it lies within a few miles of the path of the greater part of the trade of Europe with the Far East—than any previous traveller. The apparently interminable war between the Dutch and the natives of Sumatra renders travelling or investigation in that marvellous island all but impossible to Europeans.

AT a meeting of the Society for Commercial Geography of Paris, held on the 21st inst. under the presidency of M. Meurand, Dr. Neis, of the Naval Medical Service, recounted the incidents of a recent journey from Saigon to the frontiers of Tonquin, and thence to Bangkok. He travelled from the basin of the Meikong to that of the Meinam, and referred in his paper to the various tribes met on the frontiers of Tonquin and Cambodia, and to the progress of England in Siam and Burmah. The Society, we observe, now numbers 1000 members.

THE following is a list of the papers arranged to be read before the Society for Commercial Geography of Oporto during the ensuing winter session:—Useful animals of Portugal and its possessions, by M. Torgo, jun.; crime from climatological and ethnological points of view, by M. Veloso; the geography of the Azores, by M. Silva; the exportation of national products to Brazil and the Portuguese colonies, by M. Gonsalvez; the climatological geography of the Portuguese colonies, by M. Monteira; recent colonial treaties with England, by M. de Sonza.

Petermann's Mittheilungen for October contains an article on the south-western portion of the province of Ciudad-Real, in Spain, with a map, by Herr Otto Neussel; one by Dr. Roukis, on the ethnography and statistics of Albania, based on a series of articles contributed to the Athens journal *Akropolis*, under the title of "The Present and the Future of Albania," by the late Greek Consul-General in that country; a third paper on Terek is a translation of one read before the Caucasian section of the Russian Geographical Society by Herr Dinnik. The "Recent Information from Corea" is that published in English Blue-books as reports from various consular officials who have lately visited the peninsula.

NOTES ON NITRIFICATION[1]

IN the following brief notes I propose to consider in the first place the present position of the theory of nitrification, and next to give a short account of the results of some recent experiments conducted in the Rothamsted Laboratory.

The Theory of Nitrification.—The production of nitrates in soils, and in waters contaminated with sewage, are facts thoroughly familiar to chemists. It is also well known that ammonia, and various nitrogenous organic matters, are the materials from which the nitric acid is produced. Till the commencement of 1877 it was generally supposed that this formation of nitrates from ammonia or nitrogenous organic matter was the result of simple oxidation by the atmosphere. In the case of soil it was imagined that the action of the atmosphere was intensified by the condensation of oxygen in the pores of the soil; in the case of waters no such assumption was possible. This theory was most unsatisfactory, as neither solutions of pure ammonia, or of any of its salts, could be nitrified in the laboratory by simple exposure to air. The assumed condensation of oxygen in the pores of the soil also proved to be a fiction as soon as it was put by Schlœsing to the test of experiment.

Early in 1877, two French chemists, Messrs. Schlœsing and Müntz, published preliminary experiments showing that nitrification in sewage and in soils is the result of the action of an organised ferment, which occurs abundantly in soils and in most impure waters. This entirely new view of the process of nitrification has been amply confirmed both by the later experiments of Schlœsing and Müntz, and by the investigations of other chemists, amongst which are those by myself conducted in the Rothamsted Laboratory.

The evidence for the ferment theory of nitrification is now very complete. Nitrification in soils and waters is found to be strictly limited to the range of temperature within which the vital activity of living ferments is confined. Thus nitrification proceeds with extreme slowness near the freezing-point, and increases in activity with a rise in temperature till 37° are reached; the action then diminishes, and ceases altogether at 55°. Nitrification is also dependent on the presence of plant-food suitable for organisms of low character. Recent experiments at Rothamsted show that in the absence of phosphates no nitrification will occur. Further proof of the ferment theory is afforded by the fact that antiseptics are fatal to nitrification. In the presence of a small quantity of chloroform, carbon bisulphide, salicylic acid, and apparently also phenol, nitrification entirely ceases. The action of heat is equally confirmatory. Raising sewage to the boiling-point entirely prevents its undergoing nitrification. The heating of soil to the same temperature effectually destroys its nitrifying power. Finally, nitrification can be started in boiled sewage, or in other sterilised liquid of suitable composition, by the addition of a few particles of fresh surface soil, or a few drops of a solution which has already nitrified; though without such addition these liquids may be freely exposed to filtered air without nitrification taking place.

The nitrifying organism has been submitted as yet to but little microscopical study: it is apparently a micrococcus.

It is difficult to conceive how the evidence for the ferment theory of nitrification could be further strengthened; it is apparently complete in every part. Although, however, nearly the whole of this evidence has been before the scientific public for more than seven years, the ferment theory of nitrification can hardly be said to have obtained any general acceptance; it has not indeed been seriously controverted, but neither has it been embraced. In hardly a single manual of chemistry is the production of saltpetre attributed to the action of a living ferment existing in the soil. Still more striking is the absence of any recognition of the evidence just mentioned when we turn to the literature and to the public discussions on the subjects of sewage, the pollution of river water, and other sanitary questions. The oxidation of the nitrogenous organic matter of river water is still spoken of by some as determined by mere contact with atmospheric oxygen, and the agitation of the water with air as a certain means of effecting oxidation; while by others the oxidation of nitrogenous organic matter in a river is denied, simply because free contact with air is not alone sufficient to produce oxidation. How much light would immediately be thrown on such questions if it were recognised that the oxidation of organic matter in our rivers is determined solely by the agency of *life*, is strictly limited to those conditions within which life is possible, and is most active in those circumstances in which life is most vigorous. It is surely most important that scientific men should make up their minds as to the real nature of those processes of oxidation of which nitrification is an example. If the ferment theory be doubted, let further experiments be made to test it, but let chemists no longer go on ignoring the weighty evidence which has been laid before them. It is partly with the view of calling the attention of English and American chemists to the importance of a decision on this question that I have been induced to bring this subject before them on the present occasion. I need hardly add that such results as the nitrification of sewage by passing it through sand, or the nitrification of dilute solutions of blood prepared without special precaution, are no evidence whatever against the ferment theory of nitrification. If it is to be shown that nitrification will occur in the absence of any ferment, it is clear that all ferments must be rigidly excluded during the experiments; the solutions must be sterilised by heat, the apparatus purified in a similar manner, and all subsequent access of organisms carefully guarded against. It is only experiments made in this way that can have any weight in deciding the question.

Leaving now the theory of nitrification, I will proceed to say a few words, firstly, as to the distribution of the nitrifying organism in the soil; secondly, as to the substances which are susceptible of nitrification; thirdly, upon certain conditions having great influence on the process.

The Distribution of the Nitrifying Organism in the Soil.—Three series of experiments have been made on the distribution of the nitrifying organism in the clay soil and subsoil at Rothamsted. Advantage was taken of the fact that deep pits had been dug in one of the experimental fields for the purpose of obtaining samples of the soil and subsoil. Small quantities of soil were taken from freshly-cut surfaces on the sides of these pits at depths varying from 2 inches to 8 feet. The soil removed was at once transferred to a sterilised solution of diluted urine, which was afterwards examined from time to time to ascertain if nitrification took place. These experiments are hardly yet completed; the two earlier series of solutions have, however, been examined for eight and seven months respectively. In both these series the soil taken from 2 inches, 9 inches, and

[1] A Paper by R. Warington, read before the Chemical Section of the British Association at Montreal.

18 inches from the surface has been proved to contain the nitrifying organism by the fact that it has produced nitrification in the solutions to which it was added; while in twelve distinct experiments made with soil from greater depths no nitrification has yet occurred, and we must therefore conclude that the nitrifying organism was not present in the samples of soil taken. The third series of experiments has continued as yet but three months and a half; at present no nitrification has occurred with soil taken below 9 inches from the surface. It would appear, therefore, that in a clay soil the nitrifying organism is confined to about 18 inches from the surface; it is most abundant in the first 6 inches. It is quite possible, however, that in the channels caused by worms, or by the roots of plants, the organism may occur at greater depths. In a sandy soil we should expect to find the organism at a lower level than in clay, but of this we have as yet no evidence. The facts here mentioned are in accordance with the microscopical observations made by Koch, who states that the micro-organisms in the soils he has investigated diminish rapidly in number with an increasing depth; and that at a depth of scarcely 1 metre the soil is almost entirely free from bacteria.

Some very practical conclusions may be drawn from the facts now stated. It appears that the oxidation of nitrogenous matter in soil will be confined to matter near the surface. The nitrates found in the subsoil and in subsoil drainage waters have really been produced in the upper layer of the soil, and have been carried down by diffusion, or by a descending column of water. Again, in arranging a filter-bed for the oxidation of sewage, it is obvious that, with a heavy soil lying in its natural state of consolidation, very little will be gained by making the filter-bed of considerable depth; while, if an artificial bed is to be constructed, it is clearly the top soil, rich in oxidising organisms, which should be exclusively employed.

The Substances susceptible of Nitrification.—The analyses of soils and drainage waters have taught us that the nitrogenous humic matter resulting from the decay of plants is nitrifiable; also that the various nitrogenous manures applied to land, as farmyard manure, bones, fish, blood, rape-cake, and ammonium salts, undergo nitrification in the soil. Illustrations of many of these facts from the results obtained in the experimental fields at Rothamsted, have been published by Sir J. B. Lawes, Dr. J. H. Gilbert, and myself, in a recent volume of the *Journal* of the Royal Agricultural Society of England. In the Rothamsted Laboratory, experiments have also been made on the nitrification of solutions of various substances. Besides solutions containing ammonium salts and urea, I have succeeded in nitrifying solutions of asparagine, milk, and rape-cake. Thus, besides ammonia, two amides, and two forms of albuminoids have been found susceptible of nitrification. In all cases in which amides or albuminoids were employed, the formation of ammonia preceded the production of nitric acid. Mr. C. F. A. Tuxen has already published in the present year two series of experiments on the formation of ammonia and nitric acids in soils to which bone-meal, fish-guano, or stable-manure had been applied; in all cases he found the formation of ammonia preceded the formation of nitric acid.

As ammonia is so readily nitrifiable, we may safely assert that every nitrogenous substance which yields ammonia when acted on by the organisms present in soil is also nitrifiable.

Certain Conditions having Great Influence on the Process of Nitrification.—If we suppose that a solution containing a nitrifiable substance is supplied with the nitrifying organism, and with the various food-constituents necessary for its growth and activity, the rapidity of nitrification will depend on a variety of circumstances:—(1) The degree of concentration of the solution is important. Nitrification always commences first in the weakest solution, and there is probably in the case of every solution a limit of concentration beyond which nitrification is impossible. (2) The temperature has great influence. Nitrification proceeds far more rapidly in summer than in winter. (3) The presence or absence of light is important. Nitrification is most rapid in darkness; and in the case of solutions, exposure to strong light may cause nitrification to cease altogether. (4) The presence of oxygen is of course essential. A thin layer of solution will nitrify sooner than a deep layer, owing to the larger proportion of oxygen available. The influence of depth of fluid is most conspicuous in the case of strong solutions. (5) The quantity of nitrifying organism present has also a marked effect. A solution seeded with a very small amount of organism will for a long time exhibit no nitrification, the organism being (unlike some other bacteria) of very slow growth. A solution receiving an abundant supply of the ferment will exhibit speedy nitrification, and strong solutions may by this means be successfully nitrified, which with small seedings would prove very refractory. The speedy nitrification which occurs in soil (far more speedy than in experiments in solutions under any conditions yet tried) is probably owing to the great mass of nitrifying organisms which soil contains, and to the thinness of the liquid layer which covers the soil particles. (6) The rapidity of nitrification also depends on the degree of alkalinity of the solution. Nitrification will not take place in an acid solution, it is essential that some base should be present with which the nitric acid may combine; when all available base is used up nitrification ceases. It appeared of interest to ascertain to what extent nitrification would proceed in a dilute solution of urine without the addition of any substance save the nitrifying ferment. As urea is converted into ammonium carbonate in the first stage of the action of the ferment, a supply of salifiable base would at first be present, but would gradually be consumed. The result of the experiment showed that only one-half the quantity of nitric acid was formed in the simple urine solution as in similar solutions containing calcium and sodium carbonate. The nitrification of the urine had evidently proceeded till the whole of the ammonium had been changed into ammonium nitrate, and the action had then ceased. This fact is of practical importance. Sewage will be thoroughly nitrified only when a sufficient supply of calcium carbonate, or some other base, is available. If, instead of calcium carbonate, a soluble alkaline salt is present, the quantity must be small, or nitrification will be seriously hindered. Sodium carbonate begins to have a retarding influence on the commencement of nitrification when its amount exceeds 300 milligrammes per litre, and up to the present time I have been unable to produce an effective nitrification in solutions containing 1·000 gramme per litre. Sodium hydrogen carbonate hinders far less the commencement of nitrification. Ammonium carbonate, when above a certain amount, also prevents the commencement of nitrification. The strongest solution in which nitrification has at present commenced contained ammonium carbonate equivalent to 368 milligrammes of nitrogen per litre. This hindrance of nitrification by the presence of an excess of ammonium carbonate effectually prevents the nitrification of strong solutions of urine, in which, as already mentioned, ammonium carbonate is the first product of fermentation. Far stronger solutions of ammonium chloride can be nitrified than of ammonium carbonate, if the solution of the former salt is supplied with calcium carbonate. Nitrification has in fact commenced in chloride of ammonium solutions containing more than 2 grammes of nitrogen per litre.

The details of the recent experiments, some of the results of which we have now described, will, it is hoped, shortly appear in the *Journal* of the Chemical Society of London.

Harpenden, July 21

RESEARCHES ON THE ORIGIN AND LIFE-HISTORIES OF THE LEAST AND LOWEST LIVING THINGS[1]

II.

BUT the point of difficulty was *B. termo*. The demonstration of its flagella was a task of difficulty which only patient purpose could conquer. But by the use of our new lenses, and special illumination we—my colleague and I—were enabled to demonstrate clearly a flagellum at each end of this least of living organisms, as you see, and by the rapid lashing of the fluid, alternately or together, with these flagella, the powerful, rapid, and graceful movements of this smallest known living thing are accomplished. Of course these fibres are inconceivably fine—indeed for this very reason it was desirable, if possible, to *measure* it, to discover its actual thickness. We all know that, both for the telescope and the microscope, beautiful apparatus are made for measuring minute magnified details. But unfortunately no instrument manufactured was delicate enough to measure *directly* this fibre. If it were measured it must be by an indirect process, which I accomplished thus:—The diameter of the body of *B. termo, i.e.* from side to side, may in different forms vary from the 20- to the 50-thousandth of an inch. *That* is a measurement which we may easily make directly with a micrometer. Having ascertained this, I deter-

[1] By Rev. W. H. Dallinger, LL.D., F.R.S., F.L.S., Pres. R. M. S. Continued from p. 622.