demjenigen dagegen, der den Gegenstand bereits kennt, einen großen Genuß bedeutet und tiefe Einsichten vermittelt. Das Buch kann daher dem Vorgerückteren, der sich um solche tiefere Einsicht bemüht, angelegentlich empfohlen werden. W. KUHN

## Ion Exchange

*Theory and Application*

By FREDERICK C. NACHOD
411 pp., 85 figs. and 33 ill.
(Academic Press Inc., New York, 1949)
($ 8.50)

In Zusammenarbeit mit 16 Spezialisten aus dem vielseitigen Gebiete des Ionenaustausches wurde von Dr. NACHOD eine kleine Enzyklopädie über dieses Fachgebiet geschaffen. Die ersten drei der gesamthaft 16 Kapitel befassen sich mit der Theorie und Empirie dieser, in neuester Zeit wieder in vermehrtem Maße angewendeten Arbeitsmethoden. In klarer und knapper Darstellung werden die empirischen Adsorptionsgesetze erläutert. Vom Gesichtspunkte des Massenwirkungsgesetzes aus und von der kinetischen Betrachtungsweise her werden die Austauschvorgänge beleuchtet. Sehr interessant ist das Kapitel über die fundamentalen Eigenschaften der künstlichen Austauschharze. Die übrigen Beiträge sind teils für den am Ionenaustausch interessierten wissenschaftlichen Chemiker, teils aber speziell für den Betriebsleiter geschrieben. Wenn die Kapitel über die Austauschharze, die Anwendung zur Trennung von Alkaloiden, die Trennung von Aminosäuren durch Ionenaustausch-Chromatographie, die katalytische Verwendung der Harze und über die gemischten Anwendungen des Ionenaustausches von großem allgemeinem Interesse sind, so dürften die Beiträge über mehrstufige Systeme, Entsalzung von Meerwasser und Zuckerraffinerie eher den Betriebsleiter interessieren. Daneben findet man Kapitel über Metallanreicherung und -Gewinnung, über die Anwendung von Ionenaustausch in der analytischen Chemie sowie biochemische und physiologische Verwendung dieser Harze, die mehr Spezialgebiete behandeln.

Allgemein ist zu sagen, daß dieses Buch mit wenigen Ausnahmen hauptsächlich den Austauschharzen gewidmet ist. Es wäre aber wünschenswert, die chromatographische Adsorptionsanalyse mit diesen neuen Mitteln etwas eingehender zu behandeln. Ebenso dürften manche Leser die Behandlung natürlicher Austauscher, wie Erden, Böden usw. vermissen.

Sehr angenehm empfindet man die klare Darstellung in den einzelnen Kapiteln, wenn auch die Zusammenstellung der Beiträge etwas übersichtlicher hätte gestaltet werden können. Die Autoren geben jeweils eine sehr reiche Literaturübersicht und helfen so mit, dieses Buch zu einem wertvollen Hilfsmittel für alle am Ionenaustausch und seiner Anwendung interessierten Chemiker zu machen. A. UFFER

# Informations - Informationen - Informazioni - Notes

### STUDIORUM PROGRESSUS

## Bacteria in the Soil

By FRANCIS E. CLARK[1], Ames, Iowa (U.S.A.).

A gram of fertile soil contains fantastic numbers of living microorganisms. Of the types visible with the compound microscope, the smallest, as well as the most numerous representatives of the plant kingdom, are the bacteria. The weight of a single living bacterium is of the order of $16 \times 10^{-10}$ mg. Recent estimates of bacterial numbers in soil, based on direct microscopic examination of soil combined with staining procedures to differentiate living and dead organic matter, indicate as many as $9 \times 10^9$ living cells per gram of soil[2]. Microbial populations that can be demonstrated in soil by means of dilution and cultural methods and the counting of individual colonies seldom exceed more than one per cent of the value cited. It is probable that this discrepancy is due in large part to the failure of many single cells of known species to establish growth in artificial culture, and not entirely to the existence of unknown bacterial types.

Of the bacteria that can be cultivated from soil, the majority are aerobic types that are capable of using a wide variety of food materials. They break down complex organic substances to simple compounds, such as carbon dioxide, water, and ammonia. They are primarily responsible for the mineralization of the plant and animal residues that are continually being returned to soil. In this connection it may be pointed out that there exists in the atmosphere above the surface of one acre of soil the equivalent of 5·64 tons of carbon, and that the living organisms in an acre of highly fertile soil return this much carbon to the atmosphere during the course of one year. In this respect soil microorganisms play an essential role in the carbon cycle in nature—they continually replenish the atmospheric carbon dioxide, which in turn is again combined photosynthetically by higher plants.

The complex of species primarily concerned in mineralization and humification processes in soil derive both their cell carbon and their energy from the organic substrates attacked, and collectively, constitute the heterotrophic bacterial flora of the soil. Some organic substances are attacked by many different microbes; others, by a smaller number of species. Fewer bacteria are capable of attacking paraffin and cellulose than are capable of attacking glucose or starch. Lignin is particularly resistant to decomposition, especially in the presence of organic and inorganic colloids. Together with the dead bodies of bacteria and in combination with their proteins, lignin is believed to account for more than half the dry

[1] Division of Soil Management and Irrigation, Bureau of Plant Industry Soils, and Agricultural Engineering, U. S. Department of Agriculture, and Iowa Agricultural Experiment Station. Journal Paper no. j-1707 of the Iowa Station.

[2] S. STRUGGER, Can. J. Res. [C] *26*, 188 (1948).

weight of the soil humus. Living bacteria, even though very numerous in soil, are of such minute size that they account for no more than 0·3, and frequently no more than 0·03, per cent of the total soil weight, dry basis[1]. However, because of their high water content, and relatively low density in comparison with the mineral fraction of the soil, they may at times comprise more than one percent of the soil volume.

In view of the importance of nitrogen in the soil economy, heterotrophic bacteria in soil frequently are grouped according to their nitrogen requirements. The majority of soil bacteria require combined nitrogen, either in an organic or in a mineral form, as do all other plants except certain blue-green algæ, and all animals. But there are some soil bacteria that are able to use atmospheric nitrogen. One economically important group, the legume-nodule bacteria or *rhizobia*, are capable of assimilating atmospheric nitrogen only in symbiosis with leguminous host plants. As a result of this symbiosis, legumes are able to grow on soil poor in nitrogen but otherwise favorable. The amount of nitrogen fixed by *rhizobia* and added to soil if the legumes are plowed under varies greatly, but under average conditions, it is estimated to range from fifty to one hundred and fifty pounds of nitrogen per acre per year.

There exist in the soil free-living forms of bacteria that are capable of fixing atmospheric nitrogen. A long series of experimental studies have stemmed from WINOGRADSKY's discovery of *Clostridium pasteurianum* in 1895 and BEIJERINCK's discovery of *Azotobacter chroococcum* in 1901[2]. These types occur in relatively small numbers in soil, and their importance in soil fertility remains controversial. Increases of fifty pounds of nitrogen per acre per year have at times been attributed to *Azotobacter*, and some workers have undertaken ambitious programs of soil inoculation. Others have remained skeptical of the ability of *Azotobacter* to accomplish significant fixation under field conditions. This controversy has been reviewed by ALLISON[3].

Recently, certain of the higher pigmented bacteria have been found capable of using atmospheric nitrogen[4]. These forms, interesting also because they contain a bacteriochlorophyll permitting photosynthesis, are found in stagnant water and in mud. They are probably of little importance in the nitrogen economy of ordinary field soils.

In contrast to the heterotrophic bacteria in soil, there are others which are designated as autotrophic bacteria. These do not require organic compounds as carbon and energy sources, but derive their energy from the oxidation of inorganic substrates, and their carbon from the carbon dioxide of the atmosphere. Although as a group they are less numerous than the heterotrophs, they include specific types that are indispensable in certain soil processes. Those which oxidize either ammonia nitrogen or sulfur are particularly important, inasmuch as plants draw largely upon nitrates and sulfates for their nitrogen and sulfur requirements. Specialization as to substrate attacked is the rule and not the exception among the autotrophic bacteria. Thus the *Nitrosomonas* group of bacteria oxidize ammonia to nitrites, and the *Nitrobacter* group, nitrites to nitrates. Other groups are capable of oxidizing elementary sulfur, sulfides and thiosulfates to sulfates, ferrous to ferric compounds, and still others, carbon monoxide to carbon dioxide, and hydrogen, to water.

Census numbers either of the total population or of the various groups of bacteria in soil are of little value in evaluating soil productivity. Yet the soil microbial populations en masse are responsible for the many transformations within the soil that make it productive of plant growth. Many important microbial processes in soil were recognized before the microorganisms concerned were discovered. Thus not until some 1800 years after PLINY observed that grain crops following legumes produced higher yields was it shown that certain symbiotic bacteria were able to assimilate atmospheric nitrogen. The oxidation of ammonia to nitrates was recognized as a biological process many years before WINOGRADSKY isolated the nitrifying bacteria.

Following the establishment of the role of soil organisms in the carbon and nitrogen cycles in nature, and the isolation and description of the many different types of bacteria, the diverse ways in which soil bacteria affect the growth of higher plants have become more adequately defined.

Particularly important is the role of soil bacteria in making available to plants practically all of the elements essential for plant growth. Microbial decomposition of organic matter releases not only the carbon and nitrogen therein, but all the other contained minerals as well. In their inorganic states such minerals as iron, manganese, and sulfur are transformed from unavailable to available forms by processes of microbial oxidations and reductions. In addition, products of microbial oxidation exert solution effects upon soil parent material. When rock phosphate is composted with sulfur and manure, the sulfuric acid formed by biological oxidation renders insoluble phosphate available. Plants have been found to secure more phosphate from relatively insoluble phosphate materials when grown in the presence of microbes than when grown under sterile conditions[1]. This is not surprising—it has long been known that in conjunction with bacteria, plant roots can deeply etch buried marble slabs with which they come into contact.

Soil bacteria function not only to provide nutrients in available forms, but also to conserve those present from fixation or flocculation in unavailable forms. The situation is anomalous in that microbial products also serve to fix mineral nutrients, but biological fixation is less permanent in its effects than is mineral fixation. In the case of phosphorus, biological interference with mineral fixation is accomplished in part by the elaboration of organic acids which complex with iron and aluminum and thus prevent the formation of insoluble iron and aluminum phosphates[2].

NORMAN[3] has stated that the soil population is not a beneficent organization laboring with a singleness of purpose to the end that nutrients shall be made available to plants, but a wholly independent population, nutritionally fiercely competitive within itself. The mineral nutrients required by soil bacteria for their synthetic activities are essentially those required by the higher plants. Where one or more minerals are scarce, and the supply of available energy material abundant, the soil bacteria are extremely able competitors for the limiting

[1] FRANCIS E. CLARK, Adv. Agronomy *1*, 241 (1949).

[2] S. A. WAKSMAN, *Principles of Soil Microbiology* (Williams and Wilkins, Baltimore, U.S.A., 1932).

[3] F. E. ALLISON, Soil Sci. *64*, 413 (1947).

[4] H. GEST, M. D. KAMEN, and H. M. BREGOFF, J. Biol. Chem. *182*, 153 (1949).

[1] F. C. GERRETSEN, Plant and Soil *1*, 51 (1948).

[2] R. M. SWENSON, C. V. COLE, and D. H. SIELING, Soil Sci. *67*, 3 (1949).

[3] A. G. NORMAN, Soil Sci. Soc. Amer. Proc. *11*, 9 (1947).

nutrients. It is commonly known that immediately following the application of a considerable quantity of material of wide carbon/nitrogen ratio, as cereal straw, to soil, the available soil nitrogen becomes depleted to such an extent that satisfactory crop growth is not obtained. Fortunately, the competitive effects of the soil flora are limited to energy-rich conditions in soil, and ordinarily do not long persist. In general, the total amount of organic matter in the soil determines the rate of nutrient mineralization and not the rate of nutrient immobilization.

Not only do soil bacteria compete with plants for nutrients that are in short supply, but they also effect transformations that render nutrients unavailable to higher plants. In this fashion they may remove from crop utilization materials in excess of their own synthetic demands for those substances. These transformations are not accomplished merely as acts of pure vandalism, but occur in order that the bacteria may satisfy some demand upon their environment, or else simply because of some environmental change brought about by their metabolic activities. Thus nitrate nitrogen may be reduced to gaseous nitrogen under anaerobic conditions, in order that bacteria may satisfy their oxygen demand. The loss of combined nitrogen in such an instance is entirely apart from any utilization by bacteria for protein synthesis. Sulfate when reduced to hydrogen sulfide or manganous and ferrous compounds upon becoming oxidized similarly become unavailable to higher plants.

Soil bacteria affect the growth of plants in many less direct ways than in their transformation of nutrient elements. Microorganisms indirectly affect plant growth through their effects on the soil physical environment. These effects may be upon the composition of the soil air, upon the soil moisture-holding capacity, or upon the soil temperature. It is now generally recognized that the presence of an active soil population leads to a degree of aggregate formation not obtained in its absence. The physical binding effects of filamentous organisms, the cementing action of mucilaginous or gummy polysaccharides produced extracellularly, and cementation by products of bacterial autolysis have been shown in laboratory experiments. In addition, the electron microscope has revealed that microorganisms are intimately associated with aggregate structures in soil[1].

Soil bacteria are the enemies of many soil-borne plant parasites. Many root-invading pathogens are more destructive in their attack upon susceptible plants grown in substrates free of saprophytic bacteria than upon plants openly exposed to a mixed soil flora. An effective field control of certain root diseases is obtained by the addition of organic manures to soil. Such amendments encourage a profuse development of non-parasitic members of the soil microflora, which in turn exert competitive or lytic effects upon the crop parasite. One of the spectacular advances in human medicine in recent years has been the development of microbially produced antibiotics. Certain of these are of fungal, and others of bacterial origin. The extent to which lytic principles can be employed to secure soil sanitation offers a fertile field for study.

A discussion of the soil bacteria would be incomplete without some mention of the localization of bacteria in soil. Microbes are not uniformly distributed throughout the soil, but commonly occur in clumps or colonies of few to many thousand individual cells. Other conditions being suitable, such *loci* can be expected wherever there occurs available energy material. One site of intensive microbial colonization is found at the surfaces of plant roots. Although it is commonly considered that plant roots are in direct contact with either the soil solution or soil particles, direct microscopic examination reveals that roots and root hairs are sheathed by a film of organisms, perhaps even to the extent that there is little or no contact of the root with the soil. The microbiological environment provided by the external surfaces of plant roots together with any closely adhering particles of soil or debris is designated as the rhizoplane. Other than the fact that bacteria are many times more numerous in the rhizoplane than in the surrounding soil, and that certain types of microbes are proportionately more numerous, knowledge concerning this ecological region remains scanty. It has long been recognized that associations apparently symbiotic exist between mycorrhizal-forming fungi and the roots of a great variety of plants. It remains for future work to define more precisely the extent to which the localization of soil microorganisms on root surfaces affects the welfare of higher plants.


*Zusammenfassung*

Die in einem Gramm Erde vorhandenen Bakterien zählen viele Millionen, bisweilen sogar mehrere Milliarden. Um sich verständigen zu können, werden diese Bakterien in Gruppen eingeteilt. Als Kennzeichen dienen ihre Kohlenstoff- und Energiequellen und auch ihr Stickstoffbedarf. Von wirtschaftlicher Bedeutung sind solche Arten, die den Luftstickstoff zu assimilieren vermögen und diesen Stickstoff dann später an die Pflanzen abgeben.

Die Bodenbakterien beeinflussen das Wachstum der höheren Pflanzen auf mancherlei Art. Bodenbakterien dienen dazu, Nährstoffe in leicht verwendbarer Form zu liefern. Das kann dadurch geschehen, daß sie aus organischen Verbindungen in Freiheit gesetzt werden; überdies spielen auch verschiedene oxydative und reduktive Vorgänge eine Rolle. Hierbei werden Mineralstoffe aus unverwendbaren in brauchbare Formen überführt. Es ist allerdings zu beachten, daß die zur Zellsynthese von Bakterien benötigten mineralischen Nährstoffe im wesentlichen die gleichen sind wie die, welche höhere Pflanzen aufnehmen. Unter gewissen Bodenverhältnissen kann daher der bakterielle Bedarf an Nährstoffen den Ertrag von Nutzpflanzen ernstlich beeinträchtigen.

Die Bodenbakterien wirken auf das Pflanzenwachstum auch in anderer, weniger unmittelbarer Art als durch die Verwandlung der Nährstoffe oder als durch den Wettstreit um solche Substanzen. Sie beeinflussen das Wachstum der höheren Pflanzen indirekt durch ihre Einwirkung auf das physikalische Bodenmilieu. Saprophytische Bodenbakterien sind die Feinde mancher im Boden lebenden Pflanzenparasiten.

Die Bodenbakterien sind in der Erdmasse nicht gleichmäßig verteilt. Eine dichte Bakterienbesiedlung findet sich an der Oberfläche der Pflanzenwurzeln. Dieser Bereich wird als Rhizoplan bezeichnet. Man weiß vorderhand noch wenig darüber, in welcher Art die Lokalisation der Bodenmikroorganismen an den Wurzeln das Gedeihen der höheren Pflanzen beeinflußt.


[1] M. L. JACKSON, W. Z. MACKIE, and R. P. PENNINGTON, Soil Sci. Soc. Amer. Proc. *11*, 57 (1947).