all great problems, particularly those of our national and state governments, will be automatically placed in the hands of trained specialists? Not self-seeking politicians, nor yet men with mere theories, but engineers with a real command of fundamental principles, men with an unbroken record of big achievements and no failures, men ever ready to stake their all on their ability to handle problems in their specialty.

Professor Joseph Le Conte, in an address years ago, remarked that each of the great professions first attained high standing when it was taught as such in universities. When so taught, the professional men turned out are no longer quacks, but each has a real command of the fundamental principles in his chosen field of action. The basic relation is that any profession has standing in so far as its fundamental principles have been developed and applied. To retain standing, a profession must be continually increasing its stock of knowledge of fundamental principles through research. The engineer of standing in his profession must not be content with a mere working knowledge of rules of thumb, but must have a real command of basic principles in his chosen field and in related fields. The illuminating engineer, for example, should know not only lighting, but should possess a working knowledge of the laws of vision and of geometrical and physical optics. So the great physician or construction engineer has a command of his own field and an intimate acquaintance with related fields.

So also with research as a profession, the leaders have not only a taste for research and logical minds to clearly analyze and attack problems with thorough scientific knowledge, but have a knowledge of the principles of research; getting the most out of their own minds, avoiding side issues, cooperating with their colleageus and putting their most valuable results in permanent, readily available form. Research is one of the youngest of the professions and one with a promising future, but let no one enter it without thorough knowledge or a full understanding of its aims and methods. With sufficient attention given to research and to its application, this nation with its great national resources should at once attain and retain a permanent lead among the nations of the earth.

P. G. Nutting

THE PROOF OF MICROBIAL AGENCY IN THE CHEMICAL TRANSFORMATIONS OF SOIL

Every now and then in the development of a science it is well to stop and consider how many of the current statements are based on established fact and how many have arisen from assumptions repeated so often that they have come to be generally believed. Certain common statements in regard to the bacteriology of soil may well bear such scrutiny. Has it, for instance, been definitely proved that any particular microorganisms cause any of the well-known biological activities in soil? This question is quite pertinent at present because of statements frequently found in the literature that certain bacteria or groups of bacteria are responsible for certain chemical transformations in soil, although complete proof of the causal relation has never been obtained.

The cause of these loose statements is easy to understand when it is considered that it is practically impossible to obtain direct evidence as to what actually goes on within the soil. Laboratory experiments show what the microorganisms do under laboratory conditions, but not what they do in the soil. Even though the activity of an organism be tested in soil itself, its true activity in the field may still remain unknown, because such laboratory tests have to be carried out in pure culture, and pure cultures do not occur in the field. The activities of bacteria in soil are associ-

ative actions; and an organism capable of vigorous activity in pure culture may be almost inactive in the presence of its natural rivals. Laboratory tests, therefore, give but indirect evidence at their best. Indirect evidence has its value; but it is futile to draw conclusions from it unless results obtained by one method are confirmed by those obtained in some other way.

Similar difficulties in regard to pathogenic bacteria caused the literature of the early nineteenth century to abound in misstatements as to the relation of certain bacteria to certain diseases. Gradually, however, it came to be recognized that neither the constant presence of a given microorganism in a certain disease, nor its ability to produce a similar disease in lower animals proves it to be the causal agent of a human disease. These ideas were put in concise form by Koch when he restated and emphasized the requirements originally suggested by Henle as necessary steps in proving a given organism to be the cause of a given disease. These postulates, as stated by Koch, are as follows: (1) The organism must be shown to be present in abundance in the tissues, blood, or discharges of animals suffering from the disease; (2) it must be isolated and studied in pure culture; (3) it must be shown capable of producing the same disease in healthy animals; (4) it must subsequently be found again in abundance in the experimentally inoculated animals.

Really the case of bacterial activities in soil is analogous. The constant presence of a certain organism in manured soil, for instance, does not prove that it decomposes the manure any more than the constant presence of an organism in a given disease proves its causal relation. Neither does the fact that an organism ammonifies laboratory media prove that it ammonifies organic matter in soil, any more than the fact that an organism produces a certain disease in a lower animal proves that it produces a similar disease in man. Although this fact may be recognized in a general way by soil bacteriologists, a little thought will show that no rules as strict as Koch's postulates have ever been followed in establishing the agency of bacteria in any soil activity—with the exception of the bacteria of legume nodules. Even in regard to the nitrifiers—certain as we may be of their agency in converting ammonium salts into nitrates—we do not have the complete proof. This thought is somewhat disconcerting and shows the need of drawing up strict rules to apply to the activities of soil microorganisms. Koch's postulates can not be applied directly to soil microorganisms, because the latter operate under quite different conditions from pathogenic bacteria; but it is possible to modify his rules to fit soil conditions.

The first postulate is that the organism must be shown to be present in abundance in animals suffering from the disease in question. It is equally necessary to show that an organism is present in abundance in soil in which a certain biological activity is going on—in fact that it is more abundant in such soil than in similar soil in which the activity is not taking place—before asserting that the organism in question is the causal agent. It is also necessary to show that the organism is present in such soil in *active* form. This is necessary because at least three groups of soil microorganisms have inactive as well as active forms: namely, protozoa, molds and spore-bearing bacteria. If the organism in question belongs to one of these three groups, the mere demonstration of its presence is not enough, but it must be shown to be present in active form. In other words, Koch's first postulate must be expanded as follows when applied to soil conditions: The organism in question must be shown to be present in active form when the chemical transformation under investigation is taking place; and must also be shown to be present in larger numbers in such soil than in similar soil in which the chemical change is not taking place. These two steps have seldom been carried out in investigating the cause of any biological activity in soil, but they are nevertheless as important as Koch's first postulate in regard to pathogenic bacteria. They are perhaps a little more stringent than the first postulate of Koch's; but special stringency is necessary here in view

of the difficulty in applying Koch's last two postulates to soil conditions.

The second postulate of Koch's is that the organism be isolated and cultivated in pure culture. This can be applied without modification to soil conditions, and indeed is generally carried out by soil investigators.

The third postulate is that the organism be shown capable of producing the same disease in healthy animals. The corresponding requirement in regard to soil bacteria is extremely difficult to meet. It is possible to inoculate the organism in question into sterile soil and study its activity under such conditions—a test which is quite commonly made. Such a test, however, does not furnish conclusive proof. Sterilized soil is always different from natural soil; but worse still, activities in pure culture may be very different from activities in mixed culture. To obtain complete proof, the organism in question should be inoculated into unsterilized soil, and then if the activity under investigation occurs the organism should be shown to be present in large numbers. Such a procedure, however, is generally impossible, because of the difficulty of getting an organism to grow vigorously in soil already stocked with a bacterial flora of its own; and the interpretation of results is difficult, because—in distinct contrast to the specific agency of microorganisms in disease—the same chemical transformation in soil may be caused by distinctly different organisms. For this reason the best that can ordinarily be done is to inoculate the organism in question into sterilized soil. To do so furnishes better proof than to inoculate it into any laboratory medium, but the unsatisfactory nature of the test must be fully recognized. Perhaps it is not overstating the case to say that much of the past confusion in regard to the activities of soil bacteria has arisen from the fact that they have been studied in pure culture while pure cultures never occur naturally in soil. The inoculation of sterilized soil is ordinarily the only practical course, however, and has its value as a means of confirming the tests carried out in connection with the requirements already mentioned.

Koch's last postulate is that the organism be found in the tissues, blood or discharges of the experimentally inoculated animals. The corresponding requirement in regard to soil activities is superfluous, provided sterile soil is used for inoculation and contamination is prevented during the experiment. If unsterilized soil is used, the presence of the organism in question should be demonstrated; but the impractibility of using unsterilized soil makes this last requirement of little value as applied to soil conditions.

Summing up, it may be said that to show conclusively the agency of any microorganism in any chemical transformation occurring in soil, the following steps are necessary: (1) The organism must be shown to be present in active form when the chemical transformation under investigation is taking place; (2) it must be shown to occur in larger numbers under such conditions than in the same soil in which the chemical change is not occurring; (3) it must be isolated from the soil and studied in pure culture; (4) the same chemical change must be produced by the organism in experimentally inoculated soil, making the test, if possible, in unsterilized soil. The fourth reqiurement, however, can ordinarily be carried out only by inoculating sterilized soil, a procedure which does not give rigid proof, but which is fairly conclusive if carried out in connection with the other three requirements.

Sometimes these facts can be brought out wholly by cultural methods, such as used in the past. It must be remembered, however, that cultural methods, at their best, are open to serious error, as organisms that are naturally inactive may become active under cultural conditions, while under similar conditions naturally active organisms may lose their activity. This fact will make it necessary to check up cultural methods with methods of other sorts. Possibly the use of the microscope[1] will help solve some of the problems,

[1] See Conn, H. J., 1917, "The Direct Microscopic Examination of Bacteria in Soil." (Paper presented at New Haven meeting of the Society of American Bacteriologists.) Abstract in "Abstracts of Bact.," Vol. 1, p. 40.

or perhaps methods of an entirely new sort will be needed. At all events, more attention must be given to the steps involved in proving the causal relation of definite microorganisms to definite biological activities in the soil in order to avoid making loose statements in regard to the functions of these organisms, such as have often been made in the past.

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July 25, 1917

THE FIRST PUEBLO RUIN IN COLORADO MENTIONED IN SPANISH DOCUMENTS

THERE is in the Congressional Library, among the documents collected by Peter Force, a manuscript diary of early exploration in New Mexico, Colorado, and Utah, dated 1776, written by two Catholic priests, Father Silvester Velez Escalante and Father Francisco Atanacio Dominguez. This diary is valuable to students of archeology, as it contains the first reference to a prehistoric ruin in the confines of the present state of Colorado, although the mention is too brief for positive identification of the ruin.[2] While the context indicates its approximate site, there are at this place at least two large ruins, either of which might be that referred to. I have no doubt which one of these two ruins was indicated by these early explorers, but my interest in this ruin is both archeological and historical. Our knowledge of the structure of these ruins is at the present day almost as imperfect as it was a century and a half ago.

The route followed by the writers of the diary was possibly an Indian pathway, and is now called the old Spanish Trail. After entering Colorado it ran from near the present site of Mancos to the Dolores. On the fourteenth day from Santa Fe, we find the following entry: "En la vanda austral del Vio [Rio] sobre un alto, huvo antiquam (te) una Poblacion pequeña, de la misma forma q[e] las de los Indios el Nuevo Mexico, segun manifieran las Ruinas q[e] de invento registramos."

By tracing the trip day by day, up to that time, it appears that the ruin referred to by these early fathers was situated somewhere near the bend of the Dolores River, or not far from the present town of Dolores, Colorado. The above quotation indicates that the ruin was a small settlement, and situated on a hill, on the south side of the river or trail, but it did not differ greatly from the ruined settlements of the Indians of New Mexico with which the writers were familiar, and had already described.

A century later, 1876, we find a published reference to a ruin near the bend of the Dolores, which suggests the above mentioned. An exploring expedition of the engineer department of the United States Army from Santa Fé, New Mexico, to the junction of the Grand and Green Rivers of the Great Colorado of the west, under command of Capt. J. M. Macomb, U. S. A., in 1859, followed the old Spanish Trail. Professor J. S. Newberry, of the expedition, in a geological report described a ruin not many miles from the bend of the Dolores: "Surouaro is the name of a ruined town which must have contained a population of several thousands [*sic*]. The same is said to be of Indian (Utah) origin, and to signify desolation, and certainly no better could have been selected. . . . The houses are, many of them, large, and all built of stone, hammer-dressed on the exposed faces. Fragments of pottery are exceedingly common, though, like the buildings, showing great age. The remains of metates (corn mills) are abundant about the ruins. The ruins of several large reservoirs[3] built of masonry may be seen at Surouaro, and there are traces of acequias which led to them through which water was brought perhaps from a great distance."

[1] Published by permission of the Secretary of the Smithsonian Institution.

[2] Diario y Dereotero de las neuvas descubrimientos de tierras á los r'bos N.N.OE.OE. del Nuevo Mexico por los R.R.P.P.Fr. Silvester Valez Escalante, Fr. Francisco Atanacio Dominguez, 1776. (*Vide* Sen. Ex. Doc. 33d Congress, No. 78, pt. 3, pp. 119–127.)

[3] Probably kivas, but impossible to identify without excavations. J. W. F.