SCIENCE

VOL. LX AUGUST 8, 1924 No. 1545

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SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKeen Cattell and published every Friday by

THE SCIENCE PRESS

Lancaster, Pa. Garrison, N. Y.

New York City: Grand Central Terminal.

Annual Subscription, $6.00. Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

Entered as second-class matter July 18, 1923, at the Post Office at Lancaster, Pa., under the Act of March 3, 1879.

PREVENTION OF DISEASE[1]

MY first duty is to thank the general committee of the British Association for the great honor they have done me by electing me to the post of president. I must confess I wondered at first why I had been chosen, but soon came to the conclusion that it was an honor done through me to all army medical officers for the magnificent work done by them during the great war in the prevention of disease and alleviation of pain and suffering.

In the next place, I may be permitted to remind you that this is the fourth time the British Association for the Advancement of Science has met in Canada—first in 1884 in Montreal, in this city in 1897, and in Winnipeg in 1909. The addresses given on these occasions dealt with the advancement of knowledge in archeology and physics.

It is now my privilege, as a member of the medical profession, to address you on the advances made during the same period in our knowledge of disease and our means of coping with and preventing it.

An address on the prevention of disease at first sight does not promise to be a very pleasant subject, but, after all, it is a humane subject, and also a most important subject, as few things can conduce more to human happiness and human efficiency than the advancement of knowledge in the prevention of disease.

Think for a moment of the enormous loss of power in a community through sickness. Some little time ago the English Minister of Health, when emphasizing the importance of preventive work, said that upwards of 20,000,000 weeks of work were lost every year through sickness among insured workers in England. In other words, the equivalent of the work of 375,000 people for the whole year had been lost to the state. When to that is added the corresponding figure for the non-insured population you get some idea of the importance of preventive work.

Another way of estimating the value of prevention is in terms of dollars, or pounds, shillings and pence, and it has lately been calculated that the direct loss in England and Wales from sickness and disability amounts to at least £150,000,000 a year. In the United States, with a much larger population, the loss is put down at £600,000,000.

Another reason why this is an important subject is that medicine in the future must change its strategy, and instead of awaiting attack must assume the offensive. Instead of remaining quietly in the dressing

[1] Address of the president at the meeting of the British Association for the Advancement of Science, Toronto, Canada, August 6, 1924.

stations and field hospitals waiting for the wounded to pour in, the scientific services must be well forward in the enemy's country, destroying lines of communication, aerodromes, munition factories and poison-gas centers, so that the main body of the army may march forward in safety.

It must no longer be said that the man was so sick he had to send for the doctor. The medical practitioner of the future must frequently examine the man while he is apparently well, in order to detect any incipient departure from the normal, and to teach and urge modes of living conformable to the laws of personal health, and the public health authorities must see to it that the man's environment is in accordance with scientific teaching.

It may be a long time before the change is widely accepted, but already enormous advances have been effected, and it only depends on the intelligence and education of the populations how rapid the future progress will be. Public opinion must be educated to recognize that most diseases are preventable and to say with King Edward VII, "If preventable, why not prevented?"

To our forefathers disease appeared as the work of evil spirts or magicians, or as a visitation of Providence to punish the individual or the community for their sins.

It is not my purpose to give a detailed account of the first strivings after a better knowledge of the causes of disease, but it may be said the new era began some few hundred years ago, when it was recognized that certain diseases were contagious. For a long time it was held that this contagion or infection was due to some chemical substance passing from the sick to the healthy and acting like a ferment; and then, about the middle of last century, the idea gradually grew that microscopic creatures might be the cause. About this time it had been discovered that the fermentation of grape juice was caused by a living cell and that certain contagious skin diseases were associated with living fungi.

Things were in this position when there appeared on the scene a man whose genius was destined to change the whole aspect of medicine; a man destined to take medicine out of the region of vague speculation and empiricism and set its feet firmly on new ground as an experimental biological science. I mean the Frenchman, Louis Pasteur. It is from him we date the beginning of the intelligent, purposive prevention of disease. It was he who established the germ theory and later pointed the way to the immunization of man and animals, which has since proved so fruitful in measures for the prevention or stamping out of infectious diseases.

I need not discuss his life and work further. His name is a household word among all educated and civilized peoples. Every great city should put up a statue to him, to remind the rising generations of one of the greatest benefactors of the human race.

What the change in medicine has been is put into eloquent language by Sir Clifford Allbutt:

> At this moment it is revealed that medicine has come to a new birth. What is, then, this new birth, this revolution in medicine? It is nothing less than its enlargement from an art of observation and empiricism to an applied science founded upon research; from a craft of tradition and sagacity to an applied science of analysis and law; from a descriptive code of surface phenomena to the discovery of deeper affinities; from a set of rules and axioms of quality to measurements of quantity.

With one notable exception, the medical profession was not quick to see that Pasteur's discoveries of the nature of fermentation and putrefaction had a message for them. This exception was Joseph Lister, who had been for some years endeavoring to comprehend the cause of sepsis and suppuration, which commonly followed every surgical operation and most serious injuries involving a breach of the skin.

When, in 1865, Lister read Pasteur's communication upon fermentation, the bearing of the discovery on the problems which had so earnestly engaged his attention was apparent to him. He inferred that suppuration and hospital gangrene, the causes of which had so far baffled his imagination, were due to microbes introduced from the outside world, from the air and by instruments and hands of the operator. Remember, this was years before the microbial causation of any disease was established.

To test the correctness of his inference, Lister proceeded to submit all instruments, ligatures, materials for dressing and everything that was to come directly or indirectly into contact with the wound, the hands of the operator and the skin of the patient to treatment with chemical disinfectants. The satisfactory results which followed this practice astonished even Lister, and he spent the rest of his active life in improving and simplifying technical methods of preventing the ingress of microbes to wounds and in convincing his professional brethren of the truth of the conclusions based on this work of Pasteur.

INFECTIOUS DISEASES—(A) BACTERIAL

As soon as it was recognized that infectious diseases are caused by living germs a wave of enthusiasm swept through the medical world, and it was not long before the causation of many of the most important of them was discovered. I need not give a full list of these, but at or around about the time of the first meeting of the British Association in Canada the micro-organisms of tuberculosis, typhoid fever, Malta fever, cholera, malaria, diphtheria, tetanus and others had been discovered and described.

But it must not be assumed from what has been said that all the most important diseases are caused by living germs. Many of the ills that afflict mankind are due to quite other causes—alcoholism, for example, or the deficiency diseases, due to the absence or deficiency in our diet of some substance essential to proper growth and development. Rickets, one of the greatest scourges of industrial communities, is mainly a deficiency disease. It is reported that as many as 50 per cent. of the children in the slums of some of our big cities suffer from the effects of this disease.

Then, again, there is the whole series of diseases or conditions due to defective or excessive action of our own internal glands. Added to these, and perhaps the greatest scourge of all, there is the immense amount of chronic ill health and actual disease caused or promoted by the unhealthy conditions found in our large cities, due to bad housing and overcrowding—the so-called diseases of environment.

Malta Fever

But to return to the infectious diseases. After the living germs or parasites causing them had been isolated the process of prevention was soon begun. The methods employed were varied, and I may illustrate one of the simplest by relating briefly the history of the prevention of Malta fever, with which I was myself, to some extent, associated.

Malta fever is really a widespread disease, although it is called by a local name. It is found all round the Mediterranean, throughout Africa as far south as Cape Province, in India and China and even in some parts of America. It was very prevalent in Malta in the old days, and rendered the island one of the most unhealthy of all our foreign military stations. When I arrived in Malta, in 1884, I found that every year, on the average, some 650 soldiers and sailors fell victims to it, and, as each man remained on an average 120 days in hospital, this gave the huge total of about 80,000 days of illness per annum from this fever alone.

The British had held Malta since the beginning of the last century, and, although much attention had been given to the fever and its symptoms had been fully described, no advance was made towards its prevention until 1887, when the living germ, the *Micrococcus melitensis,* causing it was discovered. At this time a good deal of work was expended in studying the natural history of the fever and the micrococcus, but all to no purpose. Nothing was discovered to give a clue to any method of prevention.

At the Naval Hospital especially everything in the way of prevention was done that could be thought of: the water supply and drainage were thoroughly tested, the walls were scraped and every corner rounded off where dust might lie, immaculate cleanliness reigned; but all these precautions proved useless. Almost every sailor who came into the hospital even for the most trivial complaint took Malta fever, and after a long illness had to be invalided to England.

Things remained in this very unsatisfactory state for seventeen years, until 1904, when the Admiralty and War Office, alarmed at the amount of sickness and invaliding in the Malta garrison, asked the Royal Society of London to undertake the investigation of the fever. This was agreed to, and a commission was accordingly sent out in the same year and remained at work until 1906.

During the first year every likely line of approach was tried. A careful study was made as to how the micrococcus entered the body, how it left the body, its behavior outside the body, its pathogenic action on various animals; but still no indication of a method of prevention showed itself. Next year, however, in 1905, the problem of prevention was solved, and that by the merest of accidents.

In the previous year experiments had been made with the object of finding out if the goat, among other animals, was susceptible to the disease. The goats in Malta, which supply all the milk, are very much in evidence, as they are driven about in small herds and milked as required at the doors of customers. Several goats had been injected with cultures of the micrococcus, but, as they showed no rise of temperature or any signs whatever of ill health, they were put aside as being immune or refractory to the disease and nothing more was thought about them.

In the spring of 1905, about six months after these experiments had been made, Dr. Zammit, a Maltese member of the commission, who had kept one or two of these goats, happened for some reason or other to examine their blood and found that it clumped or agglutinated the micrococcus. This was strange and seemed to show that, although the micrococcus had not caused fever or any signs of illness in the goats, it must have lived and multiplied in the tissues of these animals in order to have brought about this change in the blood.

This observation led to the reexamination of the goat question, when the extraordinary discovery was made that about 50 per cent. of the goats in the island were affected by this disease, and that 10 per cent. of them were actually excreting the micrococcus of Malta fever in their milk. Monkeys fed on milk from an affected goat, even for one day, almost invariably took the disease.

Thus the weak link in the chain of causation had been found. The military authorities struck Maltese milk out of the dietary, and replaced it by an imported variety, and from that day to this there has scarcely been a case of Malta fever in the garrison. Malta, from being the most unhealthy of foreign sta-

tions, became a health resort, and was in fact used as a sanatorium during the late war. The disease had been blotted out at a single blow.

This, then, is one way of preventing an infectious disease; that is to say, by the discovery of the living germ, the study of its natural history, and so to a means of stopping it reaching its victim, man. This is the best way of prevention: shutting the stable door before the horse is stolen.

Typhoid Fever

But there are other ways of preventing bacterial diseases. Let us take, for example, a method widely used in the prevention of typhoid fever.

The fundamental and sound way of attacking this disease is by ordinary hygienic measures, especially a good water supply and good drainage. It is therefore one of the first duties of those in power to see that their people have, in addition to houses with plenty of light and air, a good water supply and a good drainage system, and money can not be spent to better advantage than in the attainment of these three essentials to health.

When typhoid fever is rife in a community it means that there is either a contaminated water supply or a faulty drainage system, and the municipal authorities ought to be called to account. In England, owing to improved sanitation, cases of typhoid fever are fifteen times less than they were fifty years ago. But it is not always possible to ensure good hygienic surroundings, for example, among troops on active service. It is therefore legitimate under certain conditions, and especially in time of war, to practice a less sound, a less fundamental, method of prevention, and this second method is known as inoculation or vaccination.

In order to understand how this acts, let us consider for a moment what takes place in a man's body when he is attacked by the typhoid bacillus. Everybody knows that the bacillus gives rise to poisons or toxins which cause the fever and other symptoms. But the cells and tissues of the man are not passive under the attack. They at once begin to fight against the infection, by forming substances in the blood to neutralize these toxins, hence called antitoxins or antibodies, and their function is finally to destroy the invading germs. If the man recovers he is immune from a further attack by the presence of these antibodies in his blood. He has become immune by passing through an attack of the disease.

This is the foundation of the second way of preventing infectious diseases. Speaking broadly, it means that you subject a man to a mild attack of the fever in order that his blood and tissues will respond to the stimulus by producing antibodies. This method takes its origin and name from that of vaccination against smallpox. Jenner solved that problem by the accidental discovery of vaccinia, a form of smallpox attenuated or weakened by passage through another species of animal. This weakening of the virulence of a microorganism by passage through another kind of animal is by no means uncommon in nature.

Pasteur, following on these lines, conceived the idea of weakening or attenuating the virulence of the living bacilli by artificial means, so as to give rise to a mild attack of the disease, and so in this way to render animals immune. This he did with marked success in anthrax and chicken cholera. The next forward step in this method of preventing disease was made by Haffkine, a pupil of Pasteur, who about the year 1894 produced a vaccine against cholera and a few years later another against plague. In the course of this work it was discovered that it was not necessary to use living cultures of the bacilli, but that vaccines made up of dead bacilli had much the same effect. This substitution of the dead bacilli for the living was a great advance in this method, being much simpler and much safer.

The next disease to be attacked by this method was typhoid fever. This was initiated by Sir Almroth Wright at the British Army Medical School and carried out with that scientist's characteristic ability and energy. The method was mainly directed in the first place to lessen the mortality from this disease among our soldiers serving in India.

After several years' experience, the mode of inoculation which was finally settled on was to give two injections of dead typhoid bacilli, one of five hundred millions, and a second, at an interval of ten days, of a thousand millions.

Now let us see what effect anti-typhoid inoculation has had on the prevention of typhoid fever among our soldiers in the field. In the South African War, at the beginning of the century, before the method had been developed, in an army the average strength of which was only 208,000 there were 58,000 cases of typhoid fever and 8,000 deaths. In the Great War, on the Western front, with an average British strength of one and a quarter millions, there were only 7,500 cases and 266 deaths. In other words, there were fewer cases of the disease in this war than there were deaths in the South African. It is also interesting to learn from French sources that at the beginning of the war the French soldiers were not inoculated, whereas the British were. The result for the first sixteen months was striking. During this time the French had some 96,000 cases, with nearly 12,000 deaths. The British had only 2,689 cases and 170 deaths. Afterwards the French soldiers were very thoroughly vaccinated, with the result that their immunity eventually became as striking as our own.

What the number of cases and death-rate from typhoid fever might have been in the huge armies

fighting on the different fronts had it not been for this preventive inoculation is impossible to say, but undoubtedly the suffering and loss of life would have been enormous. I may therefore conclude this account of anti-typhoid inoculation by saying that it certainly constituted one of the greatest triumphs in the prevention of disease during the recent war.

Tetanus and Diphtheria

I shall now pass on to consider a third method of preventing bacterial diseases which has also been evolved during the time under review; that is, by the injection of specially prepared blood sera. These are known as antitoxic sera, and the most familiar examples are antitetanic and antidiphtheritic. We have seen how the injection of living or dead bacilli or their toxins into animals gives rise to the production of antibodies or antitoxins. The blood serum of such animals in virtue of the antibodies contained in it can be used to combat disease.

Let us take in the first place the case of tetanus, until recently considered to be one of the most fatal of maladies, at least 85 per cent. of the cases succumbing. As you are aware, antitetanic serum is prepared by injecting horses with large quantities of tetanus toxin. When the blood is as full as possible of antibodies it is drawn off and the serum allowed to separate out.

The idea lying behind this third method of preventing disease is to pour in these ready-made antitoxins in order to assist the body in its first struggle with the invading disease, and give it, as it were, a breathing space to prepare its own defences.

Naturally the immunity produced by these antitoxic sera is of a passive nature and of short duration, as compared with that produced by the disease itself or even by the milder form brought about by vaccination or inoculation. Antityphoid inoculation will protect a soldier for, let us say, two years; antitetanic serum will only protect for a week or ten days. It is therefore impossible to inoculate a whole army against tetanus. It is necessary to wait until there is a danger of the disease occurring.

To illustrate this I shall describe briefly the history of the prevention of tetanus during the Great War. When the British Expeditionary Force went over to France, in August, 1914, only a small quantity of antitetanic serum was taken and that for the purpose of treatment rather than prevention. But shortly after the outbreak of hostilities the number of cases of tetanus among the wounded became so alarming that no time was lost in grappling with the danger. Large quantities of serum were hurried to the front, and some two months after the beginning of the war it was possible to make an order that every wounded man should receive an injection of antitetanic serum as soon after he was wounded as possible. Later on, after further experience had been gained, the single injection was increased to four, given at intervals of a week. This helped the wounded man over the dangerous time and the results were very successful.

In August and September, 1914, before the prophylactic injection was given, roughly speaking nine or ten out of every thousand wounded were attacked by tetanus and some 85 per cent. of these died. After the antitetanic injections had been introduced the incidence fell to little more than one per thousand and the mortality to less than half. To put the matter broadly: during the war there were 2,500 cases of tetanus in the British Army, with 550 deaths. If there had been no prophylactic injection of antitetanic serum there would probably have been 25,000 cases with 20,000 deaths— a very striking example of the recent development in the prevention of disease.

Another very important and widespread disease, somewhat resembling tetanus, is diphtheria, and there is no better example of the advance of science in methods of cure and prevention than is found in this disease. Thanks to the work of Klebs and Löffler in the early eighties and, some years later, to the brilliant researches of Roux and Yersin, the causation and natural history of this disease were very thoroughly elucidated.

Antidiphtheritic serum is prepared much in the same way as the antitetanic. By the repeated injections of gradually increasing doses of the bacilli or their toxins, a serum is produced which has a marked curative effect in cases of diphtheria. It is stated that the introduction of antidiphtheritic serum in 1894 has reduced the death-rate from 40 to 10 per cent. and if used on the first day of the disease to almost *nil*. The serum is essentially a curative agent and is useful only to a limited extent in prevention.

But lately essentially preventive measures in diphtheria have come into vogue. The procedure employed is to bring about an active immunization by a mixture of toxin and antitoxin in individuals who have been shown to be susceptible to the disease by what is known as the Schick test. In the United States a campaign on these lines has been begun against this disease which promises brilliant results. It is confidently stated that by their new measures there is a possibility of robbing diphtheria of all its powers to kill and injure.

The mode of prevention of these diseases—Malta fever, typhoid fever and tetanus—illustrates the three principal methods of preventing bacterial diseases: In Malta fever, by getting down to bed-rock and stopping the disease at its source; in typhoid fever, by giving, as it were, a mild attack of the disease, by vaccination or inoculation, so as to bring about a greater power of resistance; in tetanus, by pouring

in antitoxins, already prepared in the serum of another animal, in order that they may neutralize the toxins of the invading bacilli as soon as they are formed.

Tuberculosis

There are other important bacterial diseases, however, which can not be attacked so simply. For example, there is tuberculosis, a disease distributed over the whole world and one of the greatest scourges of civilized communities. It is a disease which has been known from time immemorial, but it is only within our own time that the bacterial cause has been recognized. I can well remember a day in 1882, when I met a fellow-student who had just returned to Edinburgh from Germany. He told me that it had been recently discovered that the disease was really caused by a living germ, the tubercle bacillus. It was difficult at first to believe such a revolutionary idea, but such was the interest and excitement raised that many workers at once took up the study of the subject and in a short time the truth of Koch's great discovery was fully proved. This was a magnificent example of research work, most admirably, carefully and completely carried out, and placed Koch at once in the front rank of scientific workers.

Before Koch's discovery a good deal had been done in the way of prevention. Before all things, this disease is a disease of environment. Its birthplace and home is the sunless, ill-ventilated, overcrowded room. The late Professor Edmund Parkes, professor of hygiene at the Army Medical School, reduced to a great extent the incidence of tuberculosis in the British Army by procuring for the soldier more floor-space and more air-space in his barracks. It is related of General von Moltke that when he heard of the death of Parkes he said that every regiment in Europe should parade on the day of his funeral and present arms in honor of one of the greatest friends the soldier ever had.

The prevention of tuberculosis is thus seen to depend fundamentally on the provision of a better environment and the education of the people in physiological living. To attain this in the older civilizations will be a hard task, entailing enormous expenditure of money and energy. In the report of the Royal Commission on the Housing of the Industrial Population of Scotland in 1917 is described the unsatisfactory sites of houses and villages, insufficient supplies of water, unsatisfactory provision for drainage, the gross overcrowding in the congested industrial towns, occupation of one-room houses by large families, groups of lightless and unventilated houses in the older burghs, clotted masses of slums in the great cities—a terrible picture, the heritage of the age of ignorance, internal strife and walled towns.

The people of new countries should see to it, and doubtless will see to it, that these old evils are not perpetuated. As Sir Robert Philip, professor of tuberculosis in the University of Edinburgh, has eloquently said:

> Were it possible to begin afresh the scheme of civilized life, were it possible to undertake anew the creation of cities and the homes of our people, were it possible to place within the recreated dwellings an understanding race, detuberculization might be quickly attained. What a magnificent opportunity for the builders of the new cities, the moulders of fresh civilizations, with the grand purpose of "No tuberculosis." The architect, the sanitarian and the citizen would agree in insisting that physiological laws should be paramount, that there should be effective obedience to the larger demands of hygiene in the home, the school, the workshop, the meeting-place and the cow-shed.
>
> Mankind was born into air and sunlight: these are his natural heritage. They are more—they are the irreducible conditions of life.

In regard to the tubercle bacillus, it is so widespread, so ubiquitous in civilized communities, passing from one infected host to infect another, that it would seem impossible under existing conditions to prevent its spread. At present it is taught, and on what seems good evidence, that the majority of the population of our crowded cities has at one time or another been attacked by this disease. But in every hundred men who die in England, only about ten die of tuberculosis, which shows that a large percentage of the population successfully resists the tubercle bacillus. When this occurs it means that the person attacked possessed powers of resistance which enabled him either to destroy its invading bacilli or to otherwise deal with them so as to render them harmless.

A point of importance in this connection is that it has recently been demonstrated that the disease is usually acquired in childhood. The fact is of capital significance, for, if the disease is recognized sufficiently early and the child is placed under good hygienic conditions, there is a very good chance of effective resistance and immunity against a second attack being set up. The present evidence goes to show that the presence of a latent tubercle prevents a second invasion. If further outbreaks take place, they would seem to be due to a flaring up of the old latent tubercle rather than to a fresh infection.

Metchnikoff studied the question in a remote part of Siberia where the tubercle bacillus was unknown. He states that very many of the young men and women who migrated from this clean country into the big cities died of acute and rapid tuberculosis, on account of not having been exposed to infection in their childhood.

The experience of Colonial troops in the late war

is instructive. Thus, in France the Senegalese, who are almost without tuberculosis in their native condition and were found to be free from tuberculosis on reaching France, developed in large numbers an acute and fatal form of tuberculosis in spite of the hygienic measures enforced by the army authorities. This raises a curious point. If it were possible for any country to clear itself of the tubercle bacillus, it would appear to be incurring a great risk for an inhabitant to migrate into any neighboring country. But, in spite of this, it is the duty of medical men to keep in check, as far as possible, the ravages of the disease.

The preventive measures against tuberculosis at the present time are, in the first place, improvement in the general hygienic conditions. Thereby individual resistance—and communal resistance—can be remarkably increased. In the second place, as every case of tuberculosis must arise from a previous case, either human or bovine, it is very necessary that methods of early diagnosis, preventive treatment and segregation of the more infective types may be provided for. This is done by the setting up of tuberculosis dispensaries, care committees, sanatoria, hospitals and colonies. These several elements are combined in the model tuberculosis scheme which is now universal throughout Great Britain. In the third place, if much can be done to anticipate and limit the progress of infection by the use of tuberculin, much caution is required in assessing the claims, sometimes hasty and extravagant, advanced by adventurers in this field of research.

Many other points might be brought forward, but the subject is such a vast one that I must content myself with drawing attention to the importance of a sound milk supply. The contamination of our home herds with tuberculosis is so great that no pains should be spared to secure a safe milk supply, and I understand that the city of Toronto is a model in this respect.

The result of these methods of prevention against tuberculosis may be given briefly. Sir Robert Philip writes that in Scotland ten years before Koch's discovery the death-rate from this disease was 404 per 100,000; in 1920 it had fallen to 124 per 100,000, a fall of 69.3 per cent. He also points out that the

> recent acceleration of rate of reduction which is noticeable in England and Scotland is of arresting interest.
>
> In Scotland the acceleration of fall in the mortality rate likewise arrests attention. Thus, during twenty years up to 1890, the percentage fall in mortality from all forms of tuberculosis was 35, while during twenty years from 1900–1919 the percentage fall was 45.

This is very satisfactory, and has only been arrived at by hard work on the part of medical men, nurses and voluntary workers. Any tuberculosis scheme, however perfect in theory, will require untiring energy, patience and perseverance to bear fruit. On this side of the Atlantic, in the United States, these antituberculosis schemes have been pursued with enthusiasm, with the result that Washington in 1920 had a death-rate from all forms of tuberculosis for 100,000 of the population of only 85, Chicago 97 and New York 126. London in the same year had a death-rate of 127, practically the same as New York. Other nations have not been so energetic in preventive measures, Vienna having in 1920 a death-rate of 405 and Paris 279 per 100,000 from the same cause.

It is evidently the duty of every nation to take up arms against a disease which exacts such a terrible toll of death, suffering and inefficiency. If this were done with energy and enthusiasm it is not too much to hope that in a few generations the tubercle bacillus would be practically brought under control and with it many other malign influences.

INFECTIOUS DISEASES—(B) PROTOZOAL

I shall now pass on to the consideration of the second great group of infectious diseases, the protozoal, and consider what methods of prevention have been found applicable to them.

The scientific study of the protozoal diseases of man may be said to have begun with the epoch-making discovery of the malaria parasites in 1880 by the illustrious Frenchman, Laveran; next, in 1893, the discovery by Theobald Smith and Kilborne of the cause of Texas fever and the part played in its dissemination by the cattle-tick; in 1894 the discovery of the trypanosome of nagana and its intermediate insect host, the tsetse fly; in 1898 the working out of the development of the malaria parasite of birds in the mosquito by Ronald Ross, greatly aided and abetted in the work by Patrick Manson, which led, through the work of Grassi and his fellow-workers in Italy, to the final solution of the malaria problem. A year later the important discovery of the mosquito carrier of yellow fever was made by the American Army Commission, under the directorship of Reed, and in 1903 Leishman announced his discovery of the protozoal cause of kala-azar.

These protozoal diseases are world-wide, like the bacterial, but it is in the warmer climates that their effect is most felt. The great plagues of the tropics, such as malaria, amœbic dysentery, kala-azar and sleeping sickness among men, Texas fever, tsetse-fly disease and others among domestic animals, are caused by minute microscopical animal parasites. Large tracts of country have been and are still rendered uninhabitable to white settlers by their presence. The opening up of Africa, for example, was rendered

difficult by the tsetse fly, before the advent of railways. No sooner had an expedition started for the interior than the fly attacked the cattle transport, and before long the expedition had to make its way back as best it could to its base on the coast. The only way to get into the country was on foot with native porters.

The protozoal diseases of domestic animals have also led to enormous loss in all parts of the world. Texas fever, or red-water, has swept whole countries of their cattle. After the Boer war, South Africa was devastated by the introduction of East Coast fever, another protozoal disease of cattle closely related to Texas fever.

How is the prevention of these diseases to be brought about? We find that up to the present little can be done by way of vaccination or inoculation or by the use of anti-sera as in the bacterial diseases. On studying the natural history of these protozoal parasites, however, it is found that many of them depend on an intermediate insect host for their continued existence, and it is by taking advantage of this characteristic that methods of prevention can be devised.

To illustrate this, I might cite the classical examples of malaria and yellow fever, but, as these must be familiar to you all, I shall take instead the trypanosome diseases of Africa, the best known of which are sleeping sickness in man and nagana or tsetse-fly disease in the domestic animals.

Nagana or Tsetse-fly Disease

In 1894, a year after Theobald Smith and Kilborne had published their famous monograph on Texas fever, a severe epidemic among native cattle in the north of Zululand was reported to the Natal government. The disease was called nagana by the natives, and it is curious that there was no suspicion at the time that it had any connection with the tsetse fly.

At this time a very enlightened administrator, the late Sir Walter Hely-Hutchinson, was governor of Natal and Zululand, and it was due to him that the investigation of the cause of the Zululand outbreak was at once undertaken. As I happened to be stationed in Natal at this time, I was chosen to undertake the work, and at once started on the long journey, mostly by ox-wagon, to the scene of the outbreak.

On examination of the blood of the nagana cattle, a minute active flagellated protozoal parasite, belonging to the genus Trypanosoma, was discovered, and after many experiments on dogs, horses and cattle it was decided that in all probability it was the cause of the disease. Trypanosomes had previously been described in the blood of rats and horses in India by Timothy Lewis and Griffith Evans, but nothing was known as to the mode of their transmission from animal to animal. It seemed as if the discovery of the nagana trypanosome would have ended the investigation in Zululand without any means of preventing the disease being discovered, but another observation made at this time threw more light on the subject.

In the low country between the high ground, on which the nagana camp was situated, and the sea there happened to be a so-called "fly belt." Every schoolboy had read about the tsetse fly in books of travelers and hunters, especially in those by the most famous of them all, David Livingstone, the missionary, and out of curiosity I decided to find out what happened when an animal was bitten by the fly, or, as it was termed, fly-struck. Natives were therefore sent with cattle and dogs into this "fly country," with orders to form a camp and expose the animals to the bites of the fly. This was done and it was with great surprise that on their return to the hill the blood of these fly-struck animals was found to contain the same parasite as that found in the nagana cattle.

Nagana and tsetse-fly disease were finally proved to be identical. The tsetse-fly disease was shown to be caused, not, as had been believed, by the poisonous bite of the fly, but by the transference of a protozoal parasite from the fly to the animal in the act of sucking blood. Now the question arose as to where the fly found the parasite. As the tsetse flies constantly lived among and fed on wild game, such as buffalo and antelope, these animals were suspected. Their blood was examined, and before long it became evident that the wild animals acted as the reservoir of the disease, the trypanosome living in their blood as harmless parasites. When the tsetse fly fed on blood containing the trypanosome it became infected and was capable by its bite of giving rise to a fatal disease in cattle, horses or dogs; whereas if it fed on a wild animal nothing happened, as the wild game are immune to the disease, much in the same way as the goat is immune to Malta fever.

Now that the natural history of the disease had been so far worked out it was evident that its prevention might be attempted. This can be done in any of three ways: by getting rid of the wild game, the reservoir; or by getting rid of the fly, the vector or carrier; or, lastly, by removing the cattle, horses and dogs to a safe distance from the "fly country."

This work on nagana led later, in 1903, to the discovery of the cause and mode of prevention of sleeping sickness.

Sleeping Sickness

About the beginning of the century an epidemic of this disease raged round the shores of Lake Victoria in Central Africa. It had been introduced into Uganda from the West Coast, where it had been known for many years as a curious and unaccountable

disease. It was observed that although the disease spread in a West African village from man to man apparently by contact, no such thing occurred among natives exiled from their homes. The disease never spread if introduced into native compounds in the West Indies or America, however closely the slaves might be herded together.

The disease remained shrouded in mystery and nothing had been done in the way of prevention, until the matter was taken up by the Royal Society of London in 1902 and a commission sent out to investigate.

It is not necessary to go into details; suffice it to say that after one or two false starts the commission in 1903 came to the conclusion that the disease was caused, as in nagana, by a species of trypanosome.

The question of the distribution of sleeping sickness in Uganda was then taken up. This disclosed the remarkable fact that the disease was restricted to the numerous islands in the northern part of the lake and to a narrow belt of country skirting the shores of the lake. In no part of Uganda were cases found more than a few miles from the lake shore.

The next important step in the working out of the etiology was made when it was shown that the distribution of the disease was identical with the distribution of the common tsetse fly of the country, *Glossina palpalis*. Where there was no fly there was no sleeping sickness.

The problem was now solved. The epidemic could be stopped either by getting rid of the fly or by removing the natives out of the fly area. As the destruction of the fly was impracticable under the circumstances, the second method was decided on. The natives were moved from the islands and lake shore and placed on healthy inland sites, and the epidemic, which had cost the Protectorate some 200,000 lives, speedily came to an end.

This method of preventing disease, by removing man out of the zone of danger, is an extravagant one and can only be done in exceptional circumstances. In Uganda the native population could be easily moved, but it meant that from about 1910 until the present day some of the most fertile land in Uganda has been lying derelict, has returned to the primitive jungle. The war delayed things, of course, but it is only now that the natives are being returned to their old homes on the islands and lake shore, in the hope that the fly by this time has lost its infectivity.

The other method, by the destruction of the tsetse fly, has been carried out successfully in other places. For example, in the island of Principe, off the West Coast of Africa, by destroying the wild animals which supplied a large part of the food of the fly and by clearing the jungle the tsetse flies disappeared, and with them the disease. This is the method employed in malaria and yellow fever. It was by destroying the mosquito carrier that Gorgas drove yellow fever out of Havana and later both malaria and yellow fever from the Panama Canal Zone.

Thus through the work of Manson, Laveran, Ross, Reed and others has it been made possible to deal with these two scourges of the tropics, malaria and yellow fever. I include yellow fever among the protozoal diseases, although Noguchi in 1919 brought forward strong evidence that it was caused by a spirochete.

In regard to the yellow fever the victory has been almost won. During the last century this disease, known as "yellow jack," devastated the West Indies and Central and South America. At the present time, thanks chiefly to the unremitting efforts of the late General Gorgas and the International Health Board of the Rockefeller Foundation, the disease has been driven out of the West Indies and Central America and only retains a precarious foothold in Mexico and Brazil.

So also in the case of malaria. A dozen years ago, based on the experience gained by Ross on the West Coast of Africa and Ismailia and by Watson in the Federated Malay States, the method of prevention by mosquito control and drainage has been so perfected that the practical blotting out of malaria from a given locality is now merely a matter of expense. A great deal of work has been done during the last few years in the way of experiment in the United States, and Vincent, the president of the Rockefeller Foundation, lately stated that there is evidence that "under normal conditions an average community can practically rid itself of malaria at a *per capita* cost of from 45 cents to $1 per year."

This is an altogether inadequate account of the methods of preventing these highly important protozoal diseases. From the few examples given it will be seen that they are most rampant in warm climates, that they are as a rule conveyed from the sick to the healthy by an insect intermediary, and that it is by an attack on this insect, be it mosquito, tsetse fly or tick, that the best chance of success in prevention lies.

INFECTIOUS DISEASES—(C) UNDETERMINED GROUP

In addition to the bacterial and protozoal infectious diseases, there is a third and large class, known as the "undetermined group," in which the parasite is either unknown or doubtful. Many of these undetermined diseases are very common and familiar, such as influenza, measles, scarlet fever, smallpox, typhus fever, trench fever, dengue fever and sand-fly fever; among animals, rabies, rinderpest, foot-and-mouth disease and African horse-sickness.

The theory generally held at present in regard to most diseases included in this group is that the living

germs causing them are ultra-microscopical in at least some part of their life history, and this is strengthened by the fact that many of them pass through porcelain filters, which keep back the smallest of the visible bacteria. Hence the name, "filter-passers."

Many of these undetermined diseases are highly infectious and appear to infect at a distance through the air, as, for example, in the case of influenza, scarlet fever and smallpox. In some of them there is no attempt made at prevention, except that the sick are isolated and placed under quarantine for a longer or shorter period. But in others there are well-known methods of prevention even when the virus is quite unknown. The best example is smallpox, the ravages of which have been completely held in check since the memorable discovery of Jenner. As has already been argued, this method of prevention, by inducing a mild or attenuated form of the disease, is at best a clumsy one, and when the natural history of the smallpox virus is better known it may be hoped that a more fundamental method of preventing this disease may be discovered. In the meantime the best means at our disposal is by the use of vaccine lymph, and people should recognize their responsibility to the community if through ignorance or selfishness they refuse to have their children vaccinated.

Another well-known disease, with an unknown virus, rabies or hydrophobia, has also, by the genius and intuition of Pasteur, been robbed of many of its terrors. The mortality following bites of rabid animals has fallen from 16 per cent. to less than 1 per cent. But in rabies, when the conditions are favorable, the radical method is to drive the disease altogether out of the country by the careful administration of muzzling and quarantine laws. This was carried out successfully in England at the beginning of the century.

Trench Fever

There are among the diseases of undetermined origin a few which are slowly emerging from the unknown into the known. One of the most interesting of these is trench fever, which came into great prominence during the war. The history of the investigation of this fever is interesting and well illustrates the method of studying a disease with a view to its prevention.

Before the war, trench fever was unknown, though there is some evidence that it had been recognized at an earlier date in Poland and called Wolhynia fever. Be that as it may, it is quite certain that, though it was unknown on the Western Front at the beginning of the war, it is no exaggeration to say that it became one of the most powerful factors in reducing our man-power, probably more than a million cases occurring among the Allies on the Western Front. In 1917 in the Second British Army alone, out of a total of 106,000 admissions to hospital at least 20,000 of the cases were trench fever.

Although this fever has well-marked characteristics of its own, such as a peculiar type of temperature curve and other symptoms, yet for a long time it was unrecognized as a separate entity and remained mixed up with other diseases, such as typhoid fever, malaria and rheumatism. In 1916, MacNee, Renshaw and Brunt in France made the first definite advance by showing that the blood of trench-fever cases was infective. They succeeded in transferring the disease to healthy men by the injection of the blood. The most careful microscopic examination of the blood corpuscles and lymph failed, however, to reveal any living germ. Nothing more was done until the following year, when the British War Office took the matter up seriously and formed a committee for the purpose of investigating the disease.

The United States of America, on coming into the war, at once recognized the importance of trench fever and without delay also undertook its investigation. In October, 1917, at the first meeting of the Medical Research Committee of the American Red Cross in Paris, Major R. P. Strong recommended that a research into trench fever should be undertaken. He stated that, after several months' study of the problems relating to the prevention of infectious diseases occurring in the Allied Armies on the Western Front, it became evident that the subject of the method of transmission of trench fever was one of the most important for investigation in connection with the loss of man-power in the fighting forces.

At the next meeting, in November, 1917, this was agreed to, and a Trench Fever Committee, under the chairmanship of Major Strong, was formed. The research was organized and experiments begun on February 4, 1918. In less than six months the investigation was completed and the report in the hands of the printer. This is a striking example of research work which, if carried out at the beginning of the war instead of at the end, might have saved the Allied armies hundreds of thousands of cases of disease, which, although never fatal, were often of long duration and led to much invaliding.

The most important result of the work of these two committees was that it was amply proved that the louse, and the louse alone, was responsible for the spreading of the disease. This discovery meant that in a short time trench fever would have disappeared from our armies on the Western Front. Just as the elimination of goat's milk blotted out Malta fever, the elimination of the mosquito, malaria and yellow fever, so would the elimination of the louse have completely blotted out trench fever.

This method of prevention, by the destruction of

the louse, although doubtless requiring careful organization and energy in carrying out, was shown before the end of the war to be a perfectly practicable proposition, and there can be little doubt that, if the war had lasted much longer, trench fever, like tetanus, would have practically disappeared.

Besides the main discovery from the preventive point of view that the louse is the carrier, there are many other points of interest in the natural history of trench fever. The living germ causing it has never been recognized in the human blood or tissues, probably on account of its extreme minuteness and its consequent liability to confusion with other small granules. But when the louse sucks blood from a trench-fever case there is apparently a great multiplication and development of the supposed micro-organism. In five to nine days the louse becomes infective, and there is seen in the stomach and intestines enormous numbers of very minute bodies. What the exact nature of these bodies is, is unknown, but there can be little doubt that they are the infecting agents by which the louse passes on the disease. They pass out in countless numbers in the droppings or excreta of the louse, and it is to these bodies in the excreta that infection is due. The louse seldom if ever gives rise to the disease in the act of biting. It is the infective excreta thrown out on the skin which causes the infection. The micro-organisms or so-called Rickettsia bodies contained in the excreta find their way into the blood through abrasions or scratches and so give rise to the fever.

From what has been said it will be seen that trench fever is an interesting disease. It also explains why it disappears in times of peace. As soon as the war was ended and our men could leave the trenches and resume their normal habits, the disease disappeared. The louse was eliminated and the trench fever with it.

Typhus Fever

Another disease of the undetermined group closely related to trench fever and also carried by the louse is typhus fever, another of the furies following on the heels of war. The French and British armies escaped this scourge to a great extent, but some of the other countries, such as Serbia, Bulgaria and Poland, were not so fortunate. It is stated that 120,000 Serbians died of this disease during the war, and it was only after vigorous steps had been taken in sanitary measures directed against the louse that the epidemic was got in hand.

After the long, exhausting Napoleonic wars, with the resulting poverty and destitution, typhus fever was prevalent in Great Britain and Ireland. About the middle of the century the improved economic conditions gradually led to the disappearance of the disease in Britain, although cases still occur in some parts of Ireland.

It is to Nicolle that we owe this advancement in our knowledge of this important disease. His work in Tunis on this subject dates from 1909. He showed that the blood of typhus cases is infective to monkeys, and, most important of all, that the infection takes place through the body louse. Just as in trench fever, the louse becomes infective after some five days, and it has lately been shown by the late Arthur Bacot, of the Lister Institute, that the excreta is also infective.

The minute bodies found in the typhus louse are subject to some differences, very similar to those found in trench-fever louse and have been named *Rickettsia prowazeki* by Rocha Lima. What group these bodies belong to is still a matter of discussion. Some consider them to be protozoa, with an ultra-microscopical stage in man and a developmental stage in the louse, while others look on them as minute forms of bacteria. Although there is still some doubt as to the pathological significance of these Rickettsia bodies, the work of Sargent, Rocha Lima, Arkwright and Bacot, Wolbach, Todd and Palfrey has done much to establish a causal relationship between them and these two diseases, typhus and trench fever. From the point of view of prevention, the important fact is that the infection is carried by the louse, and in the next great war it will be almost as necessary to prepare means for the destruction of the lice as of the enemy.

Rocky Mountain Fever

A third disease belonging to this interesting little group—Rocky Mountain fever—occurs in certain localities in the United States. It provides another instance of a virus transmitted by an invertebrate host to man. As the result of the work of Ricketts and of Wolbach the woodtick, *Dermocentor venustus,* is now recognized as the vector. Rickettsia bodies closely resembling those found in association with typhus and trench-fever virus have been shown to be present in the stomach and tissues of the tick, and the same bodies have also been demonstrated in the tissues of infected guinea-pigs.

Another interesting disease of the undetermined group is sand-fly fever, the virus of which is conveyed from man to man by the sand-fly. A new era in its study has been opened up by the work of Whittingham and Rook, who have learned how to handle, breed and keep sand-flies in captivity and have shown that the virus is transmitted from generation to generation of flies without intervening passage through man or other higher animal. The knowledge of the life history of the flies will no doubt lead in due course to the suppression of the disease.

Another type of invertebrate vector is the Kedani mite, *Trombicula akamushi,* which transmits the virus of Japanese river-fever to man from wild animals. The dangerous character of this disease (Tsutsuga-

mushi) and the minute size of the mite together have presented great difficulties to the Japanese investigators. Protection from the mite by special clothing and bathing after exposure to risk of infection are at present the most hopeful methods of prophylaxis.

The prevention of diseases of this group by means of antitoxic sera has also been used with some measure of success. Degkwitz and others in Germany have been reputed as having been very successful in protecting children from measles and scarlet fever by injecting them with a small quantity of serum from convalescent patients. This method has also been found very useful under suitable conditions to protect cattle from foot-and-mouth disease.

But far more hopeful than protection by serum alone is the use of a vaccine to produce a lasting immunity, combined with antitoxin to prevent the vaccine from producing unpleasant results—the so-called toxin-antitoxin method. Most of the diseases for which this method of prophylaxis has proved valuable have been diseases of animals, such as pleuropneumonia of cattle, rinderpest and foot-and-mouth disease; but quite recently the method of Dick, of Chicago, in scarlet fever has been supported by a number of observations. The system of testing and producing immunity is planned on the same lines as the Schick method for diphtheria.

DIETETIC DEFICIENCIES—DEFICIENCY DISEASES

The preceding account is but a short and meager history of the marvelous advance which has been made in the prevention of infectious diseases in our times, an advance due in great part to the work of two men, Pasteur the Frenchman and Koch the German; those who have come after them have merely followed in their footsteps, been their disciples.

Time will not permit even to touch upon the advances made in the prevention of other important diseases, such as the surgical infections and those caused by intestinal parasites, prominent among which are the hookworms and bilharzia. This advance has not been limited to the infectious group; it has been shared by other groups, notably those due to dietetic deficiencies, the so-called deficiency diseases. These deficiency diseases are just as important or even more important than the infectious, since they are always with us and exact an enormous toll in lowered health, lowered vitality, malformation and inefficiency.

Until a few years ago it was taught in the schools that a complete diet consisted of certain proportions of proteins, carbohydrates, fats and salts. But our knowledge is constantly increasing, our ideas about things constantly changing, and what is looked on to-day as absolute immutable truth to-morrow is seen in the light of some newer knowledge to be but a crude beginning. So the teaching concerning what constitutes a complete and healthy diet has changed, inasmuch as certain substances have been discovered in foodstuffs in the absence of which an adequate number of calories supplied in the form of proteins, carbohydrates, fats and salts can alone neither promote growth nor support life indefinitely. These accessory food factors or vitamins, as they have been named, are present in such minute quantities in foods that they have never been isolated, and their chemical composition is therefore unknown. It is still a matter of opinion as to whether they really constitute parts of the structure of living tissues or whether they merely act as catalysts of stimulators in the processes of growth and metabolism. That they are definite chemical substances which can be added to or removed from a foodstuff, with good or evil results, has, however, been abundantly proved.

The untutored savage living on the natural fruits of the earth and the chase knows no deficiency diseases. It is only when man begins by artificial means to polish his rice, whiten his flour and tin his beef and vegetables that the trouble begins. Civilized man, living in comfort, drawing his food supply from the whole earth and able to vary his dietary at will, is in little danger; but it is otherwise with children and adults living under institutional conditions, with armies on active service, encountering extremes of climate, and with young infants on their naturally restricted diet. While it is true that deficiency diseases will only develop to their well-marked dangerous stage if the deficiency of accessory factors is severe and protracted, a slighter deficiency, if prolonged, may cause a condition of general ill health and inefficiency not less important although ill defined and difficult to diagnose. This fact is of special importance in the case of infants and young children.

The Discovery of Vitamins

At the present time three, and possibly four, distinct vitamins have been described and studied, and it is probably only a matter of time for others to be discovered.

The discovery of vitamins dates to the middle of the eighteenth century. In 1747, James Lind, a surgeon in the British Navy, carried out a series of experimental observations upon sailors suffering from scurvy, the conception and performance of which were entirely admirable. By appropriate control experiments he showed that the medical means in vogue for the treatment of the disease were futile, when not harmful, but that orange and lemon juices were a specific cure. Lind attempted to ascertain the relative antiscorbutic value of various fruits and green vegetables, but was unable to observe a "superior virtue" in one rather than in another. He confirmed Kramer's observations made at the beginning of the

eighteenth century, during the war between the Turks and the Holy Roman Empire, that dried vegetables were useless, and adopts the explanation of his friend Cockburn "that no moisture whatever could restore the natural juices of the plant lost by evaporation," which Cockburn imagined were "altered by a fermentation which they underwent in drying." Lind was struck with the beneficial effect of cow's milk in the treatment of scurvy. He explained it on the supposition of the milk "being a truly vegetable liquor, an emulsion prepared of the most succulent wholesome herbs." Lind applied himself to the applications of these discoveries for the prevention of scurvy in the navy, and recommended lemon juice concentrated to a syrup by evaporation to be carried in all ships and served out to the sailors.

By the beginning of the nineteenth century the carriage of lemon juice was made compulsory, first in the navy and subsequently in the mercantile marine, with the result that the ravages of scurvy were prevented. With the advent of steam traction, too, the length of voyages was curtailed and supplies of fresh provisions were obtained at more frequent intervals. Scurvy became rare, and the medical profession, being no longer faced with this disease of dietary deficiency, soon forgot the significance of Lind's discoveries.

Before leaving this subject a curious fact may be related. The lemon juice supplied to the navy was at first made from lemons grown in Spain and the Mediterranean countries. Afterwards, when England took over the West Indies, it was made from the lime, and scurvy again broke out. The reason of this is now known to be the fact that, whereas the lemon is particularly rich in antiscorbutic vitamin, the lime is correspondingly poor.

The scientific study of the disease may be said to have lapsed for a century and a half, until Holst and his coworkers in Copenhagen investigated the etiology of scurvy anew on modern lines, with the help of experiments on animals. Their work, published in 1907 and 1912, formed the basis for the numerous researches carried out in England and America during and since the recent war. As a result of this work the etiology of scurvy, discovered in effect centuries earlier, has been firmly established as due to lack of a specific, undetermined and as yet unisolated constituent of fresh foods, especially of fresh vegetables and fruits, now known as Vitamin C.

In the meantime the existence of a second vitamin, the so-called anti-beri-beri, or antineuritic vitamin, had been discovered. Eijkman's admirable studies at the end of last century, in 1897, on the etiology of beri-beri in the Dutch Indies brought forward evidence for the view that this disease was of dietetic origin and was caused by a diet consisting too exclusively of highly milled and polished rice. He showed that the disease could be prevented if the outer layer (or pericarp) and the embryo of the seed, which had been removed in the process of milling, were restored to the "polished" rice. Eijkman's discovery of the analogous disease in birds, *Polyneuritis gallinarum*, provided the necessary tool for further investigation of the subject. The researches of Grijns and others showed that the bran and polishings of rice were only one of many rich natural sources of the unknown principle preventing beri-beri, and it became evident that, while the disease is usually confined to tropical races subsisting largely on rice, the European white-bread eater is only protected by the varied diet he usually enjoys. Experience on active service shows that beri-beri may really develop on a diet of tinned meat and white bread or biscuit.

During the late war two examples of the use made of this new knowledge occurred in Mesopotamia.

At the beginning of the campaign, on account of a difficulty in transport, there was a shortage of fresh food, with the curious result that scurvy broke out among the Indian troops and beri-beri among the British. The Indians were living on dried pulses, such as peas, beans and lentils; the British on tinned beef and biscuits. The former diet was deficient in the antiscorbutic vitamin on account of the complete drying of the seeds; the latter in the anti-beri-beri factor on account of the use of white flour from which the germ had been removed.

Some years ago it had been discovered that if dried seeds are germinated, a quantity of the antiscorbutic vitamin is produced by the act of sprouting. This was done. The dried peas and beans were soaked in water and then spread out in shallow layers, to cause them to sprout, which they readily did in the warm climate. The germinated seeds were then issued to the Indian troops and cooked in the usual way. As a result of this simple procedure the scurvy completely disappeared, no new cases occurred and the sick recovered. In regard to the British troops it was known that the anti-beri-beri vitamin is contained in large quantities in certain cells, and notably in yeast cells. A small quantity of this substance in the form of marmite was added to the soldier's diet of bully-beef and biscuits, and the beri-beri in like manner disappeared.

It may seem strange that the conception of the rôle of vitamins in nutrition should have come first from the pathologist, and should not have emerged from the important advances in our knowledge of the physiology of nutrition which were made during the second half of the last century. The physiologists were preoccupied with the chemical composition of foodstuffs and their value for supplying energy and supporting growth, and with the necessity for supplying the requisite number of calories in a diet, distributed appropriately among proteins, fats and car-

bohydrates, with adequate selection of mineral salts. It was only when these researches led to experiments in which animals were fed upon various mixtures of purified food elements that the investigators in this field began to realize that their repeated failures to rear animals upon such carefully arranged diets were not due to accident. The truth was suspected by Lunin in 1881, but it was not until 1912 that Hopkins published the classic experiments which proved the fact beyond a doubt. In the course of work along the same lines in the United States, McCollum and Davis in 1915 rediscovered Vitamin B, and, in addition, a third essential dietary constituent, a fat-soluble vitamin, present in butter-fat and certain other fats of animal origin, especially in cod-liver oil and other fish oils. This vitamin is known as fat-soluble Vitamin A.

Rickets as a Deficiency Disease

The discovery of the fat-soluble vitamins proved to be of great importance in elucidating the etiology of this disease, which had for long been an unsolved problem. Some authorities had erroneously considered it to be an infectious disease, like tuberculosis. Another school held the so-called domestication theory, that it was caused by unnatural surroundings, involving a want of sunlight, fresh air and exercise. A third considered rickets to be caused by improper feeding, though opinions differed as to the exact nature of the dietetic defect. The conclusion, first put forward by Mellanby in 1918, that a deficiency of fat-soluble vitamins plays a most important part in the causation of the disease is now generally accepted. This has been established by a large amount of work, both experimental and clinical, carried out by Mellanby himself, McCollum and Hess and their respective coworkers in the United States, and Korenchevsky and others in England. It may be laid down that if a young animal is supplied with a sufficiency of these vitamins, rickets will not develop. The question of prevention is therefore one of economics. The difficulty is that these fat-soluble vitamins are chiefly found in such foodstuffs as butter, eggs, the fat of beef and mutton and fish oils, all expensive articles of diet which the poorer classes can seldom afford. The only "butter" used by them is probably some form of margarine, made from vegetable oils which contain little or no antirachitic vitamin. The question of prevention is for the sociologist. Science can only discover the causes and point the means. It is for governments and local authorities to carry out preventive measures in practice, and it is to be feared that science is often far ahead of the community in its share of the work.

Although the theory that rickets is an infectious disease has been exploded, a great and remarkable truth was contained in the domestication and hygienic theories which held that, among other unhygienic conditions, want of sunlight was concerned in the etiology of the disease. During the last five years it has been discovered that exposure to sunlight or to the ultra-violet rays of the mercury vapor quartz lamp can cure rickets in children. Experiments on animals have shown that the effective rays in the sunlight are also the ultra-violet. This discovery has indicated lack of sunlight during winter as one factor concerned in the large spring incidence of the disease in industrial cities in northern climates.

A complete and well-controlled research showing the interaction of diet and light in the prevention and cure of rickets in infants was gained in Vienna, since the war, by Dr. Harriette Chick, of the Lister Institute, and her four colleagues. There the curious fact came to light that infants fed on a diet deficient in antirachitic vitamin only developed the disease in winter and not in summer, and, moreover, could be cured in winter by exposure to artificial forms of radiation or by administration of cod-liver oil without any other change in diet or management. Another set of children who had a sufficient supply of fat-soluble vitamins in their diet, in the form of cod-liver oil, escaped the disease altogether.

Experiments on rats have also shown that in animals fed on a rickets-producing diet, rickets does not occur if the rats are exposed regularly to sunlight or to the rays of the mercury lamp, or other form of artificial ultra-violet radiation; whereas, if they were kept in the dark, rickets does develop. If, on the other hand, the diet was complete in all respects, including abundance of fat-soluble vitamins, the animals do not develop the disease, even if kept constantly in the dark. How this is brought about is not known. At one time it was thought that the action of the ultra-violet rays on the tissue might enable the animal to synthesize fat-soluble vitamins, as it does in the tissues of plants, but recent evidence brought forward by Miss Margaret Hume, in Vienna, and by Goldblatt and Soames at the Lister Institute, suggests that light can neither create nor act as a substitute for the vitamin. It seems rather to act as a stimulant, enabling the animal to make full and economical use of its store of fat-soluble vitamins, and when the store is used up growth ceases in spite of the continued action of the rays.

An important and practical point in regard to the connection between diet and sunlight and the formation of the antirachitic vitamin is the relation to cow's milk. Recent work carried out by Dr. Ethel Luce at the Lister Institute has shown that milk obtained from a cow on pasture in summer contains a sufficiency of the growth-promoting and antirachitic fat-soluble vitamins. In winter, on the other hand, if the cow

is stall-fed and kept in a dark stable, the milk may become deficient in these respects and young animals fed on it may become rachitic. This work shows that the seasonal variation in quality of the cow's milk may be an additional factor in the seasonal incidence of infants reared upon it. It also disposes of the idea, very current in some quarters, that cow's milk possesses low and negligible antirachitic properties and that the antirachitic properties of cod-liver oil are specific and peculiar to that substance. Enough has been said to show that rickets may be regarded as a disease of sunless houses, combined with a diet deficient in the antirachitic vitamin, and the means of prevention are sufficiently obvious, if not always easy and simple to carry out.

Doubtless in the future this new knowledge in regard to the accessory food factors in diet will be used to a greater extent than it has been up to the present, in which case it is not too much to expect that the city children of some future generation will have better-grown bodies and stronger, healthier teeth than their predecessors of the pre-vitamin age. This might be attained in a comparatively near future if only man could be allowed to work out his salvation in peace. Instead of this, great wars come and throw back the work for generations.

To saddle the country with a million and a half of unemployed, with the consequent poverty, insufficient food, clothing and housing, is not calculated to further the prevention of disease and raise the standard of health. Is it too much to hope that sometime in the revolving years a time may come when by a Confederation or League of Nations the world may be so policed that no one country will be able with impunity to attempt the destruction of its neighbor? Until this happens it is difficult to see how rickets, tuberculosis and other diseases can be adequately dealt with in our city populations.

Diseases due to Ductless Glands

I can only briefly allude to the astonishing advance in our knowledge of the diseases caused by a defect or excess of secretion of the ductless glands. Many of these discoveries are among the fairy tales of science. All this advance has taken place in the comparatively short space of time under review. Professor Starling, one of the chief protagonists in this advance, in his Harveian Oration a year ago states this very vividly:

> When I compare our present knowledge of the workings of the body and our powers of interfering with and of controlling those workings for the benefit of humanity with the ignorance and despairing impotence of my student days, I feel that I have had the good fortune to see the sun rise on a darkened world, and that the life of my contemporaries has coincided not with a renaissance but with a new birth of man's powers over his environment and his destinies, unparalleled in the whole history of mankind. Not but there is still much to be learned: the ocean of the unknown still stretches far and wide in front of us, but for its exploration we have the light of day to guide us; we know the directions in which we would sail, and every day, by the cooperation of all branches of science, our means of conveyance are becoming more swift and sure. Only labor is required to extend almost without limit our understanding of the human body and our control of its fate.

There is one point of likeness between the vitamins which we have been considering and these glandular secretions or hormones, as they are named. Just as we have seen that the presence or absence of an extremely minute quantity of a vitamin may determine growth and health or disease and death, so an extremely minute quantity of glandular secretion may have a similar effect.

The anterior lobe of the pituitary gland is a very small body, yet an excess of its secretion will cause a child to grow into a giant; a deficiency, and the growing child will remain an infant.

The best known of the ductless glands is the thyroid, and the effect of its secretion is truly marvelous. A deficiency, and the child grows up a heavy-featured, gibbering idiot. Rectify the supply of thyroid secretion: the heavy features disappear, the eyes brighten, the intelligence returns, and instead of the former heavy-jowled imbecile you have a bright, happy and normal schoolboy. On the other hand, if there is an excess of the thyroid hormone, exophthalmic goiter, or Graves's disease, is the result. Remove the redundancy and health returns.

The active principle of the thyroid has lately been shown to be a compound containing iodine. If there is no iodine in the soil or water, goiter is the result, as in parts of Switzerland, Canada and the United States. This aspect of the subject was taken up some ten years ago by Dr. David Marine and his colleagues at Cleveland, Ohio. They found that endemic goiter may be prevented by the simple method of giving for a time minute doses of iodine, and conclude that with this simple, rational and cheap means of prevention, this human scourge, which has taken its toll in misery, suffering and death throughout all ages, can and should be controlled, if not eliminated, and look forward in imagination, a few generations hence, to the final closing of the chapter on endemic goiter and cretinism in every civilized nation in the world.

Many advances have also been made in our knowledge of the function and uses of other ductless glands, and, as you know, the latest victory in this field is the discovery of insulin and the successful treatment of severe diabetes, for which magnificent work your own townsmen Banting and Best deserve the highest honor.

In many other directions than those touched upon has there been progress in the prevention of disease. It would take more than one address to describe the activities of the Rockefeller Foundation alone. Campaigns for the relief and control of hookworm disease, malaria control, the eradication of yellow fever, antituberculosis work and education are being pursued on such a scale and at such a lavish expenditure of money as to leave us in the Old Country breathless with admiration and envy. This foundation, incorporated in 1913, was founded, in the words of the president, "to stimulate world-wide research, to aid the diffusion of knowledge, to encourage cooperation in medical education and public health." Its chartered purpose is to promote, not the exclusive prosperity of any one nation, but "the well-being of mankind throughout the world."

Science, indeed, knows no boundaries of nations, languages or creeds. It is truly international. We are all children of one Father. The advance of knowledge in the causation and prevention of disease is not for the benefit of any one country, but for all—for the lonely African native, deserted by his tribe, dying in the jungle of sleeping sickness, or the Indian or Chinese coolie dying miserably of beri-beri, just as much as for the citizens of our own towns.

From what has been said it is abundantly clear that during the comparatively few years that have passed since this association first met in Canada, enormous advances have been made in the prevention of disease. Before that time we were still in the gloom and shadow of the dark ages. Now we have come out into the light. Man has come into his heritage and seems now to possess some particle of the universal creative force in virtue of which he can wrest from nature the secrets so jealously guarded by her and bend them to his own desire. But let there be no mistake; much has been done, but much more remains to be done. Mankind is still groaning and travailing under a grievous burden and weight of pain, sickness and disease. Interruptions are sure to come in the future as they have in the past in the work of removing the incubus, but, in spite of these, it is the duty of science to go steadily forward, illuminating the dark places in hope of happier times.

DAVID BRUCE

ORGANIZED COOPERATION AMONG MUSEUMS

IN the spring of 1923 the museums of the United States embarked upon a program of joint effort. The American Association of Museums was made over, so to speak, into an organization dependent no longer upon volunteer work, as it had been for nearly two decades. National headquarters were established at Washington, D. C. The nucleus of a permanent staff was engaged, a program was laid out for the ensuing year and a prospectus was drafted for many years to come. All this was made possible by an assured support from various sources of $25,000 for the first year and of $30,000 for each of two years more.

Appropriately enough, these events transpired at the Charleston meeting of the association, which marked the completion of a century and a half of museum history in America.

The first year of this experiment has just come to a close, with the nineteenth annual meeting of the association, which was held in Washington, D. C., on May 10 to 13. The meeting ended with a dinner at which the speakers were His Excellency, the ambassador of the French Republic, the United States commissioner of education, the president of the Carnegie Institution of Washington and the permanent secretary of the National Research Council. This event was an appropriate finish to an occasion which has gone far towards establishing the association on a high plane and which has given new energy to the movement which the organization represents.

The report of the secretary showed what program twelve months have witnessed. A few excerpts follow:

The work of the year has divided itself between the Old World and the New. In Europe, Director Charles R. Richards has pursued a two-sided study, having made a survey of museums of industrial art and of applied art conditions in general on the one hand, and of museums of industry on the other. These projects have been financed by the General Education Board, which has given its cooperation to the association.

Just prior to Professor Richards's return in April, the General Education Board arranged to transfer to the association approximately $7,000—this being the unexpended balance of its original appropriation towards Professor Richards's survey. It also indicated that it stood ready to provide such further funds as might be needed for the completion of the work.

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In this country the work of the association has gone forward from national headquarters at the Smithsonian Institution.

An important accomplishment has been the financial progress which has been made. Not only have the requirements laid down by the Laura Spelman Rockefeller Memorial been fulfilled by raising $15,000 to meet their grant of $10,000 for the year, but additional income has made it possible to increase the budget. The report of the treasurer shows a total income of $27,800.35, expenditures have been $20,804.67, and the year has closed with a previous deficit wiped out and with a balance of $6,050.86 of which $4,000 is a reserved fund.

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Certain new support has developed during the year, which is now to become available for the second year of