HENRY CLAY WEEKS: 'The Practical Side of Mosquito Extermination.' (Presented by A. C. Eustis.)

JAMES CARROLL: 'Without Mosquitoes there can be no Yellow Fever.'

H. A. VEAZIE: 'Æstivo-autumnal Fever—Cause, Diagnosis, Treatment and Destruction of Mosquitoes which spread the Disease.'

Discussions of the various papers by Messrs. James Carroll, G. N. Calkins, L. O. Howard, J. H. White, S. E. Chaillé, A. C. Abbott, A. L. Metz, H. B. Ward, Quitman Kohnke, A. C. Eustis and others.

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THE EXPERIMENTAL METHOD IN SANITARY SCIENCE AND SANITARY ADMINISTRATION.[1]

THE value of experimentation in all branches of inquiry is now generally recognized; its philosophical significance and its limitations are less often understood and appreciated. In the present paper I propose to show that there is no hard-and-fast line between the results of experiment and those of experience, and that in the field of sanitation, in which of necessity laboratory experiment is difficult when not impossible, the data of experience carefully studied and rigidly verified are capable of yielding results no less valuable than those derived in some other subjects by experiment.

To avoid confusion let us understand clearly at the outset exactly what we mean by the terms *experiment, experience* and *observation.* Originally signifying much the same thing as experience, namely, both the processes and the results of trial or test, the word *experiment* has in recent times come to be used chiefly for a prearrangement, and an artificial arrangement, of conditions in such a way that specific questions shall be answered; while the term experience has come to be used most often to describe a result rather than a process—a result, moreover, obtained without prearrangement, and under natural or unpremeditated, rather than artificial or premeditated, conditions. We speak, for example, of an *experiment* upon the strength of materials and an *experience* with a broken rail, or railway bridge. The term *observation* requires no special comment. Without this, both scientific experiments and scientific experience are worthless. *Verification* is, of course, the checking, controlling or testing of the data and results of experiments or experiences, in order to determine their accuracy or degree of truth; and we are still indebted to George Henry Lewes for his striking exposition of the fundamental and indispensable function of verification in all sound and scientific inquiry.

Now a little reflection will show that experiment, in the somewhat narrow sense here laid down, is necessarily comparatively limited, and very likely to be confined largely to the laboratory, for the reason that any prearrangement of conditions which shall be actual tests or trials of natural phenomena must oftenest be made under cover, in limited space, with comparatively few objects, and at comparatively small cost. Hence it has come to pass that the experimental sciences have been chiefly those which could be advantageously pursued in laboratories and workshops, and upon the small, rather than the large, scale. There can be little doubt that this fact has tended to magnify the importance of subjects or parts of subjects lending themselves readily to laboratory experimentation, and has served to draw off attention from, and thus to hinder, the development of other sciences, or portions of sciences, quite as important as those capable of advancement by laboratory experimentation. In physics, for example, we may well suspect that materials at hand, such as air or water,

[1] Address of the vice-president and chairman of Section K, American Association for the Advancement of Science, New Orleans, December, 1905.

and problems at hand, such as the behavior of bodies at various moderate temperatures, have received more study than their intrinsic importance requires, while remoter objects such as the heavenly bodies, and very high and low temperatures have not received the attention which they deserve. Doubtless the same fact holds in the biological sciences, including physiology and medicine. Experiments upon the physiological action of drugs have probably received, especially in the past, relatively too much attention, because of the ease with which they could be carried out; while the more difficult and more costly experiments, for example those required to determine the purity of large bodies of water, such as rivers and lakes, or those upon the purification of sewage, have until recently received but little attention.

There is danger, moreover, that in the instinctive recognition of the difficulties of laboratory experiments upon large and difficult problems, investigators shall turn aside from the careful study and verification of the data and results of another class of experiments which, for the sake of differentiation, we may call natural rather than artificial experiments, and which in everyday language are described as experience. It is, for example, obviously unwise to regret our inability to test by the methods of ordinary artificial experiment the effects of polluted drinking water upon large communities, when there are frequently being exhibited, all about us, by such communities, natural experiments on a grand scale, the conditions of which can often be accurately determined, even after the fact, and the results of which are as capable of verification as are those of artificial experiments prearranged to answer specific questions.

When, in 1893, the city of Lawrence, Mass.—long in the habit of drinking the unpurified water of the polluted Merrimac River, into which only nine miles above the intake of the Lawrence waterworks the raw sewage of the city of Lowell was poured—set up between that water and its citizens a barrier of defense (a sand filter) permeable by water but impermeable by disease germs, an experiment was undertaken under conditions quite as clear and as favorable as those under which many laboratory experiments are conducted. The data at hand concerning this experiment—concerning its cause, inception, conduct and consequences, were such as to enable those having the opportunity to study it to reach results, and to draw conclusions, of high accuracy, and even to predict with confidence the consequences of similar experiments elsewhere. This experience of a modern American municipality was also an experiment in the narrower sense—although not a laboratory experiment; for it was made artificially, and by prearrangement, in order to solve a specific problem, namely, to get rid of typhoid fever in a community in which that disease had long been, in the old phraseology, 'endemic.'

One experiment often leads to another, and so also an experience often leads to an experiment. Years before, in 1872, acting under the best engineering and scientific advice of the time, the city of Lawrence had introduced for the benefit of its citizens a public water-supply drawn directly from the Merrimac River nine miles below the mouths of the sewers of Lowell, as already stated above. In doing this there was no thought of making any scientific or sanitary experiment, but only of supplying the city with water for fire purposes and domestic convenience. Unwittingly, however, an important experiment was really being made by that municipality. As surely as if by premeditation and prearrangement a trial was being made, day by day, and year by year, of the effect upon the public health of the city of the use of a water-supply polluted with human excrements; and when, in 1890, typhoid fever appeared among the citizens to such an extent as to constitute a terrible epidemic, and to cause careful observation and study of the past as well as the present, it became evident that a most important experiment had been going on ever since 1872—quietly, naturally and unobserved—and an experiment not merely dire in its consequences, but rich in its sanitary teachings.

Careful studies of the various phases of this long-continued and tragically-ending experiment showed that the citizens of Lawrence had submitted themselves to, and participated in, conditions such as no premeditating experimenter in his wildest flights of fancy would have dreamed of proposing; for they had, for twenty years, been drinking the diluted excrements and other wastes of a large and dirty city. Further studies revealed the fact that so long as these excrements were unmixed with those of typhoid fever patients no excess of typhoid fever ordinarily appeared in Lawrence, but that if typhoid fever abounded in Lowell then, after the lapse of a period of time such as would be required for its transmission to the citizens of Lawrence, and for its usual incubation, typhoid fever invariably appeared in the lower city. In the end, this unpremeditated experiment proved to be remarkably instructive, for while Lawrence and Lowell were thus unconsciously experimenting, Haverhill, on the same river a few miles below, and Nashua, a few miles above, experimenting with relatively pure water supplies, suffered no excess of typhoid fever. These facts threw great light upon the cause of a constant excess of typhoid fever long characteristic of Lowell, and calmly accepted by the local physicians and sanitary officials as 'endemic'—whatever that might mean—and regarded by them as unavoidable. For when the opportunity came to test their theory by a premeditated experiment, namely, the purification of the water, this 'endemicity' of typhoid fever in Lawrence disappeared. It then became clear that the so-called 'endemic' was really an epidemic condition; an epidemic condition characterized by the constant existence of a moderate number of cases, rather than the occasional existence of a great number, *i. e.*, by constancy, rather than magnitude.

These simple facts will serve quite as well as any more extended discussion to establish the fact which I desire especially to emphasize in this paper, namely, that the experimental method is not necessarily confined to laboratories, or applicable only to individuals. Some of its best examples, and some of its richest fruits, may be found in sanitation, as well as in physiology or hygiene; in the environment, as well as in the individual.[2]

The practical importance of the recognition of these facts is very great. Comparatively few physicians or sanitarians are in a position to conduct artificial experiments of great importance, whether inside or outside the laboratory, but almost any wide-awake observer, whether he be physician, physiologist, sanitarian or engineer, may, if he will, find going on all about him natural experiments, the conditions of which may often be learned with great accuracy even after the experiment

[2] The author believes that a natural and serviceable distinction may be drawn between hygiene and sanitation, the former term being kept for those aspects of general hygiene, or the public health, affecting chiefly individuals or groups of individuals, the latter for those affecting chiefly environments. He has used this distinction with advantage for some two or three years past in his teaching and in his writing, *e. g.*, in the *Encyclopedia Americana*, Vol. XIV., article 'Sanitary Science and Public Health,' New York, 1904, and in a paper, 'The Readjustment of Education and Research in Hygiene and Sanitation,' in the forthcoming volume of *Proceedings* of the American Public Health Association.

is completed, and which may yield conclusions quite as capable of verification as are those of experiments made in the laboratory. This should be a matter of no small encouragement, especially for younger workers who, wherever they are, and whatever they may be doing, may safely rest assured that if they will bring to bear upon the experiments which nature is making all about them the same careful observation, generalization and verification which they would apply to laboratory experiments, they are no less likely to reach results of the highest consequence, as well as to win the cordial appreciation of all competent scientists.

Many communities, moreover, are nowadays embarking upon new phases of water supply, sewerage, and sewage-disposal which, rightly considered, constitute veritable experiments in sanitary science and sanitary administration. And one of the most encouraging signs of the sanitary times is the custom, now universally approved and already widely adopted, of instituting elaborate and often extensive experiments, before embarking upon costly and far-reaching improvements, the outcome of which would otherwise be doubtful or uncertain. The establishment by the State Board of Health of Massachusetts in 1886 of a sanitary research laboratory and water and sewage experiment station, on the shore of the Merrimac River, in Lawrence, marked the beginning of a new and important era in practical sanitation, because it was the introduction of the experimental method into a field of human activity in which hitherto the results of natural experiments had been the only guide. Imbued with the scientific spirit, and convinced of the importance of the experimental method in sanitary science, as demonstrated at the Lawrence Experiment Station, where they were among the earliest workers, Messrs. Allen Hazen and George W. Fuller, now sanitary engineers of the first rank, caused the same methods to be invoked and applied before embarking upon the actual purification of the water supplies of Pittsburgh, Albany, Louisville, Cincinnati and other cities, with which they have had to deal. Still more recently, Mr. Fuller has planned and conducted, at an expense of $50,000 or more, a series of elaborate experiments in order to determine the best methods for the purification of the sewage of the city of Columbus, Ohio. The results of all these experiments are everywhere conceded to have been so valuable and instructive that well-advised municipalities to-day rightly hesitate to embark upon large and costly schemes of sanitation without first having made extensive experiments, locally conducted, bearing upon the solution of their own peculiar problems. It has been learned, moreover, by both experiment and experience, that the terms 'water' and 'sewage' which have so long been used in the abstract in sanitary science, when applied to concrete natural waters, and municipal or manufacturing wastes, ought rather to be made plural, for the reason that the waters of various parts of the country, and the sewages of different communities, differ so widely, one from another, as to require widely different methods for their successful treatment.

In other forms of sanitary practise also, such as the drainage of marshes, the petrolizing of ponds or stocking them with fish, the experimental method has been usefully employed. Experiments upon the improvement of cows and cow-stables have given good results in cleaner and more normal milk. Experiments in street cleaning have shown that dirty streets are an evil, but not a necessary evil. Experiments in the separation and utilization of wastes have yielded results of sanitary and financial importance. Experiments like that of the city of Munich on the effect of sewerage upon the public health; experiments upon the cost and importance of systems of heating and ventilation; experiments upon the efficiency of copper sulphate as an algicide; experiments on the influence of pasteurized milk upon infant mortality—all these, and many more that might be given, testify to the value of the experimental method in sanitation. And yet, in most cases of this kind, we have to say, as Adams said of political experiments, 'these can not be made in a laboratory or determined in a few hours.'

There remains, however, one department of sanitation, viz., that of sanitary administration, in which the results of experience are more abundant than those of experimentation, results, too, which can not be regarded with either pride or satisfaction. I refer to the constitution and sanitary work of our various state and local boards of health. In some few cases these boards are well constituted, courageous, intelligent and efficient. In a few cases they are even famous for their good work. In some other cases, although themselves incompetent, boards of health have had the good sense, or good fortune, to employ as their agents real experts, and to delegate to these their sanitary work. But experience shows that some state boards, and many local boards, of health, in the United States, are badly constituted, inefficient if not ignorant, and cowardly. The experiment has now been fully tried of appointing to such boards mere place-seekers and incompetents, with the natural results of poor public service and dangerous neglect of the sanitary interests of the people. It requires some knowledge, skill, courage and wisdom, to administer the sanitary affairs of a modern community, and few indeed are the American cities or towns which have made the experiment of organizing their boards or commissions of health to meet these requirements. Too often a hack politician or two, a second-rate doctor or two, and one or more vain or place-seeking nobodies —useless but not harmless—make up our local boards of health; and as no stream can rise higher than its source the services of such boards are disgracefully small in quantity and poor in quality. It requires no further use of the experimental method, to predict from such direction or control of sanitary affairs, in further trials, dismal consequences.

Worst of all, this foolish and almost criminal experimenting is going on while we have to-day in America opportunities for some of the most interesting sanitary experiments that any scientist could desire. We are establishing model dairies, model municipal water filters, model sewage and garbage disposal-plants. Why can we not also experiment with a few model boards of health, which shall boldly set to work, and themselves make the experiment of trying to give to the city or town under their care the best possible sanitary (and I may add hygienic) conditions? Why can we not have more boards constituted, like that of Montclair, N. J., of one or more leading physicians, one or more good civil engineers, one or more good lawyers or business men? Why can we not have more boards experimenting upon the control of milk supplies, as are to-day the boards of Montclair, of New York and of Boston? More boards studying experimentally the conditions required to secure proper heating and ventilation of public halls and public conveyances? More boards experimenting upon the suppression of the smoke nuisance, the dust nuisance, the noise nuisance? It is of comparatively little use to make good laws if no one will enforce or obey them, and improved methods of sanitation (and hygiene) are of small value unless intelligent, courageous and energetic boards of health adopt and enforce them.

In Massachusetts the district medical examiner has displaced, with great advantage to all concerned, the aforetime local coroner. And if, as there is much reason to suspect, local influences and prejudices make it almost everywhere difficult to secure able and aggressive local boards of health, then the experiment should be tried of having district, county or state officials, authorized and willing to do the necessary sanitary work. The present plan is a failure experimentally demonstrated; let us continue to invoke the experimental method, in which we believe, but abandoning our present customs, which have been experimentally proved—for the thousandth time—to be hopeless, and trying something more promising. We can not do much worse; we ought to do much better.

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SYMPOSIUM ON YELLOW FEVER AND OTHER INSECT-BORNE DISEASES.

The Protozoon Life-Cycle: GARY N. CALKINS.

The wonderfully successful results obtained in New Orleans in the struggle against *Stegomyia fasciata* has shown that in yellow fever, as was long the case in smallpox, protective measures may be understood and applied, although the specific cause of the disease is unknown.

I do not intend to discuss the question as to whether this specific cause is a bacillus or a protozoon, nor to consider the various organisms that have been found in infected yellow-fever mosquitoes. I purpose, rather, to speak upon some of the general biological phenomena distinctive of protozoa, and of the variations in vitality at different periods of the life-cycle, and then to point out in how far the present data regarding the yellow-fever organism agree with these established facts.

The protozoa are minute animals, consisting for the most part of single cells having an independent life. They vary in size from minute forms, too small to be seen with the highest powers of our modern microscopes, to giant forms from two to three inches in diameter. The vast majority thrive in seas and lakes, stagnant pools and ditches, and are absolutely harmless to man; indeed, they become a boon to him by giving to thousands of microscopists the materials for a fascinating pastime. A small minority are parasitic, but these few cause vast epidemics among silkworms, fish, and domestic animals, and have been the means of great economic loss, or, through malignant human epidemics, have terrorized whole communities and have brought about untold loss of life.

A protozoon rarely retains its individuality more than a few hours. It then divides into two, or, in some cases, into a larger number of daughter individuals. The parent organism has not died, there is no unicellular corpse, but the protoplasm of which that organism was composed is now distributed by division among two or more individuals. The process is repeated again and again, and thus it continues, a repetition of growth and reproduction. We can not speak, therefore, of the life-cycle of an individual protozoon, but must consider rather the protoplasm of which that individual is composed. It is this protoplasm that goes on through generation after generation of individuals, and through all the phases that constitute the aggregate of phenomena which has been termed the life-cycle.

It was formerly believed that this protoplasm, having all of the necessary functions required for an indefinitely continued existence, gives to the protozoon the attribute of an endless life—physical immortality. Experiments made within comparatively recent times have shown, however, that this is not true and that the protoplasm of a given protozoon gradually loses its