the course of his long academic life, Leo Loeb was assisted by many loyal associates, some of whom were students guided by his genius. His thought turned to all of them in the concluding paragraphs of his Autobiographical Notes, and he sent to them this message, "In this autobiographical account I have not been able to mention my friends and to refer to my research associates who have cooperated with me in the work which has been described in this account; but their memory is dear to me and represents a precious part of my life."

KEY TO ABBREVIATIONS

Acta un. internat. contre canc.=Acta union internationale contre cancer
Am. J. Anat.=American Journal of Anatomy
Am. J. Canc.=American Journal of Cancer
Am. J. M. Sc.=American Journal of Medical Sciences
Am. J. Ob. Gyn.=American Journal of Obstetrics and Gynecology
Am. J. Path.=American Journal of Pathology
Am. J. Pharm.=American Journal of Pharmacology
Am. J. Physiol.=American Journal of Physiology
Am. J. Roentg.=American Journal of Roentgenology
Am. J. Surg.=American Journal of Surgery
Am. Med.=American Medicine
Am. Nat.=American Naturalist
Anat. Anz.=Anatomische Anzeiger
Anat. Rec.=Anatomical Record
Ann. Int. Med.=Annals of Internal Medicine
Ann. N.Y. Acad. Sci.=Annals of the New York Academy of Sciences
Arch. Entwcklgsmech. Organ.=Archiv für Entwicklungsmechanik der Organismen
Arch. exp. Zellfor.=Archiv für experimentelle Zellforschung
Arch. ges. Physiol.=Archiv für die gesammte Physiologie
Arch. Int. Med.=Archives of Internal Medicine
Arch. klin. Chir.=Archiv für klinische Chirurgie
Arch. mik. Anat.=Archiv für mikroskropische Anatomie
Arch. Path.=Archives of Pathology
Aus. J. Exp. Biol. Med. Sc.=Australian Journal of Experimental Biological and Medical Science
Beitr. chem. Physiol. Path.=Beiträge zur chemische Physiologie und Pathologie
Berl. klin. Wchnschr.=Berliner klinische Wochenschrift
Biochem. Centrbl.=Biochemische Centralblatt
Biochem. Ztschr.=Biochemische Zeitschrift
Biol. Bull.=Biological Bulletin
Biol. Sym.=Biological Symposia
Bull. J. H. H.=Bulletin of the Johns Hopkins Hospital
Bull. N.Y. Acad. Med.=Bulletin of the New York Academy of Medicine
Bull. St. L. M. Soc.=Weekly Bulletin of the St. Louis Medical Society
Cal. West. Med.=California and Western Medicine
Centrbl. allg. Path. path. Anat.=Centralblatt für allgemeine Pathologie und pathologische Anatomie
Centrbl. Bakt.= Zentralblatt für Bakteriologie
Clin. mod.=Clinica moderna
C. rend. Soc. biol.=Comptes rendus de la Société de biologie
Dtsch. med. Wchnschr.=Deutsche medizinische Wochenschrift

Fol. haem.=Folia haematologica
Internat. Clin.=International Clinics
Intrst. M. J.=Interstate Medical Journal
J.A.M.A.=Journal of the American Medical Association
J. Biol. Chem.=Journal of Biological Chemistry
J. Can. Med. Assn.=Journal of the Canadian Medical Association
J. Canc. Res.=Journal of Cancer Research
J. Comp. M. Vet. Arch.=Journal of Comparative Medicine and Veterinary Archives
J. Exp. Med.=Journal of Experimental Medicine
J. Gen. Physiol.=Journal of General Physiology
J. Imm.=Journal of Immunology
J. Inf. Dis.=Journal of Infectious Diseases
J. Med. Res.=Journal of Medical Research
J. Mo. M. A.=Journal of the Missouri Medical Association
J. Morph.=Journal of Morphology
J. Nat. Canc. Inst.=Journal of the National Cancer Institute
J. Pharm. Exp. Therap.=Journal of Pharmacology and Experimental Therapeutics
J. Rad.=Journal of Radiology
Klin. Wchnschr.=Klinische Wochenschrift
M. Life=Medical Life
M. News=Medical News
M. Rec.=Medical Record
Mont. M. J.=Montreal Medical Journal
N. Y. Med. J.=New York Medical Journal
Penn. M. J.=Pennsylvania Medical Journal
Phila. Polycl.=Philadelphia Polyclinic
Physiol. Rev.=Physiological Reviews
Physiol. Zool.=Physiological Zoology
Pop. Sci. Mth.=Popular Science Monthly
Pr. méd.=Presse médicale
Proc. Am. Phil. Soc.=Proceedings of the American Philosophical Society
Proc. Am. Physiol. Soc.=Proceedings of the American Physiological Society
Proc. Nat. Acad. Sci.=Proceedings of the National Academy of Sciences
Proc. Path. Soc. Phila.=Proceedings of the Pathological Society of Philadelphia
Proc. Soc. Exp. Biol. Med.=Proceedings of the Society for Experimental Biology and Medicine
Sci. Month.=Scientific Monthly
S.G.O.=Surgery, Gynecology and Obstetrics
Tr. Acad. Sci. St. L.=Transactions of the Academy of Science of St. Louis
Tr. Assn. Am. Phys.=Transactions of the Association of American Physicians
U. Cal. Pub. Physiol.=University of California Publications on Physiology

U. Penn. M. Bull.=University of Pennsylvania Medical Bulletin
Va. M. Semi-month.=Virginia Medical Semimonthly
Virch. Arch.=Virchows Archiv für pathologische Anatomie und Physiologie und für klinische Medizin
Wash. U. Med. Alum. Quart.=Washington University Medical Alumni Quarterly
Zentrbl. Physiol.=Zentralblatt für Physiologie
Ztsch. Imm. u. exp. Ther.=Zeitschrift für Immunitätsforschung und experimentelle Therapie
Ztsch. Krebsfrch.=Zeitschrift für Krebsforschung

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