tive indicators of vitality. It therefore seems highly probable that the theory here presented may be applied in those cases where other criteria of antagonism (such as motion, growth and length of life) are employed.

It will be seen that action in a saturated surface is the essence of this explanation. It is evident that so long as this essential feature is preserved it makes little difference what theory of antagonism we adopt. If the antagonistic substances act in a saturated surface antagonism must be governed by Weber's law.

Summary.—The fact that Weber's law governs antagonism is explained by a dynamical theory formulated by the writer.

This theory assumes that injury and death result from processes which are inhibited by salt compounds formed by the union of salts with the protoplasm. If these compounds are formed in a surface the amounts will (above a certain limit) be independent of variations in concentration and will depend only on the proportions of the antagonistic salts. From this it results that Weber's law must govern the phenomena of antagonism.

No matter what theory of antagonism we adopt, it is evident that if the antagonistic substances act in a saturated surface antagonism must be governed by Weber's law.

W. J. V. Osterhout

Laboratory of Plant Physiology,
Harvard University

DO FUNGI LIVE AND PRODUCE MYCELIUM IN THE SOIL?

The recent investigations on soil microorganisms have revealed the fact that fungi are found in soils in very large numbers sometimes reaching as high as 1,000,000 per gram of soil. These numbers are found by diluting the soil and then plating out only a small portion of a gram. The colonies developing on the plates represent the spores or pieces of mycelium found in the soil. But this does not tell us about the actual active life of the fungi in the soil. However large the numbers that are found, it remains to investigate whether those organisms existed in the soil only in the form of spores, which were brought in by some outside agency, or are a result of active life in the soil in the form of mycelium which may or may not result in the formation of spores in the soil. The question is not how many numbers and types of fungi can be found in the soil, but what organisms lead an active life in the soil. To what depth are these organisms found to produce mycelium in the soil? And finally, do all or at least most of the organisms isolated from the soil actually produce mycelium in the soil?

At the suggestion of Dr. Charles Thom, of the Bureau of Chemistry in Washington, a direct isolation of fungi producing mycelium in the soil was attempted. Soil samples taken at different depths, under absolutely sterile conditions, were brought into the laboratory; lumps of soil, about 1 cm. in diameter, were transferred with sterile forceps into sterile plates containing cooled sterile Czapek's solution agar. The lump was placed carefully in the center of the dish, which was immediately covered and allowed to incubate for 24 hours at 20–22° C. After this period mycelium was found to radiate out of the lump of soil into the medium. This mycelium was now transferred with a sterile platinum loop to sterile slants of Czapek's agar, care being taken to select the tips of the hyphæ so as not to bring the loop in too close contact with the soil. The agar slants containing the transferred portions of mycelium were allowed to incubate till the organisms had developed well and were ready for study. The organisms thus isolated were not always pure. They had to be often separated from one another; this was accomplished by establishing pedigree cultures of the organisms.[1]

The organisms thus isolated are believed to come from the mycelium that is actually found in the soil. The period allowed for the incubation of the soil in the petri dish was not long enough for spores in the soil to germinate and produce such a mass of mycelium; this is espe-

[1] The methods of isolation and establishment of pedigree cultures, as well as the details of the work, formulæ for media used and identification of organisms will be published later.

cially true, since the medium used for incubation (Czapek's agar) is very unfavorable for the development and growth of the Mucorales, the group of organisms which had most representatives among the fungi isolated by the method previously described.

Organisms Found	Soils Used							
	Garden[2]	Orchard	Meadow	Forest	Iowa	Cranberry	Oregon	Dakota
Mucor plumbeus (Bonorden)	+[3]	+	+	+				
Mucor racemosus (Fres.)	+		+	+		+	+	
Mucor circinelloides (Van Tiegham)	+	+	+	+		+	+	+
Mucor hiemalis (Wehmer)	+		+				+	
Zygorhynchus vuillemnii (Namys.)	+	+	+	+	+			
Rhizopus nigricans (Ehrbg.)		+	+		+	+	+	
Green Trichoderma	+	+		+	+	+		
Penicillium luteum (Zukal)						+		
Penicillium sp.						+		
Fusarium sp.	+		+				+	
Sporotrichum sp.			+					
Acrostalagmus albus (Preuss.)	+						+	
Cephalosporium acremonium (Corda)			+				+	
Zygodesmus sp.							+	
Sclerotium					+		+	+
Sterile White Mycelium	+		+	+	+	+	+	+

To establish the fact whether the mycelium transferred, after the soil was allowed to remain in contact with the sterile medium, came from spores or from mycelium in the soil, the following test was made. A series of sterile plates containing cool, sterile Czapek's agar were incubated with spores and portions of mycelium from several organisms. The spores were had by shaking some spore material with 50 c.c. sterile water, then dipping a sterile platinum needle into the liquid and passing it over the surface of the sterile medium, thus dropping the single spores. The mycelium was transferred directly with a sterile needle from the culture upon the plate. The organisms used for this test were several Mucors, Trichodermæ and Penicillia. After twenty-four hours' incubation at 20–22° C. the plates were examined. Those that were inoculated with the mycelium had quite an extensive growth, the tips of the hyphæ being about as distant from the center of inoculation as in the case where the soil was used as an inoculum. But on the plates where only spores were inoculated very minute colonies could be observed with the naked eye; upon placing the dish under the microscope and examining it with the low power, one could see these colonies forming from each spore along the trace left by the needle in the medium. This fact gave reasons to believe that the mycelium developing on the plates from the soil came not from spores, but from organisms that actually live in the soil and produce mycelium there.

A number of soils of different origin, of different physical and chemical composition and treatment, were used for this investigation. The following table shows the occurrence of the different organisms in the soil, in the form of mycelium.

The results brought out in the above table are very interesting. Soils of entirely different textures, chemical and physical composition, soils widely apart from one another, contain many organisms which are alike for several of them. Of course, this refers only to the organisms that have been isolated by the above method and in the few soils studied. Other soils may contain different groups of organisms, as is found in the case of the Iowa and Dakota soils, where only very few organisms have been isolated by the direct method. It looks as if soils that are under a relatively similar range of conditions show, to a certain extent, similar groups of organisms when these are isolated directly from the soil.

Mucor circinelloides, Zygorhynchus Vuilleminii, green *Trichoderma, Rhizopus nigricans* and *Mucor racemosus* were found most abundantly. The *zygorhynchus* has been found at all depths from one to thirty inches below the surface, while most of the other organisms were isolated from the upper eight inches of soil. In most samples taken at depths of 12, 20 or 30 inches only *zygorhynchus* would develop from the soil upon the plate, with no other organism. The *sterile white mycelium*

[2] The garden, orchard, meadow and forest soils came from the College Farm, New Brunswick, N. J., Cranberry from Jamesburg, N. J., the other four soils from the respective station grounds.

[3] Indicates presence of organism.

developing from most of the soils is probably the mycelium of fleshy fungi. Other organisms, such as the *Penicillia, Fusaria* and *Sporotricha,* which are usually found in the soil abundantly when plated out by the dilution method, have been isolated by this method only in very few cases. The *Aspergilli, Alternaria, Cladosporia,* the great majority of the *Penicillia,* and other organisms commonly found in the soil, have not appeared on the plates in twenty-four hours, when the soil has been inoculated directly upon sterile medium.

SELMAN A. WAKSMAN
AGRICULTURAL EXPERIMENT STATION,
NEW BRUNSWICK, N. J.

THE AMERICAN CHEMICAL SOCIETY. IV

DIVISION OF WATER, SEWAGE AND SANITATION

Edward Bartow, *Chairman*

H. P. Corson, *Secretary*

Sanitary Surveys as a Feature of Public Health Work: H. E. BARNARD.

Sanitary Survey Methods: J. C. DIGGS.

A Sanitary Survey of Logansport, Ind.: J. C. DIGGS.

Swimming Pool Sanitation: W. LEE LEWIS.

The Rate of Ammonia Distillation in Water: F. W. BRUCKMILLER.

A Modification of the Whipple Method for Direct Nesslerization: F. W. BRUCKMILLER.

The Determination of Carbonic Acid, Combined and Free, in Water: JOHN JOHNSTON.

The Numerical Treatment of B. coli Values in Water Analysis: EARLE B. PHELPS AND WILLIAM F. WELLS.

Development at Lawrence of the Process of Purifying Sewage by Aeration and Growths—Activated Sludge: H. W. CLARK.

This paper describes the discovery and development at the Lawrence Experiment Station of the Massachusetts State Department of Health of the method of purifying sewage by aeration and growths—a method known quite generally as the activated sludge method. The paper shows that the method was developed there in 1911 and 1912, was shown to Dr. Gilbert Fowler, of Manchester, Eng., in the fall of 1912 and that the English work was largely a repetition of the Lawrence work. It quotes from Fowler and from Ardern and Lockett, his colleagues, to prove that their activated sludge work was based upon the Lawrence work. The paper further gives the statement of Dr. McLean Wilson, of England, made in his presidential address to the Association of Sewage Works Managers. This statement is as follows:

> Many investigators, including Drown, Dupre and Dibdin, Mason and Hine, Black and Phelps, Fowler and others, had sought to purify sewage by direct chemical oxidation by means of air currents and had failed. At Lawrence, however, the efficiency of growths in the purification of sewage by aeration was discovered.

The paper further describes the Lawrence work during the past four years and the results of much of this work. These results show that sewage can be fairly completely purified by this method. The paper is concluded as follows:

> Finally, the governing factors in the success of this process of sewage treatment are, as I have stated in previous articles: (1) The cost of power for supplying the large volume of air necessary; (2) a sewage that readily yields itself to this method of treatment. It is not impossible to believe that certain sewages can not be purified in this manner.

Composition of the Effluent Air from an Activated Sludge Tank: F. N. CRAWFORD AND EDWARD BARTOW.

Experiments with Activated Sludge at Milwaukee, Wis.: W. D. COPELAND.

The Aeration of Sewage in the Presence of Activated Sludge from the Standpoint of an Engineer: E. J. FORT.

Activated Sludge Experiments at the Baltimore Sewage Disposal Plant: CALVIN W. HENDRICK.

Chemical Observations of the Activated Sludge Process as applied to Stock Yards Sewage: ARTHUR LEDERER.

The Activated Sludge Process: W. D. RICHARDSON.

The Sewage Experiment Station of the Illinois State Water Survey: J. F. SCHNELLBACH AND EDWARD BARTOW.

The Experiments with Activated Sludge at Brockton, Mass.: ROBERT SPURR WESTON.

Brockton, Mass., population 62,000, discharges an average of 2,100,000 gallons fine-screened sewage daily, two thirds on 30 acres of sand beds, one third on 0.5 acre trickling filter, followed by 7 acres of sand beds. Rates are low; efficiency also. Difficulty due to stale, strong sewage containing shoe factory waste and dyes. (Suspended solids 204, free ammonia 55.8, chlorine 138.6 p. p. m.) Plain aeration with and without contact followed by Imhoff tank and trickling filter treatment was tried in 1915 with unsatisfactory results. More aeration was required. Fill and draw activated sludge tank followed by sand bed at 500,000