near the horizon, as seen from a high mountain peak." That Jupiter is not self-luminous, and that outside its cloud surface is situated a rare atmosphere capable of producing a measurable refraction, are two of the results of these observations, and taking the refraction at the cloud surface, the value $0''\cdot50 \times 0''\cdot05$ probably is not far from the truth.

THE MOON'S SURFACE.—Under the title of "The Moon's Face," a study of the origin of its features, we have before us a small book of fifty pages, containing the address, as retiring President, of Mr. G. K. Gilbert, before the Philosophical Society of Washington (*Bulletin*, vol. xii., pp. 241–292). After giving a short survey of the various theories that have from time to time been suggested as explaining the origin of the features on our satellite's surface, Mr. Gilbert has been led to put forward what he terms a "moonlet theory," which "not only harmonises with the varied details of crater character, but aids in the explanation, and even in the history, of the other features of the moon's surface." The hypothesis may be stated as follows:—Previous to the existence of the moon the earth was circled by a ring analogous to that which surrounds Saturn. The small bodies or satellites constituting this ring in time gradually coalesced, first into a large number of nuclei, and finally into one, this nucleus being our moon. The lunar craters are, to use Mr. Gilbert's own words, "the scars produced by the collision of those minor aggregations, or moonlets, which last surrendered their individuality." In discussing this hypothesis the inquiry is carried on three lines: an investigation of the ellipticity of the lunar craters, experimental investigation of the relation between the angle of incidence and ellipticity of impact craters, and of the orbital relations affecting the incidence angles of moonlets. With regard to some of the peculiar features of the lunar surface, let us briefly refer to some of the explanations given here. In the production of small craters small moonlets were employed, the cups being moulded as the result of collision. For large craters, greater moonlets are supposed to have been in action, the rims round the cups being raised partly by the overflow at the edges of the cup, or resulting in the upheaval of the surrounding plain in all directions. The central cone is accounted for by supposing that the top parts of the walls of the cup are so "weakened by the efforts of heating," that they consequently fall into the centre of the cup from all sides. In the region of the Mare Imbrium he supposes that a collision of great violence occurred, dispersing in all directions a deluge of material "solid, pasty, and liquid." The outrush from the Mare Imbrium thus introduces the elements necessary to a broad classification of the lunar surface. Smooth planes were produced by the liquid matter, parts were ground or sculptured by the solid matter, while some features were left entirely untouched. Such are one or two of the origin of surface features as put forward by Mr. Gilbert in his moonlet theory. That they are ingenious and lack not interest is true, but that the hypothesis itself is likely to be received with anything like favour seems very doubtful, since our present knowledge of the way nature works shows us that the last minor aggregations or moonlets could not very probably act in the way indicated above, because the state of the nucleus about that time would be one of intense heat in consequence of the collisions, and therefore would not be capable of receiving lasting impressions as required by the hypothesis.

AMÉDÉE GUILLEMIN.—It is with great regret that we have to record the death of M. Amédée Guillemin, which occurred recently in France. Many of our readers will have read the most interesting and valuable books which he wrote, setting forth scientific facts in a popular light. Of his many writings perhaps that which is most familiar to us are the volumes entitled "The Heavens" and "The Forces of Nature," as translated into English, and it is only quite lately that we had occasion to notice a small volume, evidently his last work, dealing with astronomical subjects, and entitled "L'Autres Mondes."

GEOGRAPHICAL NOTES.

LIEUTENANT R. PEARY, the explorer of North Greenland, has been reluctantly compelled to relinquish his projected lecturing tour in Europe, as all his time must be devoted to preparations for his new expedition toward the North Pole, which he hopes to commence this summer.

THE Governments of Sweden and Denmark have entrusted Prof. Otto Pettersson with the planning and direction of a series of simultaneous observations on the physical condition of the Skagerrack, Kattegat, and Baltic Sea. These observations are to be made on four days, three months apart, and commenced on May 1, 1893. Simultaneous observations between the Moray Firth and the north of Shetland would greatly enhance the value of the Scandinavian results, and it is possible that the Fishery Board for Scotland may undertake this work, at least on some of the observing days.

CAPTAIN RICHARD PIKE, well known as an Arctic navigator in recent American expeditions, died at St. John's, Newfoundland, in the beginning of May. In 1881 he conveyed the Greeley expedition to Lady Franklin Bay, and would have brought relief to the party, and saved the gallant explorers from their terrible experiences of starvation in 1883, had he not on that occasion been put under the orders of a United States cavalry officer, whose mismanagement ruined the expedition. Captain Pike's last Arctic work was the transport of Peary's expedition to McCormack's Bay, and his return for them in the sealer *Kite*. He had the reputation of being the best practical navigator of the Newfoundland Sealing Fleet, and his experience will be missed in connection with Lieutenant Peary's new expedition, which Captain Pike was to have taken north this summer.

THE anniversary meeting of the Royal Geographical Society will be held on Monday, the 29th, at 2.30 p.m. From the circular calling the meeting we observe that a very considerable change in the composition of the Council is contemplated. The President, Sir M. E. Grant Duff, does not seek re-election, in the hope, as he hinted at the anniversary dinner, that his "leap into the gulf in the cause of women" will heal the recent dissensions in the Society, and enable the scientific work in which it is engaged to be carried on without interruption. Mr. Clements Markham, F.R.S., has accepted the nomination of the Council as President. Captain Wharton, R.N., F.R.S., is proposed as a new Vice-President, and the following, amongst other names, are proposed as new members of Council:—Admiral Lindesay Brine, General T. E. Gordon, author of "The Roof of the World;" Mr. G. S. Mackenzie, of the British East Africa Company: Colonel C. M. Watson, and Mr. W. H. Hudlestone, F.R.S., President of the Geological Society. These nominations are subject to the approval of the annual meeting, which is expected to be unusually large and representative.

BACTERIA, THEIR NATURE AND FUNCTION.[1]

A WELL-KNOWN English writer a short time ago informed the public that Prof. von Pettenkofer, the distinguished veteran in sanitary science in Munich, expressed the opinion that "the atmospheric envelope of this globe is at present in a bacillophil humour." Expressions such as these have been repeatedly used in one form or another, some more, some less witty; the intention being, of course, to convey an exaggerated impression of the frame of mind of over-zealous enthusiasts. By such expressions more or less distinguished speakers and writers have been enabled to exhibit the smartness of their phraseology. Thus one distinguished professor relieved the anxiety of his students by the jocular observation that idleness and laziness will probably be found to be due to a specific bacillus, while another no less profound writer enunciated that crime and inebriety are probably due to bacilli. With regard to the distribution of bacteria, as well as with regard to their action, we meet with statements which are almost made humorous by smartness of exaggeration. Under the cover of the title "Science Notes," one of the London papers offered to its readers for breakfast the following palatable dish:—"In a grain of butter you have 47,250,000 microbes; when you eat a slice of bread and butter, you therefore must swallow as many microbes as there are people in Europe." Here it ought to be stated that a grain of solid matter of *London sewage* contains only a small fraction of this number of microbes. But leaving these silly exaggerations and those grotesque sayings to their authors for

[1] Lecture delivered at the London Institution, on February 27, 1893, by E. Klein, M.D., F.R.S., Lecturer on General Anatomy and Physiology at the Medical School of St. Bartholomew's Hospital, London

further improvement, it is nevertheless well established that a considerable number of phenomena in nature are intimately associated with bacterial life. The world of bacteria is comparable to an unseen flora which, in variety of character, of activity and importance in the economy of nature, compares with the visible flora, and in its extension and area of distribution is as great as, in some respects greater than, that of the visible vegetable and animal kingdom. Though unpreceived by the unaided eye, this bacterial world forces itself, by its multifarious activity, continually on our attention; it comes into prominence by the vast effects, the slow but far-reaching results which it produces on man, animal, and plant, for good and for evil, in life and in death. Some of these actions I shall have the honour to bring before you this evening, and you will see that while there are bacteria whose actions are undesired and not conducive to the well-being of man or animals, there are others which are of the greatest service both to them and to plants, and are an essential and integral part in the economy of nature.

I spoke just now of the bacterial world as of an unseen flora; I meant by this a part of the vegetable kingdom not perceived by the unaided eye, though, as you will see, it is easily brought to perception by a variety of means. The individuals that constitute the bacterial world are, as is no doubt known to you, of such extremely minute size that only by the aid of the microscope can they be seen, their size being often less than $\frac{1}{25000}$ or $\frac{1}{30000}$ part of an inch, rarely more than $\frac{1}{3000}$ part of an inch. They are spoken of as having the character of plants, because the elements, like those of a plant, are invested in a sheath of cellulose, within which is contained the essential part, the living protoplasm, the bacterial individuals being in fact comparable to unicellular plants, in which, however, no definite cell nucleus has been hitherto demonstrated. It ought, however, to be mentioned that various observers have attempted to show, and, by complex methods of staining, have succeeded in showing in some bacterial species the existence of parts which resemble, and which are considered as comparable to, the nucleus forming an integral part of the typical vegetable cell.

In speaking of bacteria as of plants there are other than morphological characters which guide us in this designation; bacteria resemble plants in this essential, that they possess the power to build up, out of simple organic compounds, the most complex substances such as the protoplasm of their own bodies. There are known not a few bacterial species which grow and multiply, *i.e.* which build up their highly complex nitrogenous albuminous substances at the expense of relatively simple nitrogenous bodies, such as ammonium tartrate, urea and allied substances, or which can do this even by the absorption of free nitrogen of the air. Other species require for their growth and multiplication as complex nitrogenous substances as the animal body itself, and like this latter are capable of breaking them up into simpler combinations. Pathogenic bacteria—many of the species concerned in the decomposition and putrefaction of albuminous substances—belong to this group.

All bacteria multiply by division; hence their name, schizomycetes, or fission fungi, the typical process of multiplication consisting in the enlargement of an individual, and in subsequent splitting into two by fission, at the conclusion of which process two new individuals are the result, each of them capable of enlarging and again dividing in the same way into two, and so on. But it can be easily shown by comparative observations and examination of suitably prepared specimens of artificial cultures of the different species that not seldom the process of multiplication does not follow this line.

I show you here a lantern slide of a microscopic specimen of one of those species which, owing to the spherical or nearly spherical form of the elements, is called a coccus, or micrococcus; and owing to the manner of growth in clusters and continuous masses, is called a staphylococcus; this microscopic specimen has been obtained by the method of making "impression preparations," that is to say, by means of a thin glass pressed on to a recent, *i.e.* a young colony or colonies growing on the surface of a solid medium, an exact impression is obtained of the growth, and a good and correct insight is obtained of the manner in which the colony enlarges, and the way in which the individuals constituting the colony grow and multiply. You see in this photographic representation that there are a good many individuals many times (4–10 times) as large as others, that some of these large elements are uniform, while others show just the indication of a transverse fissure by which the large element is dividing; still others show two fissures at right angles, by which the big element becomes divided into four smaller ones. But you see also the majority of cocci are only minute dots, some in pairs, others in clusters, the former looking like two demilunes separated by a straight clear line; in fact, this latter appearance denotes the typical manner in which one coccus, having first enlarged a little, divides into two small elements. But the presence of the huge elements mentioned above tells us also that one coccus may go on growing to a very large size without dividing, and having reached this huge diameter, then commences to divide, first into two, then into four, eight, and sixteen individuals of the typical size.

I show you here an impression preparation of a recent colony of another species (*Bacillus coli*), the individuals of which are rod-shaped or cylindrical, and are what are called typical bacilli. Here the great majority of the individuals are of cylindrical shape, and of a fairly uniform size; a few only are shorter, and arranged in the form of a dumb-bell, indicating that one of the longer individuals has by fission split up into two smaller individuals. But if you look at a third impression preparation, of which I here show you a photograph (Proteus), you will see that while there are a few chains of cylindrical bacilli, indicating successive division of the individuals and the new offsprings remaining joined end to end—thus constituting what is spoken of as a leptothrix—there are other threads in the colony which either show a division into cylindrical elements only imperfectly or not at all, appearing uniform and unsegmented threads; where the segmentation is imperfect the individuals are of very various lengths, some not longer than those typical bacilli in the first-mentioned chains, others three and more times as long. These appearances indicate that the multiplication of the bacilli does not always take place in that typical manner in which it is generally represented, viz. one individual elongates a little, then splits up into two short individuals; but a bacillus may go on elongating till it reaches the manifold length of the typical rods, and having reached this great length then segments into a great number of cylindrical rods. This mode of multiplication can be made out not only in these impression preparations, but can be actually observed in the fresh condition under suitable conditions, *e.g.* on the warm stage.

That this mode of growth appertains not only to cocci and bacilli, but also to the third morphological group of bacteria, viz. the vibrios, or spirilla, is ascertained by the fact that often one vibrio, *i.e.* a more or less curved rod-shaped individual or a comma-shaped bacillus, grows into a uniform homogeneous spiral or wavy thread, which is capable of splitting up into a number, *i.e.* a chain of comma-shaped vibrios.

We have then the typical mode of division, by which one individual, a coccus, or bacillus, or vibrio, as the case may be, slightly enlarges, and then by fission divides into two; or an individual continues to grow to abnormal size or length, and then splits up into a series of individuals of the typical size; this latter mode of multiplication implies a deficiency of fission for the time being, and is not, as far as can be made out, due to any abnormal conditions affecting the growth, for in many species this occurs in recent and active colonies under conditions which in all other respects must be pronounced as favourable for growth and multiplication.

Another interesting appearance, shown by some species of bacteria, is generally ascribed to degeneration or involution, *i.e.* the bacteria assume peculiar abnormal shapes stated to be due to abnormal influences, insufficient or unfavourable soil, unfavourable temperature, &c., &c.; but while it is true that such influences do produce abnormal shapes, disintegration, &c., there are certain changes in shape that are observed in some species of bacteria while growing under perfectly favourable conditions and with the normal rapidity, and which are anything but degenerating.

A recent colony of the bacillus anthracis, like the photograph I show you here, growing on nutritive gelatine, is made up of twisted and convoluted threads of cylindrical rods, which threads are seen to shoot out and to extend like filaments from the margin of the colony. Now, you notice in the next photograph that instead of these filaments being made up of the typical cylindrical rods the former consist of relatively huge spindle-shaped or spherical masses many times the diameter of the typical rods. The threads of this colony are perfectly active, and are growing with vigour and in perfectly normal circumstances as regards soil, temperature, and all other known conditions. As a matter of fact, a few days later, as comparative specimens show, all threads may be, and as a rule are, again of the typical aspect, *i.e.* uniform threads and chains of rod-shaped elements.

Another photograph which I show you here is from a colony of the bacillus of diphtheria. Here also you notice the appearances already mentioned of the anthrax bacilli, viz. shorter or longer filaments, in which some of the elements show a conspicuous enlargement: pear-shaped, spherical, or club-shaped. Such forms are not involution forms: they occur in vigorous and actively growing young colonies.

A still further illustration, and one of great importance, is shown by this photograph, illustrating a similar change of the tubercle bacilli. This change has now been confirmed by several independent observers. The typical tubercle bacilli of human or bovine tubercle and of early cultivations are cylindrical rods. In cultivations of long duration but still actively growing you notice forms which are more filamentous, and, as in the present illustrations, are branched filaments with club-shaped enlargements.

From all this the conclusion is justified that in all these cases of bacilli the typical cylindrical bacilli show occasionally an indication that reminds one of forms belonging to the higher or mycelial fungi, in which the growing filaments remain unsegmented and become thickened and even branched. These thickened, branched, and club-shaped forms of the bacilli would correspond to an atavism, and would recall a probable former fungoid phase in the evolutional history of these bacilli.

The next point to which I wish to call your attention is the rapidity with which multiplication of the bacteria takes place. This differs according to the amount and nature of the nutriment or soil on which they grow, and to the temperature. While some bacteria multiply even at lower temperatures at a great rate, others do so only at higher temperatures. But in order to give you an idea of the power and the rate of multiplication I may mention the following:—Direct observations show that the rate at which bacteria divide at a temperature of 20°C. varies from eighteen minutes to thirty minutes or a little longer, and at higher temperatures correspondingly faster. A tube of nutrient broth was inoculated with a trace of the growth of a staphylococcus (*Staphylococcus pyogenes aureus*), the number of cocci introduced into the tube having been previously determined to be 8 per cubic centimetre. The tube was then kept at 37°C.; in the first twenty-four hours the cocci had multiplied to 640,000 per cubic centimetre; in the second twenty-four hours to 248 millions per cubic centimetre, and in the third twenty-four hours to 1184 millions per cubic centimetre.

A point of interest is the motility exhibited by some bacteria. In some species most, in others comparatively few, individuals show active locomotion, spinning round and darting to and fro; in many other species no motility is observed. In the motile species it is known that this motility is due to the presence and active motion of cilia or flagella, and these have been seen and photographed in former years in some of the larger forms, but only within recent years has it been possible, by means of new methods (Löffler), to actually demonstrate in the smallest forms these flagella, and here the remarkable facts have been shown that while some possess only one flagellum at one end, in other species the bacillus possesses a bundle of them, or is covered with the flagella on its whole surface. I show here some photos of the flagella, one possessing two flagella at one end (spirillum volutans), the other (cholera bacillus) one at one end, and the third (typhoid bacillus) is covered with quite a number of flagella.

A not less interesting point is the formation of spores: the only trustworthily ascertained mode of spore formation is that which is called endospores, as is shown in the following photograms; a bacillus at a certain phase develops in its protoplasm a minute glistening granule, this increases in size and becomes oval, while the rest of the substance of the bacillus becomes pale, swells up and gradually degenerates and disappears, leaving the fully formed oval bright spore free. These spores are of great resistance to temperature, chemical obnoxious substances, drying, &c., so that even after long periods and various adventures, when again brought under proper and suitable conditions, they are capable of germinating into the bacilli. These then grow and divide and continue to do so, producing new crops. Non-sporing bacteria are for this reason more liable to succumb in the struggle for existence, although many species of non-sporing bacilli have such a vast power of multiplication and are so little selective in their requirements that they manage to keep their crops perpetually going; some notorious putrefactive cocci and bacilli belong to this class. Having now mentioned the essential features in the morphology of bacteria, as far as is possible in the limited space of time at my disposal, I proceed to give you a short summary of some of the most important activities which bacteria exhibit.

Bacteria causing Decomposition of Albumen.

Foremost in importance and vastness of result is the action which certain species of bacteria have on albuminous matter, an action which is termed *putrefactive decomposition of albumen*, animal or vegetable. All organic matter when deprived of life is resolved into simpler compounds, is broken up into lower nitrogenous principles, like leucin, tyrosin, indol, phenol, &c., of which the ultimate products are ammonia, nitrites, and nitrates. The plant, it may be said in a general way, builds up albuminous matter from nitrates, this albuminous matter it is which forms the protoplasm of its cells, this albuminous matter it is which serves as nitrogenous food for animals; these again supplying the food for other animals and man. In the living body of these the albuminous matter becomes broken up, yielding nitrogenous principles like urea and allied substances, which again, after further oxidation in the soil and in water, serve to supply nitrates to the plant; but also the bodies of animals and plants after death form a large stock from which by a long chain of processes, induced and sustained by micro-organisms, lower nitrogenous compounds, and ultimately ammonia and nitrates are produced, from which the living plants principally draw their nitrogen.

From this it is evident that the vegetable kingdom is dependent for its nitrogen chiefly on processes by which from the albumen of dead organic matter, by the activity of micro-organisms, in the first place lower nitrogenous principles and ultimately ammonia, and in the second place, also by micro-organisms nitrites and nitrates are formed. Now, the micro-organisms which are capable of producing the first series of decompositions of dead albuminous matter form, so to speak, the first army of attack; it is this army which, while multiplying at the expense of albumen, decomposes it, and thereby is instrumental in changing it into lower nitrogenous principles such as leucin, tyrosin, indol, and ammonia. Amongst the large number of species of putrefactive bacteria I will describe two only, which by their great distribution may be considered as playing a very important part in this decomposition of albumen. The first is the species known as *Proteus vulgaris*, the second is the *Bacillus coli.*

(*a*) *Proteus vulgaris.*—This species is the common putrefactive organism; it is almost invariably present in dead and decaying albuminous matter; it is the organism which in dead animals and man plays the principal part in the destruction and resolution of the body; it is present in the cavity of the normal intestine; it is found in connection with effete and dead matter occurring in the body in health and disease; it has a wide distribution in nature, and is present wherever organic matter happens to be in a state of putrescence; it is liable to pass from this and to be transmitted to other putrescible matter by air currents, by dust, by water, by human contact or otherwise, and then to set up in this new organic matter the same state of putrescence. The same applies to the bacillus coli, which has also a very wide distribution, and which is in most instances associated with putrefaction and decomposition of albuminous matter; it is a normal inhabitant of the human and animal intestine, and from here often passes into the soil, water, and air.

These two species of organisms may be considered then as being of great importance in the destruction and resolution of putrescible matter, in short of dead albuminous matter.

I show you here photographs of these two species as they appear in artificial cultures, under various forms of cultivation, and under the microscope under a magnification of 1000. Both these species are motile bacilli.

The *Proteus vulgaris*, as its name implies, presents itself in forms so varied, that it is at first sight difficult to recognise them as belonging to one and the same species: coccus forms, short ovals, short and long cylinders, homogeneous long threads, and even spiral forms. But by artificial cultivation by exact methods they can be shown to belong to one and the same species; and it can also be shown that under particular conditions of cultivation the bacillus almost invariably shows itself as cylindrical and thread-like forms; whereas under other conditions it assumes the character of cocci and ovals. The photographs which I show you here give an exact representation of these cylindrical and thread like forms observed in early gelatine plate cultures; later on, when the growth has proceeded for some days, and the gelatine has almost entirely become liquefied, the majority of the individuals are very short—either coccus-like or short ovals.

It is on account of this unstable or protean character of its form that Hauser gave it the name of Proteus, and being the common microbe of putrid decomposition, he called it *Proteus vulgaris.*

This organism, as a first and important action, peptonises albumen and liquefies and peptonises gelatine; then this peptone is decomposed, yielding, amongst other substances, leucin, tyrosin, indol, skatol, phenol, and further, ammonia.

(*b*) *The Bacillus coli.*—The normal inhabitant of the intestine of man and animals is another powerful albumen decomposing microbe, but, unlike the proteus, it decomposes albumen without first converting it into peptone; it therefore does not liquefy gelatine like the proteus; it rapidly decomposes albumen, forming indol and allied bodies, and even ammonia.

Bacteria causing Ammoniacal Fermentation of Urea.

In connection with these true putrefactive bacteria I have to mention a group of bacteria which, though not strictly connected with decomposition of albuminous matter, play an important part, inasmuch as their action supplements that of the former, the group in question consisting of species which can change urea and allied substances into ammonium carbonate. This action is generally and justly considered of the nature of a ferment or hydrating action, like that of other organised ferments to be presently described. But we mention this group here because by changing urea into ammonium carbonate it prepares, in one sense, the way for the action of certain other bacteria which, by oxidising ammonia into nitrites and nitrates, are the direct food-providers for the vegetable kingdom. Urea and allied substances, as stated above, are the last products of albuminous metabolism in man and animals, and therefore form an integral part of the material destined for the soil in which the plants of our gardens and fields live and thrive. I show you here one of the species of this group—for there are several—the *micrococcus ureæ;* this is a coccus growing as a white staphylococcus, and forming connected masses in the natural or artificial culture media; it does not liquefy gelatine, grows extremely rapidly at higher temperatures.

The photographs give you an idea of the character of this organism in plate, in streak- and stab-culture, and in microscopic specimens; in these latter you notice that neither in size, nor arrangement, nor mode of division does this microbe show anything that would distinguish it from other species of staphylococcus; its action on urea being its chief distinguishing character, being capable of converting it into ammonium carbonate.

At present it is well established that nitrogenous principles like indol, phenol, and ammonia are produced during the decomposition of albumen by proteus, bacillus coli, and other putrefactive bacteria; and, further, that substances, as indol, phenol, and the like, are, by the activity of certain other bacteria not yet sufficiently investigated, converted into ammonia. We have now traced the decomposition of albumen down to ammonia, and in this condition it is subjected in the soil to the action of the *nitrifying bacteria*—that is, bacteria which oxidise ammonia and convert it into nitrites and ultimately into nitrates; these bacteria complete then the series of processes by which the nitrogen ultimately returns from where it started. It started as nitrates in the soil surrounding the roots of plants, and as nitrates it ultimately again finds itself in the soil; first it had been used by the plant in order to build up its albumen, then as vegetable albumen it represents the food of animals; in these it serves to build up the protoplasm of the animal body, from which it passes as food for carnivorous animals. The albumen of animals or plants becomes decomposed by putrefactive bacteria, the ultimate products of this, ammonia, becoming converted by the nitrifying bacteria of the soil into nitrites and finally into nitrates. "From earth to earth" expresses the beginning and end of this wonderful migration and change!

Nitrifying Bacteria.

Schlœsing and Muntz were the first to show that the conversion of ammonia into nitrates in the soil is most probably caused by micro-organisms, but not till the researches of Warington, Winogradski, and P. Frankland, were these micro-organisms isolated and more carefully experimented with. Warington, and particularly Winogradski, have shown that there are two species of bacteria which play an important part in these processes, one species converting ammonia into nitrites, the other these finally into nitrates. I show you here some lantern slides of Winogradski, in which these two species are well shown; the slides are of preparations of artificial cultivations, in which Winogradski has been extremely successful. These two species (the nitrous and the nitric organism) are minute rod-shaped or oval bacteria; when in the act of dividing, they form short dumb-bells; the nitrous organism is larger than the nitric, but both show forms which possess celia, and which therefore are possessed of motility. Winogradski has by artificial cultivations obtained both these species in large quantities, and, on testing them on liquids of suitable composition, found that the one is capable of converting ammonia into nitrites, the other these latter into nitrates. There can then be no doubt that the problem of the manufacture on a large scale of these nitrifying microbes, so important for agriculture, must be considered as solved.

Bacteria of Leguminosæ.

I have now to introduce to your notice a group of organisms which, like the former, are of interest and importance to the vegetable kingdom, at any rate to one portion of it, viz. the plants belonging to the leguminosæ.

Hellriegel and Wilfarth had shown that the excess of nitrogen in leguminosæ is obtained from the atmosphere by the instrumentality of bacteria in the soil around the roots of the leguminous plants; that these bacteria "fix" the free nitrogen contained in the soil, derived, of course, from the atmosphere; and that if the soil be sterilised, by which the bacteria are killed, no fixation of nitrogen can take place, and the growth of the leguminous plant remains appreciably attenuated. The roots of leguminous plants growing in the ordinary soil are known to possess numbers of nodular growths. These nodules have been thoroughly investigated by a large number of observers, and their importance in the process of fixing the nitrogen, and in the proper development of the plant, has been satisfactorily worked out; foremost amongst these stand the investigations of Prof. Marshall Ward, of Sir John Lawes and Dr. Gilbert, of Beyerinck, Prazmowski, Nobbe, and Frank. Beyerinck, then Prazmowski, and particularly Nobbe, have shown that the nodules on the roots owe their origin to the growth in the tissues of the root of certain bacteria, and it is these bacteria which are instrumental in fixing the free nitrogen. These bacteria represent well-defined species, and, as Nobbe has shown, differ for the different leguminosæ.

My friend Prof. Marshall Ward has been kind enough to supply me for examination with roots of lupines containing the nodules, and I show you here some photos as the result of this examination, illustrating the distribution in the tissue of the nodules of particular species of bacteria, then the character of these bacteria under cultivations, and their aspect and size in microscopic specimens. This species of bacilli is composed of motile cylindrical rods, which, cultivated in gelatine, liquefy this, and produce in the liquefied gelatine a peculiar greenish fluorescent colouring; on agar they also produce this colouring; the nature of the young colonies in plate cultivation, their manner of spreading and swarming, are well shown in these photographs.

Chromogenic and Phosphorescent Bacteria.

Time does not permit of more than a passing allusion to those remarkable species of chromogenic bacteria which have the power to produce pigments, either pigments which become dissolved in the medium in which these bacteria grow, or remain limited to the substance of the bacteria themselves. Species of bacteria there are which produce pigments of scarlet red, orange, yellow, yellow-green, green, greenish-blue, blue, violet, or pink colour. The nature of these pigments and the meaning and object of their formation are still shrouded in a good deal of mystery, though Erdmann and Schrötter showed long ago that many points of similarity exist between some of these pigments and certain anilin colours. I show you here cultivations of some of those chromogenic bacteria, and in a diagram the spectrum of one species, viz. of the *Bacillus prodigiosus;* this is the more common of the chromogenic bacteria, being occasionally present in water and in air. The pigment is soluble in alcohol, though only to a limited degree, and when the spectrum of such a solution is examined it is seen to present a characteristic absorption-band in green; the spectrum of a watery distribution of these bacteria shows two bands: one narrow one in green, the other broader in greenish-blue; both are less deep than the single band of the alcoholic solution.

Nor have I sufficient time to do more than allude to another remarkable group of bacteria, which comprises several species, all having the power to produce luminosity of themselves and the medium in which they grow. These phosphorescent bacteria have been long known (Pflüger) to be concerned in the production of the phosphorescent condition of decomposing sea fish, but within recent times Ludwig, Fischer, Katz, and particularly Beyerinck have studied more in detail the conditions under which these bacteria grow, and have identified and cultivated several species. Dr. Beyerinck has kindly sent me one species of these phosphorescent bacteria. The elements of this species are short oval rods, often dumb-bells; they grow in fish broth, and when the growth becomes conspicuous to the unaided eye it is luminous when viewed in the dark. I show you here some cultures which, as you see, when I place them in the dark, show a beautiful phosphorescent appearance. The phosphorescence is more or less limited to the surface layer, that is the one in contact with the oxygen of the air; in the depth it is absent, but when shaking the flask the phosphorescence appears also in the depth.

Fermentation.

I have mentioned, in connection with a previous group, bacterial species which have the power to change by hydration urea into ammonium carbonate, a change which is called a fermentative action. Changes similar to these are caused by micro-organisms in many processes playing an important part in industries. Amongst these changes I may mention one in particular, the souring of milk. There are a good many others, the viscous or mannit fermentation, the butyric fermentation, the indigo fermentation, the dextran fermentation, the acetic acid fermentation, and others, but time does not permit me to describe more than one, viz. the common bacterium lactis. I show you here a number of photographs of the bacterium lactis under cultivation, and as seen under the microscope. It is a minute oval bacterium, which multiplies with great rapidity, and which, introduced into milk, turns this sour in 12 to 24 hours at the ordinary temperature; when sterile milk is inoculated with this bacterium and kept in a warm place at a temperature of 60° to 65° F., the milk is found solid and curdled before 20 or 24 hours are over, and in this curdled milk large numbers of the bacterium lactis are present either as dumb-bell ovals or as short chains. When a needle is dipped first into such curdled milk and then into normal milk, the same coagulation with the same appearances takes place in the latter. When a plate cultivation of such milk is made it is seen that a large number of colonies all of the same character are developed, which colonies are made up of the bacterium lactis; through however numerous generations this organism is cultivated in artificial cultivations,—it grows well on nutritive gelatine to which whey or only lactic sugar has been added—and if then transferred to fresh milk, it always produces this souring and curdling; that is to say, it changes lactic sugar into lactic acid, and as this is being formed it coagulates and precipitates the casein of the milk. With a trace of milk that has gone naturally sour—that is to say, to which the bacterium lactis has found entrance, and in which by its multiplication it has produced curdling, any amount of normal milk can be successively turned sour and curdled. The bacterium lactis is not by any means a rare organism; it is widely distributed, and can at any moment, in dairies and other places, through impurities of the utensils, by dust, &c., find access to milk which would soon succumb to its attacks; when, for instance, in dairies or in one or another locality the milk has a frequent tendency to turn sour, this means that the bacterium lactis has taken firm footing in such a locality. It is well known that only extreme measures of cleanliness, thorough boiling of all utensils and vessels, cleaning of walls and floors can banish or reduce it. In this the analogy with an epidemic of an infectious disease is obvious. Just as in an epidemic, every susceptible individual to which the contagion has had access becomes smitten by infection, and just as in an epidemic the contagium of the disease, being of wide distribution, and, having taken a firm hold of the locality, attacks an increasing number of individuals, and thus causes the epidemic—so also in the case of the bacterium lactis: when this has taken a firm hold of, and has acquired a great distribution in, any locality, any sample of milk (*i.e.* susceptible individual) may take the infection, either by coming in contact, directly or indirectly, with a trace of the milk already infected, *e.g.* by being placed in vessels in which infected milk has been kept previously, or becoming infected through dust charged with the bacterium lactis, or coming in contact with water poured from a vessel in which traces of the microbes were still left. All this finds its complete analogy in the case of an epidemic infectious disease. The fermentative processes due to microbic activity, and playing an important part in industries (alcoholic and other fermentations), illustrate in a very striking manner some of the essential features observed in the nature, in the production, and in the spread of infectious diseases in man and animals. The fermentative processes, thoroughly established as being due to microbic activity by the researches of Pasteur, were by Pasteur, and others after him, used as illustrations of the way in which infectious disorders in man and animals arise, and it was exactly these considerations which led Pasteur to his brilliant studies of these diseases, the results of which studies have been of such signal service in sanitary science in general, and in the prevention of infectious diseases in particular.

In the fermentative processes studied by Pasteur and others it was shown that each specific fermentative process is due to the growth and multiplication of a specific microbe. Just the same is the case with the infectious diseases—when from a substance which is in the process of fermentation, a trace containing the particular microbe is introduced into fresh fermentible substance, this latter undergoes the same fermentation; further, it is shown that, however great the number of accidental non-specific bacteria which may be introduced at the same time, unless that particular bacterium be present amongst them, the specific fermentative change does not ensue. The same is the case with infectious diseases: the number of non-specific bacteria in water, dust, air, various common articles of food, &c., is sometimes great, but no amount of these would set up any of the infectious diseases, like cholera or typhoid fever, tetanus or diphtheria; in order to do so there must be amongst them the particular microbe of cholera or typhoid fever, &c. Again, in each fermentative process the substance which is to undergo the fermentation must be susceptible of the particular fermentation: a substance that contains sugar can undergo the alcoholic fermentation, a substance that contains alcohol can undergo the acetic acid fermentation, &c. The same is the case in the infectious diseases: an individual must be susceptible to the disease, though it is not quite clearly established what the meaning of this is. Further: just as in the fermentative process the susceptibility of the substance alone is not sufficient, is only a preliminary condition, the actual infection with the specific microbe being the essential, so also in the infectious disease: in order that a susceptible individual should become the subject of the disease it is essential that the specific microbe should be present and should find entrance into this susceptible individual. Just as little as a particular condition of the atmosphere, of temperature, &c., is capable of producing the souring of milk, so also a particular atmospheric or telluric condition, season, or other external circumstances alone cannot produce an infectious disease. What is wanted in the first place is the presence of the bacterium lactis in the one, the specific pathogenic microbe in the other; atmospheric or telluric conditions may and do favour the more rapid multiplication and dissemination of the bacterium lactis or other specific microbes, but without the presence of the specific microbes these processes could not take place. "Thunder in the air" could not turn the milk sour, could not make meat tainted, could not turn beer or wine sour, without the presence of the specific microbes, which by their presence and multiplication produce those undesired changes in these substances; the particular condition of the air could and would increase their rate of multiplication and distribution, and therefore increase the chances of infection of these substances and therefore a more conspicuous manifestation of the effects of the activity of those microbes, but it could not produce the microbes themselves.

Pathogenic Bacteria.

The different pathogenic bacteria connected with and causing the different infectious diseases have then the power of growing and multiplying within the infected individual and through the different poisonous substances—toxins—which they therein produce, of causing the changes which characterise the particular disease.

I show you here photographs of a variety of such pathogenic bacteria, and you will see from them that both as regards the manner of distribution of these bacteria in the tissues of the infected individuals as also in their morphological and biological characters in artificial cultures, most of them are sufficiently distinguished from one another and from other non-pathogenie bacteria. In considering the general action of pathogenic bacteria we find that they may be grouped into (*a*) such as are entirely, so far as our knowledge at present goes, dependent on the living body of man or animals; these are endogenic bacteria or true parasites, for they do not appear to lead an existence independent of the living body: when, therefore, infection by them takes place, it takes place by direct transference from an infected individual to a new one; this is so in small-pox, in vaccinia, and in hydrophobia; (*b*) a second group comprises those which are capable besides a parasitic life, *i.e.* growing and multiplying within the animal body, to lead also an existence independent of the animal body; that is to say, they, like many other non-pathogenic bacteria, are capable of thriving in suitable materials in the outside world; such are anthrax and fowl cholera, asiatic cholera and typhoid fever, tetanus and diphtheria, and others. But also amongst these some can lead such an "ectogenic" life comparatively easily, while others do so only in a restricted sense; while, for instance, anthrax, tetanus, typhoid fever can lead such ectogenic life easily, *i.e.* growing and multiplying outside the animal body; others, like tubercle and glanders, do so only to a very small extent. The former are obviously the more dangerous to man and animals on account of their more ready distribution than the latter, of which the ectogenic existence is considerably restricted by various conditions, *e.g.* they require higher temperatures to grow at, they require a much more specialised nutritive medium than is generally attainable by them.

Time does not permit me to show you in detail the many and wonderful results obtained within a comparatively short recent period by a large number of workers, as regards the identification of many of the pathogenic bacteria, their habits of life, their mode of spread and infection; the way in which their action can be attenuated, their effects weakened, and such weakened cultures used for protective inoculations; the brilliant results achieved by Pasteur and many others in these protective and curative inoculations against anthrax, against fowl cholera, against tubercle, against hydrophobia, against tetanus and other diseases. But I will ask you to bear in mind that almost the entire study of bacteria, the exact methods first introduced by Koch and now universally used not only in regard to pathogenic bacteria, but in all other branches of bacteriology; the exact knowledge that we possess of some of the most important branches of hygiene: as the knowledge of the exact nature of contagium, its mode of spread, the means of disinfection, the methods of protective inoculation, and a hundred and one other important points have been the result of, and gained by, experiment on animals. Amongst the wilderness of misery, cruelty, and death inflicted by mankind on animals for gain, for sport, pleasure, and other similar objects, to decry, as some do, the use of a comparatively few animals for the sake of gaining knowledge of the most important and complex phenomena of life and of disease, and of securing power to apply this knowledge in the interest not only of mankind, but of the animals themselves, is apt to make one remember the words: "Ye blind guides! which strain at a gnat and swallow a camel," or the words, "Thou hypocrite! cast out first the beam out of thine own eye, and then shalt thou see clearly to pull out the mote that is in thy brother's eye."

SURGERY AND SUPERSTITION.

TO those unversed in the history of surgery it may come as a surprise that many of the appliances commonly regarded as the inventions of yesterday, are but the perfected forms of implements long in use. It is astonishing to find amongst the small bronzes of the National Museum at Naples, bistouries, forceps, cupping-vessels, trochars for tapping, bi-valvular and tri-valvular specula, an elevator for raising depressed portions of the skull, and other instruments of advanced construction which differ but little from their modern congeners. The invention of such instruments, and the skill displayed in their construction, presupposes a long period of surgical practice. We find, accordingly, that four hundred years before our era, Hippocrates was performing numerous operations bold to the verge of recklessness. Thus he was accustomed to employ the trepan not only in depression of the skull or for similar accidents, but also in cases of headache and other affections to which, according to our ideas, the process was singularly inapplicable. Strangely enough, the Montenegrins are, or recently were, accustomed to get themselves trepanned for similar trifling ailments, and it is probable that in both instances the procedure was but the surviving custom of primeval ages. That such operations were then performed Dr. Robert Munro, in his admirable article upon prehistoric trepanning in the February number of the *Fortnightly Review*, conclusively shows. His paper records a strange blending of the sciences of medicine and theology in their initial stages; for, whilst he makes it clear that during the neolithic period a surgical operation was practised (chiefly on children) which consisted in making an opening through the skull for the treatment of certain internal maladies, he renders it equally evident that the skulls of those individuals who survived the ordeal were considered as possessed of particular mystic properties. And he shows that when such individuals died fragments were often cut from their skulls, which were used as amulets, a preference being given to such as were cut from the margin of the cicatrised opening. The discovery arose as follows. In the year 1873 Dr. Prunieres exhibited to the French Association for the Advancement of Science an oval cut from a human parietal bone, which he had discovered in a dolmen near Marvejols, embedded in a skull to which it had not originally belonged. His suggestion that it was an amulet was confirmed on the discovery of similar fragments of bone grooved or perforated to facilitate suspension. When Dr. Prunieres's collection was examined by Dr. Paul Broca he pointed out that that portion of the margin of the bone which had been described as "polished" owed its texture to cicatricial deposits in the living body, and that, where these were wanting, death had ensued before the pathological action was set up, or the operation had been *post mortem*.

These discoveries led to widespread investigation, and to the production of trepanned skulls from Peru, from North America, and from nearly every country of Europe. These were not restricted to any particular race or period, but ranged from the earliest neolithic age to historic times, and included skulls of dolichocephalic and brachycephalic types.

The method of conducting the operation appears to have been to gradually scrape the skull with a sharp flint, though there is occasional evidence of its use in a sawing manner such as obtained when the ruder implement was superseded by one of metal. The process was almost exclusively practised upon children, probably on account of the facility with which it could then be accomplished, and possibly also as an early precaution against those evils for which it was esteemed a prophylactic. What the dreaded evils were was suggested by Dr. Broca, who, whilst he believed that the operation was primarily conducted for therapeutic purposes, saw behind these the apprehension of a supernatural or demoniacal influence. Readers of Lenormant's "Chaldean Magic" will remember "the wicked demon which seizes the body, which disturbs the body," and that "the disease of the forehead proceeds from the infernal regions, it is come from the dwelling of the lord of the abyss." With such an antiquated record before us it is, therefore, by no means an extravagant theory to broach, as Dr. Broca has done, that many of the convulsions of childhood, which disappear in adult life, were regarded as the result of demoniacal possession. This being granted, what more natural than to assist the escape of the imprisoned spirit by boring a hole in the skull which formed his prison. When a patient survived the operation he became a living witness to the conquest of a fiend, and it is comprehensible that a fragment of his skull taken after death from the very aperture which had furnished the exit would constitute a powerful talisman. Chaldean demons, as we know, fled from representatives of their own hideous forms, and, if they were so sensitive on the score of personal appearance, others may have dreaded with equal keenness the tangible record of a previous defeat. It is certain that to cranial bones medicinal properties were ascribed, a belief in the efficacy of which persisted to the dawn of the eighteenth century; whilst, in recent years, such osseous relics were worn by aged Italians as charms against epilepsy and other nervous diseases. When once the dogma was promulgated that sanctity and a perforated skull were correlated, fond relatives might bore