pathologists who have had the opportunity of examining the nervous centres after death tell us that distinct marks of feebly inflammatory decay are not inconspicuous in the brain; the spinal cord being normal. Especially in the Rolandic area signs of a slow pia-arachnitis are found, with degeneration of the cortical cells and some chronic cell proliferation. There are no affinities of this disease to rheumatic fever, but it would seem to be a result of some infection. In this case, as in others of the kind, the heart is unaffected. The causes of the malady are in complete obscurity; the discussions of its antecedents in the textbooks are trivial.

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THE NECESSITY FOR FULLER CONSIDERATION OF THE LOCAL PROCESSES OF DISEASE AND REPAIR IN THE TREATMENT OF PULMONARY TUBERCULOSIS.

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THE recent discussion at the Medical Society of London, together with the leading article in the *BRITISH MEDICAL JOURNAL* of December 8th, 1917, have served to focus attention on the fact—which has been becoming increasingly plain for some time—that the sanatorium treatment of pulmonary tuberculosis is not fulfilling all the hopes of those who believed that in it a really satisfactory treatment had at last been attained, and that by it the therapeutic problem of consumption had been definitely solved. The method has had a long and thorough trial, but it must now be recognized that the results of it are not such as to justify us in continuing to regard it as a standard method, adequate to deal with the disease with reasonable success, and without radical improvement or addition. We cannot say that in the average case treated by sanatorium methods complete and permanent cure is the normal event. In any given case the result of the treatment is uncertain and extremely difficult to foretell; the immediate mortality remains considerable, the ultimate mortality large, while our power of completely arresting the disease and of restoring the patient to active life is still disappointingly capricious. While we are able in a large number of cases to produce the most gratifying improvement in the general condition and diminution of the symptoms, it must be admitted that the tendency to the persistence of some few signs or symptoms and to ultimate relapse after the resumption of working conditions are disappointingly common.

It is the object of this paper to inquire into the significance of the comparative failure of sanatorium treatment and to indicate some principles which that treatment ignores, but which must be taken account of before we can hope to establish a method in any sense definitive.

GENERAL PATHOLOGICAL CONSIDERATIONS.

In dealing with the problems presented by the treatment of pulmonary tuberculosis it is necessary to keep in mind constantly and vividly the general pathological features of the disease. Certain broad and quite elementary features of the processes involved in the disease will therefore be recalled. The application of these facts is so obvious, and seems when written so helpful, that no apology will be made for giving some account of them here. A familiarity with the pathology of consumption is usually taken for granted, and is therefore but little referred to in discussions upon treatment. A critical consideration of such discussions will, however, frequently reveal evidence that such pathological elements are, in fact, not always kept steadily and clearly in mind, and even that the appreciation of them is sometimes imperfect or confused.

The tubercle bacillus, when it infects man, shows itself to be an organism of slight general toxicity and slight local virulence. It does not in itself produce marked constitutional symptoms and the fever that it so commonly

causes is benign even when considerable in degree; similarly, the presence of the organism in the tissues has remarkably little direct destructive effect (as compared with the pyogenic organisms, for example), but rather stimulates them to produce a special tissue, the function of which is to surround and destroy the invading micro-organisms. This special tissue is, of course, granulation tissue and constitutes the well-known granuloma of tuberculosis. It is essential to grasp clearly the peculiarities of this tissue. It has no feature peculiar to tuberculosis, but is the normal response of the body to a mild continuous irritation. The function of the granuloma is to dispose of the irritant by destroying it, and its destiny, like that of all other granulation tissue, is, when its work has been accomplished, to be converted into fibrous tissue. If a few tubercle bacilli be introduced into a healthy tissue, the normal sequence of events is the formation of a granuloma round the bacilli, the destruction of the latter by the granuloma, and the direct development of the latter into a small healthy scar. Now we can define with fair precision the conditions necessary to ensure this sequence of events: (1) The general resistance of the patient to tuberculosis must be good; (2) the dose of the organism must be reasonably small; and (3) the part infected must be kept under certain local conditions known to be favourable to cure, of which by far the most important is a state of rest. When these three requirements are not satisfied the granuloma as a protective mechanism fails and becomes itself an agent of injury. Supposing such a failure to occur either from low general resistance, largeness of the dose (or what may virtually be the same thing, exceptional virulence of the organism), or unsatisfactory local conditions, the result is a progressive enlargement of the granuloma.*

This has two important consequences:

1. The granuloma enlarges at the expense of the surrounding healthy tissues, which it attacks and destroys, as it were to make room for itself, with a vigour approaching that of a malignant tumour. This is the mechanism whereby tuberculosis produces its destructive effects, which are then seen to be part of the actual defence against the disease. As is well known, the destructive effect of the enlarging granuloma is not equal against all tissues and is apt particularly to be restrained by any dense fibrous membrane and by the parietal pleura—a feature which is one of the few absolutely characteristic of tubercle.

2. The granuloma from its very nature draws its blood supply chiefly from capillaries, any other vessels it may receive being very imperfectly developed. The consequence is that when the granuloma reaches any considerable size the central parts become very feebly nourished and therefore undergo fatty degeneration with consequent caseation and liquefaction. As long as caseation has not occurred, direct conversion of the granuloma into fibrous tissue is still possible under favourable conditions; recovery with loss of tissue but without loss of substance then takes place. When caseation has occurred there is necessarily loss of substance as well as loss of functioning tissue. There is thus actual cavity formation, and recovery is no longer possible without diminution in volume of the affected part. When the irritation caused by the micro-organism is very mild the tendency to the direct conversion of the granuloma into fibrous tissue is very strong and is in action continuously, even though the disease is progressing. The lesion then much more closely resembles the syphilitic gumma than the traditional caseous tubercle. This continuous fibrous transformation is probably the mechanism that leads to fibrous phthisis and the fibrosing tuberculosis of lymphatic glands.

The fibrous tissue into which the successfully resistant granuloma ultimately is transformed tends, of course, to contract and to diminish the volume of the affected part, even although there may have been little or no caseation and loss of substance. Diminution in volume of the lung is thus seen to be an essential feature of recovery from phthisis; it is, as we have seen, rendered necessary in two ways—through actual loss of substance of the organ in consequence of caseation, and through the contraction which must accompany the conversion of granulation tissue into a mature and healthy scar. So essential a part

* I set aside for the moment the possibility that the failure of local control of the disease may be so complete that a generalized tuberculosis occurs.

of this conversion is the process of contraction that if the latter be prevented the actual formation of fibrous tissue will ultimately be arrested. This can often be seen in cases of chronic ulcers surrounded by much rigid induration or fixed to a bone. Here the inability of the newly formed fibrous tissue to contract is often demonstrably the sole cause of the arrest of healing. Thus some shrinkage of the lung is an essential part in the actual process of recovery. If the necessary shrinkage is no more than is rendered possible by the falling in of the chest walls, costal, phrenic, and mediastinal, and other circumstances are favourable, recovery proceeds satisfactorily. If the necessary shrinkage is greater than can be readily and without undue delay compensated thus, the contraction, which naturally always tends more or less to pull on the walls of the intra-pulmonary bronchi, must now occur chiefly by means of this factor. Thus when shrinkage is embarrassed not only is the actual healing of the tuberculous process unfavourably affected, but a complication—distortion and dilatation of the bronchi—is apt to be set going, which may, even if the patient is able completely to throw off his tuberculosis, prove as disabling as the primary disease.

One further fact in the natural history of scar tissue should perhaps be borne in mind: While contraction is indispensable during the formation of a healthy scar, such fibrous tissue once formed and fully mature can by constant and gentle tension be stretched permanently to almost any degree.

FACTORS OF TREATMENT.

The foregoing pathological considerations have indicated that there are three main lines along which the treatment of pulmonary tuberculosis must be discussed: (1) The influencing of the general resistance of the body to tuberculosis. (2) The means whereby the local conditions can be made favourable to the healthy evolution of the granuloma as a defensive mechanism. (3) The special importance in the case of the lung of the contraction which accompanies all healthy scar formation and the necessity of providing for its occurrence if healing is to be satisfactory and bronchial deformation to be avoided. We thus have three fairly distinct problems to consider—the general problem, the local problem, and the mechanical problem.

The General Problem.

Sanatorium treatment as such concerns itself solely with attacking the disease through increasing the general resistance. The avoidance of reinfection and intercurrent respiratory infections, the hygienic life, and the use of exercise, are its chief weapons. We have enough evidence to-day to conclude that powerful as these weapons are they are not able in an average case to guarantee success or to obtain it often enough to enable us to hope that any degree of detailed improvement in the method will give us a definitely effectual treatment.

The subject of the general resistance to tuberculosis in man is still very far from being fully understood. It is probable that most people living under the conditions of present day Western civilization are infected with tubercle at one time or another, though in the great majority the disease never becomes recognizable during life. It is to be presumed that the development of clinically recognizable tuberculosis is an evidence of a resistance less than normal. We may suppose that, occasionally, a power of resistance greatly below the normal is inherited. Such individuals would be found out by the disease early in life, and they probably account for the cases of general tuberculosis of infancy and early childhood.* Those who escape this danger otherwise than by mere accidental avoidance of infection are to be regarded as having a definite general resistance to the disease. In the great majority of people this resistance is strong enough to crush any early infection before it becomes clinically recognizable. In a minority the resistance must be near or below the point where this extinction of the disease in a larval stage is possible. Such persons are those who develop clinically recognizable phthisis. Cases of very rapid and intractable disease probably represent individuals in whom the resistance is exceptionally low, and near the point that would permit of a primary generalized infection. Intermediate

degrees of immunity will produce types of the disease of corresponding severity. At the top of the class will come individuals whose resistive powers are nearly adequate to deal effectively with an infection in its larval period. Now there is a good deal of evidence that the general resistance to tubercle varies, within limits, with the general health of the individual. The improvement in the general health effected by sanatorium treatment progresses in certain favourable cases *pari passu* with improvement in the disease. It is probable, therefore, that the (comparatively limited) class of cases curable by sanatorium treatment is made up of individuals whose resistance is nearly or quite normal—that is, who are by nature nearly or quite able to dispose of the infection in its earlier stages, but who have had their resistance temporarily depressed by a decline in general health with which the infection has coincided. It is to be feared that this class is limited, for the concurrence of circumstances necessary to produce it is somewhat complex—namely, a natural resistance quite near the normal, a depression of this resistance through the general health, and the acquisition of the infection just at this moment.

That the effect of the general health in heightening the resistance to tubercle is quite limited is shown by the numerous cases in which, under sanatorium treatment, there is a great improvement in the general health and no corresponding improvement in the disease. Here we may suppose the natural resistance to be low and quite outside the narrow range of influence of the general health.

The Local Problem.

It is a fact very familiar to surgeons that in cases of so called surgical tuberculosis in parts subject to movement, such as bones, joints, and tendon sheaths, immobilization of the part has a remarkably favourable effect on the disease. Without any other treatment it may render the granuloma completely effective as a defensive mechanism, causing it to cease to enlarge, to become less liable to caseation, and to undergo fibrous transformation in the normal way. General treatment to raise the power of resistance is by itself quite useless in these cases, and no surgeon of experience, if compelled to choose in a given case between it and immobilization, would hesitate for a moment in preferring the latter. Doubtless general treatment reinforces local treatment strongly, and should, of course, always be used if possible, but the indispensable condition for recovery in a part subject to movement is immobilization. There is no reason to suppose that these principles are not equally applicable to tuberculosis of the lung. The element of motion in the affected part is even more conspicuously present than in the case of a joint. That general treatment alone is sometimes effective in spite of continued movement suggests that the lung, probably on account of its vascularity, is naturally unfavourable to the disease; that general treatment alone frequently fails suggests that the local factor, which is indispensable in the case of a joint, is also necessary here. Surgeons have learnt that the immobilization of a tuberculous joint to be efficient must be absolute, and the same may be expected to apply to the lung. It is certain that the relative diminution of movement obtained by keeping a patient in bed has no claims whatever to be regarded as possessing any of the qualities of true immobilization as applied to a joint.

The Mechanical Problem.

It is a fortunate coincidence that the means whereby alone can be effected the institution of absolute rest in a diseased lung are also the means whereby the requirements of healing and the solution of the mechanical problem can best be met. The collapsed lung is not only immobilized but is in a condition to undergo the necessary shrinkage which accompanies the formation of healthy fibrous tissue; thus are promoted by one and the same measure the effective functioning of the granuloma as a protective mechanism, its due transformation into fibrous tissue when its function is fulfilled, and the prevention of the transformation leading to that distortion of the internal structure of the lung which is so apt to cause a permanent and disabling bronchiectasis.*

* Apart from its occurrence in early life, general tuberculosis seems mostly to be a terminal phenomenon, setting in only when the general resistance has been broken down by very extensive local disease.

* The importance of the mechanical factor and of the treatment of it is so great that I have dealt with it separately in another paper published in the *Quarterly Journal of Medicine*, April, 1918.

The effect of each of the four methods of treatment which I shall mention directly is to put the whole or part of the lung either temporarily or permanently out of action, and at the same time to compensate for the mechanical disabilities which have been produced by the morbid changes. Two of these methods have for their object the collapse of the whole of one lung; they are nitrogen displacement, which collapses the lung only, and rib mobilization, which collapses the lung together with the chest wall. The other two influence a part of the lung only; the one is division of the phrenic nerve in the neck, which produces paralysis of the diaphragm and is followed by immobilization and a partial collapse of the lower lobe; the second is the local replacement of one part of the lung, usually the apex, by a foreign body (Tuffier).*

Nitrogen Displacement.

Although each of these methods reduces the mobility and compensates for the disabilities caused by the mechanical factor, yet the selection of the type of case which will benefit by any of these methods of surgical intervention, and the choice of which method will produce most efficient results, is a matter of great importance. The lack of greater appreciation in this country of the value of the simplest even of these four procedures, nitrogen displacement, is the result of an imperfect realization of the character of the pathological processes and of the seriousness of the mechanical disabilities, and of the fact that the effect of the treatment is directly antagonistic to the further development of the former while at the same time it compensates for the latter.

The effects of the collapse of the lung are, as I have said, twofold. In the first place, it arrests in that organ the movements associated with respiration, and, as collapse is followed by a striking diminution in the symptoms, it reduces greatly the very active and sudden movements which accompany the acts of coughing and expectorating. As the granulomata are, therefore, no longer subject to continual irritation and injury by the movements of the tissues in which they are situated, they are able to perform their protective function, the fibrosis is able to overtake when their work is done, and to convert them into healthy fibrous tissue. In the second place, the collapse allows the newly-formed fibrous tissue to contract. It prevents, therefore, the constant drag on and the distortion of the surrounding walls, and, more important still, the bronchial deformation. It allows also of the obliteration of cavities in the bronchi or parenchyma and so abolishes the absorption of the products of secondary infection; the beneficial effect of this on the constitution and so on the power of resistance is obvious.

An extensive invasion of both lungs by tubercle is the only contraindication which I recognize to the treatment of this disease by nitrogen displacement. If the facts which I have stated above are accepted, it must necessarily be allowed that it is the extensiveness only, and not the slightness of the lesion, which constitutes a grave and serious objection to the attempt being made. The problems how early a case and how soon after the symptoms have been recognized nitrogen displacement should be tried will probably remain subject to controversy for many years. So long as a case is an "early" one—that is, so long as the diminution in the volume of the lung can be balanced by processes of nature (the approximation of the boundary walls and emphysema of the adjacent healthy lung)—there is no necessity for artificial means to compensate the disabilities due to the mechanical factor. But there is still the local problem—the granuloma—which must be considered. It may be, in a given case, that improvement in the general health and the moderate increase in resistance this can effect, will be sufficient. If, however, the symptoms and the signs indicate that there is delay or incompleteness in the fibrosis of the granuloma, more complete rest of the lung by surgical intervention is undoubtedly indicated.

Another argument in favour of the early treatment of pulmonary tuberculosis by nitrogen displacement is

that the longer it is postponed the more probable is it that the collapse of the lung will be incomplete or impossible owing to adhesions. Interpleural fibrosis often interferes greatly with the treatment. If, however, the adhesions are few and are accessible for division, or can be stretched sufficiently to enable the lung to be reduced to about half its volume, great benefit may be expected and can be obtained from the partial collapse.

Rib Mobilization.

This is an alternative method of treatment, but as the collapse of the lung and the chest wall is permanent, and as the operation is much more serious, it must be considered only when collapse by nitrogen is impossible. All cases which can be treated by nitrogen displacement are not suitable for rib mobilization. Much more rigid selection is necessary, and active disease in the opposite lung is an absolute contraindication. The immobility of the lung obtained by rib mobilization is more complete than that obtained by nitrogen, as the variations in the size of the organ due to the absorption of gas from the pleural cavity and the periodic refills are absent.

Division of the Phrenic Nerve in the Neck.

This operation is followed by paralysis of the diaphragm on the same side. The dome rises up into the thorax one or one and a half inches above the normal level. During quiet respiration it is motionless, but during a deep inspiration it may ascend still further into the chest. The movements of the lower lobe are controlled by the diaphragm. Paralysis of this muscle abolishes, therefore, the movements of the base of the lung, and at the same time produces partial collapse. This operation is of great value under the following circumstances:

1. When there are extensive secondary changes (mechanical and infective) in the lower lobe.
2. To diminish movement in the lower lobe when it is the seat of primary tuberculous disease.
3. To prevent the aspiration of infective material (tuberculous or pyogenic) from the upper into the lower lobe.
4. Although it is not germane to the subject of this paper, it should be added that paralysis of the diaphragm may be of considerable value as a prophylactic measure against the development of bronchiectasis in cases of chronic interstitial pneumonia.

Insertion of Foreign Body.

Tuffier advocates local collapse of the lung by separating the parietal pleura from the chest wall, and filling the space thus formed by a foreign body, such as a lipoma or fibroma.

It is frequently stated that one of the great barriers to success in the sanatorium treatment of pulmonary tuberculosis is the desire of or the necessity for the patient to return to the environment in which he was when he contracted the disease. The conditions which surround the individual when he returns to his work can rarely be so favourable for maintaining the degree of resistance to the disease acquired while under treatment. His reserves become exhausted by overwork, underfeeding, irregular hours, anxieties, or infection such as cold or influenza, and the granuloma once more fails in its defensive function. It is clear, therefore, that when the treatment is confined to improvement in the general health of the patient and to increase in the resistance only it is unsatisfactory, and in a large majority of cases the benefit which is obtained must be temporary in character. But when the lung is collapsed by nitrogen, the tuberculous lesion is set at rest and the mechanical disabilities are compensated, the patient is to quite a considerable extent independent of those fluctuations in his general health which are inevitable. Once, moreover, the initial treatment is completed, he can return to his work and can lead a comparatively normal existence with much greater safety to the community and with at the same time a much more considerable hope of maintaining and of securing the improvement which he has acquired, and possibly even of becoming the master of, instead of the slave to, the disease.

* I have already dealt with the details of the technique of all these methods in various other articles: "The therapeutic value of gases introduced into the pleural cavity," *BRITISH MEDICAL JOURNAL*, April, 1914; "The operation of rib mobilization in the treatment of phthisis," *British Journal of Surgery*, vol. ii, 1915; "The importance of the mechanical factor in the treatment of pulmonary tuberculosis," *Quarterly Journal of Medicine*, April, 1918.