

fluence in the production of parotitis in the present case I must leave to others more competent to form an opinion than I am. Its relation to the choreic symptoms, though obscure, seems, perhaps, more intelligible. The occurrence of two unrecorded complications in the course of the disease is at any rate a matter of some curiosity, if not of considerable interest.

ART. III.—*An Apology for Bacteria*.^a By RICHARD TRAVERS SMITH, M.D., Univ. Dubl.; F.R.C.P.I.; Assistant Physician to the Richmond, Whitworth and Hardwicke Hospitals, Dublin.

THE title of this paper—"An Apology for Bacteria"—may probably be a source of surprise to some who perchance share the popular belief that bacteria (using the word as synonymous with microbes or micro-organisms) are one and all harmful to mankind and indefensible. To the lay mind all microbes and Man are natural and deadly enemies, ever at daggers drawn - a contest implying certain victory for the microbes. The truth is that bacteriologists, with broadmindedness begotten of extensive cultivation, are wont to vary their colouring of bacteria, whilst the general public, on the other hand, stain them all with a single dye, and that the blackest of the black. In this respect bacteria, like Man himself, are victims to the general law that evil report ever outstrips good. The scientific subject which is now-a-days most energetically dinned into public ears is the microbic origin of disease. The majority of people, therefore, shrink with abhorrence from the very thought of bacteria, and would hail with undisguised joy any scheme to promote their total extermination—truly an inestimable disaster!! A homely classification may be made of bacteria into good servants and bad masters. The bad masters are the pathogenic organisms whose action it is our special duty to study in medical science. The good servants, much the more numerous and important from a biological standpoint, are

^a Being the Presidential Address delivered to the Dublin University Biological Association, November 14, 1901.

ceaselessly and strenuously toiling for the benefit of the human race. My endeavour will be to render an account of their stewardship by indicating (in necessarily a sketchy and unfinished fashion) the part which such beneficent microbes play in the economy of nature, in our industries and arts.

First, let us consider bacteria in the *rôle* of scavengers. The attempt is entertaining, if difficult, to give one's imagination sufficient play, to mentally depict the appearance this world would present if all animals and plants, when their allotted span of life had expired, had permanently remained as they had died. To this imaginary picture of the earth let there be added the accumulated and unaltered excretions of the living animal and vegetable kingdoms since they commenced to exist, then will your mind's eye be greeted by a hideous nightmare unparalleled for horror in Dante's "*Inferno*." The dead and waste of both sea and land would, by their very bulk, have crowded out the living. Even the most superficial observation happily shows us, however, that all dead animals and plants, as also the waste products of living ones, sooner or later disappear from our ken as such. The processes called variously putrefaction, decomposition, fermentation, and decay, whereby the earth is cleansed of its dead—prodigious task though it be—is carried out in the main by bacteria. That bacteria are the scavengers of this earth's dead organic matter admits of simple proof, for, exclude them from such matter, and it will not decompose. This is done every day in preserving meat by hermetically sealing it in tins. Or if dead organic matter happens to be in a situation uncongenial to microbes it escapes decomposition. As examples of this may be mentioned that the vaults of certain churchyards, for some obscure reason or other, are not conducive to the prosperity of bacteria, so the bodies there entombed remain preserved. Again, as extreme cold is prejudicial to bacterial growth a frozen animal escapes indefinitely molecular destruction. It is recorded that the frozen Siberian mammoths, on being discovered, were in part devoured with relish by the hunters' dogs, so little altered were they; yet they must have lain for countless centuries embedded in the ice.

Next let us consider bacteria as the purveyors of suitable food to the vegetable kingdom. It is manifestly true that vegetable life cannot continue to exist indefinitely on a limited food supply. Plants extract the necessary food for their growth from an originally limited supply contained in air, soil, and water. Did not Nature provide a method by which the material so used is restored to whence it came in a form again available as food for plants—vegetable life would become extinct from starvation, bankrupt, in fact, as the result of perpetually drawing on its capital.

The extinction of the vegetable kingdom would eventually be followed by that of the animal, since the interdependence of plants and animals is absolute. This point is well illustrated by a consideration of their separate respiratory processes. Animals, on the one hand, absorb oxygen from the atmosphere and excrete carbon dioxide gas back to it, produced in their bodies by the oxidation of carbon. Green plants, on the other hand, absorb carbon dioxide gas, store up its carbon in their interior, and excrete its oxygen back to the atmosphere. In this respect it will be observed that green plants and animals utilise each other's excretion. Furthermore, the carbon which green plants store up becomes transformed into starch, sugar, &c., thereby becoming an available supply of carbon for animals instead of accumulating in the atmosphere in the form of carbon dioxide gas and asphyxiating them. Apart from this it is obvious that in the event of vegetable life becoming extinct all animals must of necessity become carnivorous, with the result that animal life would come to an untimely end, after much the same fashion, I imagine, as on the famous occasion when it was represented by certain members of the feline tribe, who, as the legend runs, were hung by their caudal appendages, out of reach of the vegetable world, in the thus famed town of Kilkenny.

These, gentlemen, are indisputable facts—that animals cannot exist without plants, or plants cannot exist unless their originally limited stock of food in air, soil, and water is continually renewed. The sources of renewal are three—

dead animals, dead plants, and the waste products of living animals and plants. The plant food itself consists of certain simple chemical compounds—water, carbon dioxide, and inorganic salts, such as sulphates, phosphates, and nitrates of potassium, calcium, magnesium and iron. The carbon dioxide supplies them with carbon, water with their hydrogen and some of their oxygen, nitrates or salts of nitric acid chiefly with their required nitrogen. The anabolic activity of plants builds these simple bodies into much more complex ones—namely, starch, sugar, fat, proteid or nitrogenous substances, all of which, together with certain inorganic salts and water, supply the animal kingdom with its essential pabulum. In the animal body some of these substances are elaborated into even more highly complex forms. So highly chemically complex does the simple food which plants require become when built up into plants and animals that it is rendered a totally unfitted diet for plants. In like manner the excretions of living animals and plants, with the exceptions of carbon dioxide, water, and certain inorganic salts, are molecularly too complex to be immediately available to plants as food. It will appear from what has been said so far that if dead animals and plants, and the excretions of living ones, are again to feed plants they must be reduced once more from complex to simple form. This transformation is at once essential, intricate, and practically ubiquitous, so must be accomplished by industrious, skilled analytical chemists, whose laboratory is the world at large. These chemists are bacteria—bacteria which, while scavenging and feeding upon the dead and upon the excretions of the living, decompose these otherwise injurious materials into suitable food for plants. Herein Nature has devised a wondrous and indispensable plan for economising her limited store, by making food traverse a circle, first leaving air, soil, and water and passing into plants, thence to animals, to be brought back once more from the dead and waste of the living to air, soil, and water by the might of bacterial activity. Indubitably, gentlemen, science has proved that without these much-maligned microbes none of us could be here at present, as without them the

circle round which food stuff must perpetually move would be broken, and the continuity of all life thus interrupted. The farmer who throws farm-yard manure on his land, knows empirically that it will increase his harvest; he never fathoms the depths of his indebtedness to bacterial action, without which the manure would remain as useless to a crop as its weight of stones.

Let us not, then, be content to call the trusty workers which we find in almost countless numbers in air, soil, and water by the slighting appellation of "harmless bacteria," for their virtues are not of this negative description. Each is there for a definite purpose if we only knew it. At times even we abuse them at their labour, as when they rot our meat or sour our milk, whereas all indulgence should be shown them, since they are endeavouring to feed plants in turn to feed us. Milk and meat, for the time being, are so much dead organic matter, idling and loitering on its way around Nature's food circuit; bacteria, like policemen, manifest a rooted dislike to loiterers, so officiously insist on their "moving on."

Unnecessary alarm is often manifested at the number of bacteria to be found in water. Here, again, it must be remembered that their number is in direct proportion to the amount of dead organic matter in the water. For this reason bacteria are most numerous in sewage and in all stagnant waters, from which they rapidly tend to disappear when they have removed the organic impurities.

It would be impossible in the time at our disposal to follow every element of food stuff throughout its circulation. If, however, nitrogen be traced it will best illustrate the essential and subtle part played by bacteria in Nature's food scheme. With a most important exception—to be afterwards mentioned—green plants get their nitrogen, not from the nitrogen which constitutes 79 per cent. of the atmosphere, but by absorbing from the soil certain salts of nitric acid, or the so-called mineral nitrates. These nitrates are widely distributed through the earth's soil, but do not exist in anything approaching accumulations except in very few places. Such a scant stock would soon become exhausted by vegetable growth were it not con-

stantly replenished from the stock of nitrogen in dead plants, dead animals, and the excretions of living ones. The nitrogen in animal excrement exists chiefly as urea in the urine of mammalia, uric acid in that of birds and reptiles. These substances when excreted are soon pounced upon by vigilant bacteria and converted into ammonia. The nitrogen in dead animals and plants exists chiefly in the form of proteids and albuminoids, &c.—all highly complex bodies. Under the influence of almost ubiquitous putrefactive bacteria these nitrogenous substances are broken down step by step till, as final products, there remain ammonia, free nitrogen, free hydrogen, methane, carbon dioxide, and sulphuretted hydrogen, the original nitrogen coming to exist chiefly as ammonia, and to some extent in the free gaseous state. That this task, which devolves upon bacteria, of converting proteid into these end-products of putrefaction is a highly complicated one may be indicated by enumerating some of the intermediate substances which are formed. Many of them are already familiar to you from the study of physiological chemistry.

1. Albumoses and peptone.
2. Aromatic bodies—indol, skatol, and phenol.
3. Amido compounds—leucin, tyrosin, aspartic acid and glycocol.
4. Fatty and aromatic acids—acetic, butyric, succinic, and valerianic.
5. Ptomaïns.

As an illustration of the specialised function of the various species of bacteria, which decompose nitrogenous substances, it may be mentioned that those which convert urea into ammonia are unable to decompose proteids, and many of those which decompose proteids have no effect upon urea.

Though the liberation of nitrogen, in the form of ammonia, from dead animals, dead plants, and their excretions, is a step in the right direction accomplished by bacteria, the ammonia so produced is still unavailable to green plants as food. To be utilised by plants the ammonia must be converted into nitrates by oxidation to nitric

acid, the acid then combining with bases. The change of ammonia into nitrates is usually spoken of as nitrification, but some authors use the term in other senses. Nature has again assigned this task to certain of her faithful servants, called by scientists nitrifying bacteria. These organisms escaped detection and isolation till quite recent years, when it was discovered that they differed from other bacteria in not being tempted to feed and flourish on any of the usual elaborate dishes of the bacteriologist's cuisine, but that they are prototrophic—that is to say, thrive best on a purely inorganic diet. The conversion of ammonia to nitrates by these bacteria is accomplished by two distinct varieties, in two separate stages. One variety, called the "nitrite bacteria," oxidise ammonia into nitrous acid which forms salts called nitrites. The other variety, spoken of as "nitrate bacteria," instantly further oxidise the nitrites, and so convert them into nitrates. In the form of nitrates nitrogen is once more absorbed by the roots of green plants, to recommence the round of the food circulation. The two varieties of nitrifying organisms are always found together in soil, from which they may be grown in pure culture and their separate actions demonstrated.

The limits of bacterial activity in circulating nitrogen are not to be drawn here. Some nitrogen is always tending to drop out of circulation and become waste, as indeed might be expected, for Nature often appears to us prodigal in her methods. As before said, during the putrefaction of proteid some nitrogen escapes into the air in the free state, so is out of reach of plants in general. Rain is constantly washing nitrates from the soil away from plants. And again, owing to the commonly adopted system of drainage of large towns, the enormous store of nitrogen contained in sewage is carried away into the sea. It must be remembered that this nitrogen is originally taken from the country soil, brought to town in the shape of plants, animals, or their produce, and after passage through the human body is swept into the sea. The invention of sewage-farms tends to obviate this last ruthless nitrogen loss by returning to the soil that which was originally taken from it.

The irresistible conclusion to be drawn from the consideration of these losses through putrefaction, rainfall, and sewage disposal is that unless some method existed of capturing free nitrogen from the large supply in the atmosphere and transferring it to the food circulation, the amount of nitrogen available for plants and animals would be steadily diminishing. Bacteria again save the situation. Let us consider how they do so.

Plants of the natural order Leguminosæ—which includes peas, beans, clover, lupins, and vetch—behave differently from other green plants in their mode of obtaining their nitrogen. All other green plants, we have seen, absorb their nitrogen as nitrates and are incapable of storing up any more during their growth than they withdraw from the soil in this particular form. Leguminous plants, on the other hand, will flourish in soil which is markedly deficient in nitrates. Despite this deficiency they store up in their interior large quantities of nitrogen, and also enrich the soil in which they grow, in nitrogen compounds.

An experiment showed that a certain quantity of peas containing 16 mgr. of nitrogen, sown in mould containing 22 mgr., gave rise to a crop containing 499 mgr., whilst the quantity of nitrogen in the mould increased from 22 to 57 mgr. This made a total gain of 518 mgr. of nitrogen between plants and mould, the only possible source of the increment being the free nitrogen of the atmosphere. So it is that all other green plants are mere consumers of soil nitrogen, leguminous ones are accumulators of it. Experience forestalled science in teaching this lesson to the farmer. It taught him the advisableness of periodically growing a crop of clover on his cultivated land in order to maintain its fertility.

The power which leguminous plants possess of rescuing free nitrogen is not an inherent one, but the outcome of co-operation with certain bacteria called nitrogen-gatherers, or bacteria of root-nodules. If a seedling leguminous plant be examined, on its rootlets may be observed small roundish, firm nodules. The cells of which these nodules are composed, when examined microscopi-

cally, are seen to be impregnated with bacteria. As the plant grows these bacteria undergo degenerative changes, till, when the pods are ripe, the nodules have shrivelled, and the bacteria have almost vanished. In normal growth leguminous plants always form root-nodules which always contain bacteria. Growing on sterilised soil these plants do not thrive, do not form nodules, and have no more power to accumulate nitrogen than other green plants. Recently the bacteria of the root-nodules have been grown in pure culture, on a medium containing no nitrogen, yet after a while they accumulated nitrogen, necessarily withdrawn from the atmosphere. These facts point to the nitrogen-fixing power being solely an attribute of the bacteria, but the leguminous plants have a share in the rescue. It is owing to certain substances in the rootlets of young leguminous plants, which chemiotactically attract the nitrogen-fixing bacteria, that the latter gain access to the root. At first the bacteria rely upon the plant for their food supply. Later, becoming more independent, the bacteria draw their nitrogen from the atmosphere and yield it later chiefly to the seeds of the plants. Analysis shows that in the lupine at the time of flowering the root-nodules contain 5.2 per cent. of nitrogen, which, by the time the pods are ripe, becomes reduced to 1.7 per cent., whilst an almost corresponding increase of nitrogen occurs in the ripe seeds. It is well known that dried leguminous seeds, such as peas and beans, are richer in nitrogen than fresh meat.

It is claimed that the discovery of these nitrogen-fixing bacteria has led to results of pecuniary advantage to agriculturists. Seventeen pure cultures have been obtained from seventeen varieties of leguminous plants. These cultures are now articles of commerce, sold under the name of "Nitragin." If nitragin be diluted and mixed with either seeds or soil before sowing the resulting crop is largely increased. Especially is this the case in dealing with soils deficient in nitrates, as some of the marshy soil of North Germany. The best results are obtained by inoculating the soil with the variety of Nitragin appropriate to the seeds to be sown, or, in other words, with a

pure culture of nitrogen-fixing bacteria, cultivated from leguminous plants identical to those of the desired crop.

A recapitulation of the circulation of nitrogen may now not be out of place. Putrefactive bacteria decompose the nitrogen-holding substances in dead animals and plants, and in the excretions of living ones, into ammonia and some free nitrogen. Ammonia is seized by other bacteria and converted to nitrites, the nitrites by others and converted to nitrates, which then feed living plants, in their turn to feed living animals. The loss of nitrogen from this circulation by putrefaction and other causes is counteracted by the power which certain bacteria possess of abstracting free nitrogen from the atmosphere and yielding it up to certain plants. Once back to these plants the nitrogen has re-entered the food circulation and returns once more to the soil either from these plants directly, or indirectly through the medium of animals.

In circulating carbon bacteria play a no less wonderful part. We have already seen that a large amount of carbon interchanges from green plants to animals in the form of carbonaceous food, and from animals back to green plants in the form of carbon dioxide gas. The amount of carbon thus interchanging between living plants and living animals would be constantly diminishing were it not for the power bacteria and other micro-organisms possess of liberating by fermentative processes the carbon bound up in dead animals, dead plants, and in plant produce as free carbon dioxide gas. Once again, in the form of carbon dioxide gas the carbon is consumed by green plants and no longer lies idle.

Yet another instance of the uses of bacteria in supplying food for plants has come to light. The sulphuretted hydrogen gas formed during putrefaction of proteid is an offensive and injurious one, quite useless to plants. Bacteria, called sulphur bacteria, feed upon the gas and store up its sulphur, which ultimately is oxidised to sulphuric acid. The acid combines with bases to form sulphates, by which means sulphur again becomes available to plants as food.

Time will not permit of any further consideration of

bacteria as food purveyors. I trust it is now plain to all that they save this world from starvation.

But Nature employs bacteria as her handmaidens for the accomplishment of others of her great schemes besides those just discussed. They probably considerably contribute to the formation of soil by furnishing acids which soften the surfaces of hard rocks, thereby assisting the weather in its crumbling action.

Coal is now-a-days thought by some to be the result of bacterial action on dead vegetable matter, under peculiar physical conditions.

There are not wanting those who so labour the Darwinian theory of evolution as to contend that man's remotest ancestors were bacteria. The suggestion is not entirely devoid of scientific support. There is little doubt that at one stage of its existence this earth was barren of any living thing—even microbes. Assuming this to be so, of what description was the first living organism to appear? Surely some form of organism which did not depend for its existence on other organisms, but could live on inorganic matter; or, in other words, the organism most likely to first put in an appearance would be the one whose food was ready for it. Certain bacteria, we have already seen, have been discovered which fulfil these requirements by their capacity to feed on inorganic diet alone and to exist independently of all other life.

Now for a brief consideration of some of the industrial applications of bacteria.

The dairyman can record amongst bacteria staunch and valuable allies, since, in the manufacture of the best butter, they are indispensable. As is well known, cream before it is churned is subjected to a process called "ripening," which merely consists in allowing it to stand from 12 to 24 hours according to circumstances. During this time it acquires, along with other changes, a peculiarly pleasant flavour and aroma absent from perfectly fresh cream. These changes are due to bacteria, which instantly invade milk after it is taken from the cow, for there is no more suitable medium for the growth of many kinds of bacteria than milk. If the process of ripening is not terminated

at a suitable moment by churning, the further changes which bacteria produce are anything but desirable. It has been claimed amongst the advantages of "ripening" that a more rapid conversion of cream to butter is ensured, and also a larger yield of the desired commodity. The main object of ripening, however, is to secure for the butter the flavour and aroma of the ripened cream, for it is upon these almost entirely that the quality of the finished article depends. Up to recent years, and to a sad extent still, butter-making was a happy-go-lucky performance. The butter of different dairies, apparently all worked on the same principles, varied greatly in their flavours and aromas, and so in their demand and value. Even the most excellent dairies would often, for unaccountable reasons, yield bad butter. This want of uniformity in the quality of butter was formerly attributed entirely to the cow's food, health, &c. Now it is recognised that the most potent factor in the production of well or ill-flavoured butter is the variety or varieties of bacteria which have ripened the cream. This knowledge once acquired many devices were tried with a view to so modifying and controlling bacterial action in the cream as to ensure the certain and uniform production of good flavour and aroma. The various methods may be classified thus:—

1. By observing the strictest cleanliness in all things appertaining to the dairy undesirable species of bacteria will, in all probability, be prevented from contaminating the cream, as the connection between dirt and bad butter is a most intimate one.

2. Having once attained excellence in the flavour of ripened cream the cream was kept and used in small quantities to inoculate fresh cream. It was urged that in this way the bacteria which produced the good flavour might be kept *ad infinitum*.

3. Fresh cream may be inoculated with a pure culture of bacteria which has been isolated from the ripened cream of a dairy whose butter is of reputed high quality. The objection to this method, as also to the last-mentioned, is that the fresh cream may have become contaminated with unfavourable bacteria before the pure culture or the well-flavoured stock cream is added.

4. Before adding the pure culture the cream is sterilised—*i.e.*, all the bacteria in it are killed by heat. This method is the most scientific and accurate, and yields the most uniform high quality of flavour. It is extensively practised in Denmark and America, and to some extent in these countries. Transatlantic butter-makers give these pure cultures the unpoetic name of starters, as they start the ripening process in fresh cream. According to the species of bacteria in the starter will the butter be flavoured. In this way butter of a particular flavour can be made to suit a particular market, with corresponding pecuniary advantages to the manufacturer.

In like manner the flavour of different kinds of cheese is due to the action of different bacteria on the fresh curd.

The manufacturer of linen would be powerless to ply his business without employing bacteria. As is familiar to anyone whose wanderings have taken him past a flax-hole in the North, putrefaction is much in evidence in the preparation of linen-fibres. The object of the putrefaction is to soften away the worthless portions of the flax plant which intimately bind together the valuable linen fibres. No mechanical method of separating the linen fibre has ever been discovered that can dispense with this bacterial putrefaction, called in the trade "retting." The particular bacteria responsible for the "retting" of the flax have been discovered and isolated.

Time will only permit mention of one more industrial application of bacteria, for the list is hopelessly long to attempt completion. The one I shall choose is the manufacture of smoking tobacco, since its widespread employment appeals to the senses of both smokers and non-smokers. Before tobacco leaves are sent to the manufacturers they are fermented in heaps. Subsequently they are cured in a great variety of methods, in all of which fermentation is largely employed. The fermentations necessary to produce smokable tobacco are the work of bacteria. These bacteria have been the subjects of extensive experimentation, from which it has been concluded that the flavour of tobacco far from being entirely attributable to the plant itself, or the locality in

which it is grown, is largely in the hands of bacteria. Dexterous manipulation of the varieties of bacteria isolated from tobacco in process of curing has enabled the industrial bacteriologist to impart the flavour and aroma of Havana cigars to tobacco leaves hitherto less highly prized.

In this address, gentlemen, it has been my object to encourage by example communications on a wider range of biological subjects than heretofore has been customary in this Association. From my own experience, on this occasion, I can assure you that such papers being change from purely medical work would afford you refreshing rest. Furthermore, there can be little doubt that even a smattering of biology in its unrestricted sense is conducive to that breadth of mind which daily becomes more essential in trying to shape definite forms from the seething mass of detail with which one is confronted in the study of medicine.

MICROCOCCHI IN VARIOLA.

VANSELOW and CZAPLEWSKI (*Vierteljahrsschr. f. gerichtl. Med.*, 1899, Heft 1) believed they had found an organism closely connected with the variola process, in what was previously named by Klebs the *Micr. quadrigeminus* (Klebs). It was very like the *Micr. pyogenes albus*. However, it liquefied solidified blood-serum, which the typical *Micr. pyogenes* is said not to do; its colour is reddish, but in this property it is variable, as is to be expected. They have already retracted this hardly probable suspicion (*Centralblatt XXV.*, 546). Almost simultaneously Sanfelice and Malato (*Centralblatt XXV.*, 641) have reported that a coccus can be constantly cultivated from cases of variola which cannot be differentiated morphologically from the *Micr. (a) aureus*, but differs in its pathologic action from all other cultures of *Micr. pyogenes* isolated by the authors. When injected into the circulation, hyperæmia of the skin and mucous membrane and sharply outlined hæmorrhages occur. Regarding the much controverted "*Cytoryctes variolæ*" (Guarnieri's) of the group of protozoa, consult the literature in Galli-Valeri's "*Kritische Uebersicht über den Zusammenhang der Variola mit Vaccine*" (*Centralblatt XXV.*, 380 and 424). [Lehmann's and Neumann's "*Atlas and Principles of Bacteriology.*" Edited by Geo. H. Weaver, M.D. W. B. Saunders & Co. 1901. Part II. Text. Pp. 187 and 188.]