of the wives and children of these sufferers on relief. It does not include the cost of home care for thousands of other patients who are not in institutions. It does not include the cost of care for 160,000 patients who have cardiovascular syphilis or for the care of the wives and families of the 40,000 of them who die every year.

Some of the 60,000 babies who are born every year with congenital syphilis will die, but many of the others will grow up to be public charges.

Studies recently completed by the Public Health Service show that the loss of life expectancy for a syphilitic white male between the ages of 30 and 50 years as against the life expectancy for the general population varies from 19.5 to 16.7 per cent. And yet we all know that life insurance companies still do not include the Wassermann test as a part of the routine physical examination for life insurance.

I can not estimate the total financial cost to this country for these latter groups any more than I can estimate in objective terms the real cost of a war or a depression. But I can point out that the first $41,000,000 for institutional care is in itself a much larger figure than any one has yet suggested for the control of syphilis.

On that basis public funds for the control of syphilis become a matter of simple economy. One does not consider a balance sheet solely in terms of amounts expended but in terms of a balance between money spent and expected returns. That kind of economics is well understood by every business man when he deals with his own business.

This is the plan of our attack upon a single battle field. It is, in small, a blueprint for the national health program along a battle front. Few things which I have said about the economic gains from controlling syphilis but apply equally to other diseases—to pneumonia, to tuberculosis, to pellagra, to cancer, to malnutrition. In every field, however far our knowledge may have gone, we have that same basic problem of research. We must perfect our instruments. In every field there are techniques developed for applying that knowledge in public health administration or the means to so apply it can be perfected. This is the union of science and engineering. We are faced with the same social facts; the same shortage of hospital and other physical facilities for good health; the same lack of laboratory facilities; the same gap between individual income and the necessary minimum of medical care. It whatever field we enter we are reminded that bad health is waste. Just as it is good economics to fight syphilis, it is good economics to fight disease wherever we find it and to improve the efficiency of human beings, the greatest of our national resources.

THE SOCIAL SCIENCES AND ENGINEERING EDUCATION[1]

By Dr. WILLIAM E. WICKENDEN
PRESIDENT OF THE CASE SCHOOL OF APPLIED SCIENCE

AN engineer is a man who spends his life in solving problems. These problems assume an infinite variety of form and detail, but always end in two questions —"Will it work?" and "Will it pay?" The scale of the solution or judgment demanded in an engineering problem is never universal and seldom widely embracing. What the man in the head office wants to know is not "Will it always work?" or "Will everybody profit?" but rather "Will it work within stated limits or under particular circumstances?" and "Will it pay the investor within a given time?" For results beyond fixed limits the engineer is not held to account, but within them he is expected to be virtually right every time. Speculative inquiry and the formulation of broad judgments from loose masses of data, he willingly leaves to others, contenting himself with limited knowledge of assured character. The business world expects an engineer to know certain elemental things about the law of contracts, but when he gets into an involved situation he is expected to consult legal counsel. In much the same way, the engineer is expected as a matter of course to know certain fundamental facts and principles of economics, government, sociology and psychology, but a wise instinct prompts him to defer to expert knowledge and judgment where involved issues are concerned.

In this introductory statement, I have attempted to reduce the engineer's hard-headed philosophy to thumb-nail dimensions. Admittedly, it is not a satisfactory philosophy. It may satisfy the individual engineer in his day-to-day work, but it does not satisfy a profession increasingly proud of its achievements and aware of their revolutionary social results. Engineers do not like to think that the world has been transformed in the last century and a half merely as a by-product of their success in solving a long series of specific problems; that civilization has become what

[1] Address of the retiring vice-president and chairman of the Section on Engineering, American Association for the Advancement of Science, Indianapolis, December 29, 1937.

it is merely because Watt invented a condensing engine, Bessemer a cheap way to make steel, Goodyear a way of toughening rubber, Taylor a scientific way to shovel ore, De Forest a three-element electronic valve and so on *ad infinitum.* The idea of merely casual progress is too fatalistic. Like other men, engineers would prefer to discern some guiding principle—some thread running through the separate beads of technical achievement—which would reassure them as to the reality of progress. What is more, they would like to think that they have consciously had a part in threading the string through the beads, and should of rights have more to say in the future as to what is to be done with the beads.

Nor does the thumb-nail statement of a hard-headed philosophy satisfy the leaders of society outside of the profession. President Roosevelt, inspired by his adventures in social planning and his crusades against the power industry, admonished the educators of engineers a little over a year ago as follows:

> Events of recent years have brought into clearer perspective the social responsibility of engineering.
>
> In respect to the wise use of natural resources such reports as those of the Mississippi Valley Committee, the National Resources Committee and the Great Plains Drought Area Committee have brought out the facts impressively. The enclosed report, ''Little Waters,'' presents in miniature many of the social-engineering problems of soil and water conservation.
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> In respect of the impact of science and engineering upon human life—social and economic dislocations as well as advance in productive power—the facts are revealed with distressing clearness in public records of unemployment, bankruptcies and relief. The responsibility of scientists has been analyzed in noteworthy addresses such as, among the most recent, those presented at the Tercentenary Celebration of Harvard University, and the meetings of the British Association for the Advancement of Science.
>
> The design and construction of specific civil engineering works or of instruments for production represent only one part of the responsibility of engineering. It must also consider social processes and problems, and must cooperate in designing accommodating mechanisms to absorb the shocks of the impact of science.
>
> This raises the question whether the curricula of engineering schools are so balanced as to give coming generations of engineers the vision and flexible technical capacity necessary to meet the full range of engineering responsibility.
>
> I am calling this matter to the attention of educators of high administrative authority in the hope that it may be thoroughly explored in faculty discussions and in meetings of engineering, educational and other pertinent professional associations.

Our Secretary of Agriculture, Mr. Wallace, who is rated by observers as the most reflective thinker among the President's close advisers, has stated the problem of the engineer's capacity in matters of general social import in more direct terms:

> There is something about engineering that tends to lay emphasis on logical, cold, hard, lifeless facts. Nearly all engineers have suffered the common punishment resulting from the remorseless discipline of higher mathematics, physics and mechanics. . . . As a result, the engineer sometimes imputes a value to precise mathematical reasoning that it does not always have. There is such a thing as life, and the mathematics of life is as far beyond the calculus as the calculus is beyond arithmetic. . . . It seems to me that the emphasis of both engineering and science in the future must be shifted more and more toward the sympathetic understanding of the complexities of life, as contrasted with the simple mathematical, mechanical understanding of material production.

The engineer may be likened to a man who has lived a very busy objective life, a hard-working extravert who has at least achieved a considerable degree of success and prominence. The time seems to have come for him to broaden out. He pauses to look about him and discovers that the people who seem to be running things are different from himself. They tell him: "You may be a big butter-and-egg man, but there are a lot of things you lack. You're a sort of Philistine, you know; hard-headed and all that; short on culture; short on emotional sensitivity; short on human understanding; a good man to help pay the bills, but hardly one to run the party." The net result of his aspirations is something of an inferiority complex. If he happens to fall into wise hands, he learns that troubles with personalities, as with nerves, are not often cured; instead, they are "adjusted." Getting adjusted means taking stock of one's limitations calmly and coming to terms with them. Limitations of nature one must accept without bitterness or envy, recognizing that most men have the defects of their virtues. Limitations resulting merely from education or experience one may strive hopefully to overcome, and especially not to repeat the errors of his own rearing in the children who are to come after him.

In this spirit let us, as engineers, look at ourselves. We recognize at the start that we have certain characteristic limitations which are apparently in our natures; otherwise we might never have become engineers. We love achievement, not speculation; we crave certainties, but shun subtleties; we are at home with precise and rigorous laws, but grow ill at ease when dealing with relations of vague and uncertain character; we value objective results over the ability to sway masses of men; we find matters congenial where the possibility of rational agreement is taken for granted; with the logic of mathematics and physics we feel at home, whereas the logic of judicial sifting of conflicts in evidence seems alien to us; we understand and practice the art of compromise where costs and values are involved, but not where political interests and emotions are in conflict. We make good administrators but poor politicians. We take command where problems in production and short-range economy are involved, but yield to others when long-time and involved questions of policy are to be dealt with. We are men who walk by sight, guided by evidence and logic; but we can not trust ourselves to walk by insight, guided by feeling and intuition. A fairly close observer has recently characterized President Roosevelt as "an artist in political emotions rather than an engineer in economic facts." I scarcely need to point out that this is a comment on us, as well as upon him.

To what degree we are what we are by nature or by nurture must be left to psychologists to decide. "Born that way" is a partial answer at best, and not a valid alibi for habits engendered by education and experience. The engineer's habit of forthrightness goes well in a world governed by the Biblical injunction, "Let your conversation be 'Yea, yea and nay, nay,'" but it tends to bar him from the world of adroit politics and suave diplomacy. His instinct for safety, his desire to be right in every case, breed a habit of deliberation, of withholding decisions until all available evidence is in, which may prove a handicap in executive positions where the risks of decision must be taken with scant deliberation. His impersonal modes of thought tempt him to think of workers and consumers as means to material ends, rather than as personalities having tastes, interests, feelings and foibles to be regarded, so that when he does venture among the subtleties of human nature he risks seeming callow and naïve.

That the characteristics sketched above can be modified by education can scarcely be denied. When the engineering graduate enters a law school, he has a difficult time adjusting himself to new forms of thought and logic. He usually overcomes the difficulty and becomes a competent lawyer, but then he is no longer an engineer. The question whether it would be possible through selection and training to alter the engineer's characteristics, especially as they affect men and society, and still leave him a competent engineer, is not so easily disposed of.

In the realm of industry two groups of problems are encountered, one to be approached through the physical sciences and the other through the social sciences. One path is well worn; the other is scarcely more than a faint trail. Through long years of association the engineer and the physical scientist have worked out a fruitful and fairly harmonious division of labor. The engineer's association with the social scientist is far less mature and effective. How far can these two go in setting up a working partnership?

The engineer's partnership with the physical scientist works because of the mutual recognition of distinctive functions. The scientist recognizes that no matter how extensive the engineer's scientific knowledge may be, science is to the latter essentially a tool, a means to certain clearly visualized ends, and not an end in itself. It is said that the engineering laboratories of one of the chief groups in the motor car industry are run by the slogan, "Where science must work, or quit!" Hard-boiled? Yes, but a perfectly proper slogan for an engineering laboratory. What is engineering but a search for the best answer to a limited problem that can be had for a limited expenditure of time and money? If all laboratories were run by that slogan, engineering progress would soon begin to slow down, then halt entirely. Engineering research pays dividends and they are soon realized, but over the decades and the centuries the richest returns come from the gratuitous and disinterested researches in pure science, from knowledge sought for its own sake alone. The goal of the engineer is tangible results, the best to be had for a given cost. To the scientist, all truth has ultimate worth and all search for truth has an inherent validity transcending any economic criteria.

As the old-time conflict between science and horse-sense in engineering has abated, engineers and researchers have worked out together a new and greatly speeded technique of progress. The old rule was first crude invention, then practical adaptation, afterward—and usually long afterward—research on fundamental principles, followed by a battle to get scientific findings accepted and adopted, and finally the perfecting of traditional practices. Men invented glass, pottery and brick at the dawn of civilization, but ceramic engineering has newly come among us. Tubal Cain, the legendary forger of metals, was of the seventh generation after Adam, but the science of metals is the work of our own generation.

The contrast between the new and the old technique of engineering progress is well exemplified in the story of the steam engine and that of radio transmission. Newcomen, you will recall, built the first workable piston engine in 1705. Nearly sixty years later Watt improved it by adding a separate condenser. Another sixty years elapsed before scientific men began to take serious interest in the engine, when Carnot published his remarkable analysis to prove that heat does work only by letting down from a higher to a lower temperature. But Carnot took no account of the heat which disappears in the process, for it was not until twenty years later that Joule established the doctrine of the conservation of energy. A science of thermodynamics scarcely existed before 1850 and its practical results were virtually nil before Rankine's attempts to set up a systematic treatment of steam engine theory in 1859. One hundred and fifty-four years from invention to analysis, and then the battle for efficiency had only fairly begun.

How different is the story of wireless communication—Maxwell propounding on purely logical grounds his theory of electrical waves in 1865, Hertz producing the waves experimentally in 1888, Marconi applying them to wireless telegraphy in 1895, Thompson and Richardson investigating the conduction of electricity through gases in the 1880's, Elster demonstrating the principle of the two-element electronic valve in 1889, Fleming applying it to radio telegraphy in 1904, and De Forest producing the vital three-element audion valve in 1907, a series of logical steps from research to application paving the way for the swift development of perhaps the most remarkable new art in all civilized history. As the philosopher Whitehead has so sagely remarked, the most important invention of the nineteenth century was the invention of the method of invention.

Science can live without technology, but its resources are immensely enriched and its activities stimulated by the union of the two. Technology, however, can scarcely exist without the fertilizing principle of science. Technological education, dissociated from vital research in the basic sciences, quickly grows sterile and routine. The intersection of research and economic application has accordingly come to be the major focus of engineering education. Is it possible to fix a second focus at the point of conjunction of technology and social science?

The above question by its metaphorical form suggests that the social sciences have a functional and not merely a cultural relation to engineering education. "Functional" is probably as strong a word as we are justified in using. Few would suggest that social science is as yet sufficiently advanced to play an "instrumental" part, that is, to supply either tools of analysis or criteria of decision for use in solving actual engineering problems. One hesitates to bring the word "cultural" into a discussion of this character, due to its almost universal loose interpretation. Probably no field of study is inherently cultural; music, literature, history or philosophy may be either cultural or technical, according to the aim of the student and the method of the teacher. The same, I believe, may be said equally of mathematics, chemistry, mechanics or even thermodynamics. At any rate, no inherent conflict exists between the professional utility of any subject and its function as a matter of general education.

Since technology can not live without the physical sciences, the mathematician, the physicist, the chemist and increasingly the biologist are all indispensable to the engineer as team-mates, but he has found no similar bond of necessity with the several groups of social scientists. He is likely to feel unsure that the social studies are actually sciences, as yet. One prominent engineer, noting the marked capacity of social scientists for disagreement among themselves, remarked that if they were all laid end to end, they would never come to a conclusion. The evolution of a science seems to exhibit three characteristic stages. First is the stage where an emerging science is able to explain events by cause and effect after they have occurred. The second stage arrives when science is able to predict events from their antecedents, and the third stage when science is able to control these results with a fair degree of certainty. The social sciences are attempts to deal rationally with the dynamics of human nature, with an interplay of simultaneous variables so numerous as to defy mathematical analysis and with little possibility of controlled experimentation. Wholesale assumptions and simplifications are necessary to make the variables manageable for logical purposes, and the so-called laws are broad generalizations, valid in only a qualitative or at best a statistical sense. They are seldom of more help to an engineer faced with a concrete problem than are the life expectancy tables of an insurance company in the hands of a doctor with a sick patient.

When the engineer faces the question, "Will it work?" he turns to the physical sciences for his data and his tools. When he faces the question, "Will it pay?" he seldom turns to the more general of the social sciences, but rather to the very concrete science of accountancy. Any appeal to economics, sociology, political science or social psychology is likely to be at the subconscious level. This appeal is not for tools, but for premises, especially the pre-suppositions of the man higher up who sets the engineer at his problem and reserves final judgment on his recommendations. Actual team work between engineers and social scientists on this basis can scarcely be expected to develop into any such intimate collaboration as that between engineers and physical scientists. Government boards and commissions may bring the two together to an increasing degree, and more rarely the general staff of some vast industry.

What the engineer learns of social science, it seems, will be chiefly through discipleship rather than teamwork. If this is limited to one or two hurried courses in college, as is so often the case at present, relatively small gains in understanding are to be hoped for. Students who give their major effort to social science as undergraduates seldom leave college with well-organized ideas, and their professors are not always noted for special aptitude in dealing with practical situations. Teachers of engineering, I fear, take a rather unholy pleasure over the economist who is habitually on the wrong side of the stock market or the sociologist who offers the bank his personal check to cover an over-draft, or the psychologist who is not particularly successful in the rearing of his children. Foundations for understanding can be laid in college, but the problem is primarily one of adult education.

This suggestion that the engineer must seek his education in the social sciences in his adult years is not meant to belittle but to magnify the importance of the premises of practical action which men draw from social laws and doctrines. We live in a world in the grip of ideologies—Marxist, Fascist, New Deal and conservative. The engineer is not immune, merely because his problems are limited in time and space, in scope and effect. Pass in review the major social changes of recent decades, and not one will be found to be without fairly direct influence on engineering decisions—the disappearance of a geographical frontier, the decline of agriculture and of rural living, the growing dominance of industry, the gradual stabilization of population, the numerical increase of the older age groups, the growth of cities and their centrifugal spread into semi-urban areas, the rise of taxes accompanying the rise in the proportion of wealth and income socially shared, the spread of secondary and higher education, the end of free immigration, the end of our traditional labor shortage, the rising importance of obsolescence of products or equipment, the development of research as a competitive weapon, the rising concentration of wealth in rapidly depreciating plant rather than in land of stable or rising value, the visible depletion of virgin resources, the universality of communication, the integration of industry under vast corporations, the growth of economic nationalism, and so on through the entire kaleidoscopic range. Engineers facing the risks of investment in new plant and replacements have a whole battery of new variables to reckon with.

We have more wealth than our fathers, but less security. George Washington was the richest American of his generation, as Henry Ford is reputed to be to-day. Is Ford the happier man? The Washington fortune, like most of the wealth of his day, was in land. With due allowance for changing weather, prices and skill, the productivity of land was fairly constant. It had a stable value which could be expressed like other values in terms of a single commodity such as gold with fair trustworthiness. Land could be left idle for a decade with only nominal care and suffer little or no deterioration in productive capacity or in value. As time went on and population increased, land values were certain to rise in proportion. Henry Ford's fortune, like most of to-day's wealth, is not in land but in physical plant. Except for a nominal scrap value, its worth is solely a matter of productivity. It may be worth a king's ransom to-day and nothing to-morrow. Keep it idle for five years and its value is all but destroyed. A strike may paralyze it without a moment's warning. Land has permanence, but plant is ephemeral. The values represented by imposing buildings and their equipment are mere transients, almost illusory, just the objectified forms of human ideas and ingenuity, the most changeable things we know. Over all our industrial wealth, and our personal jobs and fortunes as well, hovers the specter of obsolescence—not the slow and orderly wear and tear of daily use, but the threat of some new product of the inventor's ingenuity, some new stroke of the stylist's brush, some new whim of the consumer's caprice. Long as we may for a life of ordered security, whose passing was lately lamented by Herbert Hoover, we shall find it hard to recover.

Behind all other social issues looms the over-shadowing struggle, now world-wide, between collective security and free enterprise. Will the state, seeking to give its people security against foes without and economic hazards within, destroy the principle of individual freedom and initiative or so restrict it as to sap its vitality? As matters stand with us to-day, no one can give a confident answer to that question, but the present outlook is far from reassuring.

The social changes which are enumerated above all seem to point inevitably to an increasing degree of social control in economic processes. According to the scriptural legend, civilization began at the gates of Eden when man, whether by curse or by choice, began to eat his bread in the sweat of his brow. For 10,000 years or more man has been waging the struggle for more bread with less sweat. Out of this sweat has come one simple truth—you can have more wealth only as you produce it. There is a notion abroad that science holds some magical powers which, if properly manipulated, would work like Aladdin's lamp; that the productive machinery of society is already complete and self-operating; that discovery and invention represent doubtful gains; that thrift and investment are outmoded; that we need only to supply consumers with purchasing power from some hidden source; and that only the perversity and greed of economic royalists stand between the ordinary man and the horn of plenty. Over against these seductive illusions stands the stark fact that in the peak years of the 1920's we did not produce, nor could we produce, enough to provide for the reasonable needs of our people.

If civilization has taught us anything at all, it is that we can get gain in production only as we master the laws of nature, embody our ideas in useful forms, save our surplus to invest in tools of production and of distribution, and set up organizations in which men can do effective work together. Discovery, invention, thrift and organized enterprise—these are the driving forces of progress tested and proved as nothing else in all man's economic experience. But driving forces are of little use unless they are restrained, guided and lubricated. The energies of steam can be made use of only when confined in a cylinder or in the blading of a turbine, held in their courses by closely fitted bearings and guides, and their way skilfully smoothed by oils and greases. By analogy, the driving forces of progress are of no avail, without social and political institutions, but these are the casing and the frame of the engine; the driving forces of progress are useless without good human relations, and these are the lubricants of industry. But the cylinders and guides, the oil pumps and grease cups never put an ounce of energy into the machinery. To keep vital the spirit of research, of invention, of thrift and of enterprise and not to allow zeal for social control to quench the fires of progress, is to-day the first concern of educator, engineer and industrialist alike.

The issues between immediate reforms and long-range goals finds no more striking examples than in the public controversy now being waged over the electric power industry. That abundant power should become our universal servant every one agrees. Steinmetz once remarked that so little power is used because it is so dear, and it is so dear because so little is used—a squirrel-cage sort of vicious circle. The administration proposes to break the vicious circle by a closer policing of the power industry. Perhaps it is true that the power industry has never quite shaken off the luxury complex of its early days, but some of us think Mr. Roosevelt is missing the main point. Policing the industry may cut a cent or two off the rate per kilowatt-hour, whereas research may some day save us the major fraction. Ignorance, represented by the fact that 100 units of energy in the coal pile end up as three units of useful light, is costing us far more than the alleged perversity and greed or the misdirected financial magic of the utility magnates.

In this connection it is pertinent to recall the visit of a committee of the British Parliament to Faraday's laboratory at the Royal Institution, to view his discoveries in electromagnetism. One practical politician, on being shown an instrument of no apparent use, asked contemptuously, "Humph! Of what possible value is a thing like that?" "Some day," Faraday replied, "you may be able to tax it." What prophetic words! Last year the electrical industry which grew from Faraday's seemingly useless toys is said to have paid more than a quarter of a billion dollars in taxes in the United States alone, a sum many times greater than the total cost of winning for society our entire knowledge of electrical science. Taxes, as we know, represent only a minor fraction of the wealth on which they are levied. Who can guess the sum of the wealth created by Faraday's life and work? Ignorance remains, as it always has been, the chief barrier between the common man and the more abundant life, while research probably yields the greatest return, dollar for dollar, of all our forms of expenditure.

The country stands in dire need of between six and ten millions of additional jobs. If our millions of idle are ever to be employed, it will be in jobs not yet created, in serving industries not yet organized, in applying scientific truth not yet discovered, in operating machinery not yet invented, in making products not yet developed and in supplying needs of which the public are as yet scarcely aware. This is the road that leads to the more abundant life.

Mr. Roosevelt is probably justified in his doubts concerning the ability of our present forms of engineering education "to give coming generations of engineers the vision and flexible technical capacity necessary to meet the full range of engineering responsibility." The fault, I believe, is not so much with what is taught or left untaught in college, as with a scheme of education which ends too often at college doors. Foundations of social understanding should be laid in college, and are being laid far more widely and effectively than the President probably realized, but the ability to consider social processes and problems in the design and construction of engineering works or of instruments of production and to cooperate in designing mechanisms to absorb the shocks of the impact of science is the proper objective of a lifetime of education.

The work of the engineering colleges has been an active subject of discussion in professional circles these last fifteen years, with splendid gains on both sides. The profession has advanced its standards both in order and in quality and has quickened its touch on the lives of young men. The schools have moved steadily toward a type of training which is both more liberal and more fundamental, with greatly increased opportunities for advanced specialization after graduation. The lines have been mapped for years of further progress in our leading colleges. May I suggest, in conclusion, that this fine zeal on the part of the profession now be transferred for a time to a new area, that of further education for the young engineer in the first ten years of his active career? It is here, I believe, that the battle of social-mindedness is won or lost. The Engineers' Council for Professional Development, representing jointly seven national engineering bodies, has taken this period of the engineer's education as one of its principal concerns. The council is an agency for stimulation and coordination and not an operating body. What it can accomplish must be done principally through existing professional and educational institutions. What the national engineering societies can accomplish will be largely through their local chapters and sections. What the colleges can contribute to further education after graduation will be largely on a local basis. With the Engineers' Council for Professional Development now organized to give impetus and guidance on a national scale, next steps in progress seem to lie in the establishment of effective local joint councils or committees on professional education and development.

In the goals for this period of education, a mature understanding of social and economic processes should have a prominent place. It should be our concern not only to make the engineer competent to design and build with an understanding of social consequences, and to do his part to develop shock-absorbing mechanisms to ease the impact of technological change, but also to raise his voice in defense of sound economic and social policies which have stood the fire of experience.

OBITUARY

THE SCIENTIFIC WORK OF VERNON KELLOGG

WHEN one reviews the scientific work of Kellogg he finds the record of a keen, active, versatile mind, reflecting immediately the influence of his surroundings, and disclosing an eagerness to state his findings and to share his impressions. The thought leaps forth and must find expression. There is little of long and labored investigations builded into finished works, but more often a flashing exposition of some definite topic. There is not lacking, however, sustained interest, but it manifests itself over long periods of time and not in a continuous and exclusive application. Thus his first paper on Mallophaga appeared in 1890 and up until 1915, thirty-nine others on this subject followed. Sometimes several years would pass without any published work on the biting lice and then a group of as many as five articles would be written in one year.

Similarly, insect taxonomy continued to interest him and in a decade he wrote twelve papers. A like number of works on insect morphology in the same period were published.

The strong influence of his surroundings is early manifest. Accordingly, in his first year of investigation, papers upon Mallophaga, birds, preservative fluids for museum specimens and the action of a Pasteur filter were produced. In each case contact with another investigator was responsible for his interest in the subject reported upon. In the years immediately following, papers upon economic entomology predominate because of the practical work upon the chinch bug begun by Dr. F. H. Snow.

Back of his practical studies there was, in the mind of Kellogg, a growing concern for the biological principles manifest in comparative insect morphology, taxonomy and phylogeny. Association with Comstock and Jordan did much to strengthen these interests, and papers dealing with applied entomology became few. In the second decade of his work the extension of knowledge through the writing of text-books claimed much of his interest, and rarely did a year pass without the appearance of some book from his pen. Apparently this was somewhat of a diversion for an easy writer because it did not at all interrupt the steady flow of manuscripts upon a wide range of investigations. Thus in 1904 in addition to a book on "Insect Anatomy" there were papers upon such diverse subjects as parthenogenesis, amitosis, bionomics, regeneration, experimental variation, sex-characters, Mallophaga and South Sea travel. The active, discursive nature of his mind is indicated by the fact that articles characterized as Reviews, Notes and Biographies, covering a wide range of subjects, are most numerous. The breadth of his interest is best shown by the number of papers upon each subject during his first twenty-five years of study when his mind was not distracted by administrative matters. These may be summarized as follows: Mallophaga, 39; reviews and biographies, 28; books, 18; applied entomology, 18; general biological topics, 15; insect morphology, 12; insect taxonomy, 12; evolution, 10; insect development, 8; ornithology, 6; silkworms, 6; insect notes, 5; travel, 3; heredity, 3; eugenics, 3; education, 3; parasitology, 3; Lepidoptera, 3; spiders, 2; insect physiology, 2; bionomics, 2; technique, 2; regeneration, 2; insect behavior, 2; arthropods, 2; animal psychology, 1; insect cytology, 1; distribution, 1; echinoderms, 1; parthenogenesis, 1; metagenesis, 1; Coleoptera, 1. These classes are not always mutually exclusive, but taken in this way reveal the general trend of Kellogg's thinking. The first eight topics are presented in 152 papers, out of a total of 209, and show the concentration of his interest upon them. Probably his largest contribution to new knowledge came from his studies upon the Mallophaga. These were undertaken, in the beginning, because Kellogg considered the insects valuable as an index of the relations between bird species, but later the studies were continued on account of his preoccupation with the phylogeny of the Mallophaga themselves. The numerous papers that continued to