and in the form of silica flour as the best of all bases for adsorbent toilet powders.

The three cases of fatal silicosis reported by Dr. Lennane, Sir Bernard Spilsbury, and Dr. Macdonald, which occurred in girls employed in packing these powders, were beyond all comparison more rapid in their development than any cases of silicosis previously reported. The girls were aged 17, 19, and 23 years at the time of death. These cases had not been published when Mr. Green and I wrote our paper. The confirmatory evidence which they afford in favour of the colloidal theory of silicosis is so strong that it appears to put the correctness of the theory almost beyond doubt, for the combination of alkali and silica in fine subdivision only requires wetting for the immediate production of active silica hydrosol. The solution so formed is not a true solution of a definite chemical individual compound, but is a variable system of sodium oxide, silica, and water, in which, according to Weisser, the ratio of Na_2O to SiO_2 may vary from 1:1 to 1:4, and the uncombined silica is in the hydrosol state.¹⁸ Hence the colloidal activity of the silica begins immediately the dust has reached the lungs, instead of awaiting the slow hydration of the quartz particles in the pulmonary tissue by the very faintly alkaline tissue juices, as in the case of gritstone masons, quartz crushers, ganister miners, and so on.

The belief that the quartz dust particles are slowly hydrated into silica sol in the lungs is founded mainly upon the experimental work of Gye and Kettle.¹² The latter showed that such hydration occurred when powdered silica was buried in the tissues of guinea-pigs. With a view to comparing this observation with a laboratory test *in vitro* Mr. Joseph Race, biochemist to the Devonshire Hospital, Buxton, put up a number of substances containing silica (in one case—namely, asbestos—combined silica) in a modified Ringer's solution for eight months. He then decanted off and filtered the fluid, and estimated quantitatively the silica which had been dissolved out. The Ringer's fluid was made up as follows:

Sodium chloride	...	...	0.650 per cent.
Potassium chloride	...	...	0.014 "
Calcium chloride	...	...	0.012 "
Sodium bicarbonate	...	...	0.020 "
Monosodium phosphate	...	...	0.001 "

The reaction was adjusted to give pH 7.35 at 38° C. Here are his results:

Material.	Silica found in solution.*
Workshop dust from a silica sand brickworks	24
Powdered Yorkshire ganister	28
Commercial asbestos	28
Silicic acid	52
Derbyshire millstone grit (powdered)	52
" " black chert (powdered)	55
" " pocket silica sand	60

* Parts per million.

Mr. Race's investigation was done in 1928, and he would naturally wish his figures checked against the work of others before drawing deductions from them. It would be of some interest to note if a slight increase in the alkalinity of the fluid leads to an increase in the dissolved silica. But we may take it that Mr. Race has shown that the slow solution or hydration of silica dust in the lung can be paralleled *in vitro* with Ringer's fluid.

Among the substances which yielded soluble silica to the Ringer's fluid was asbestos, which is, chemically, a magnesium silicate with sometimes the addition of calcium and a little iron to its molecule. Mr. Race's experiment strongly suggests that "asbestosis" is a true silicosis. A further suggestion is that the "club-moss" growths or bodies found on microscopic examination of the lungs in cases of asbestosis are osmotic silica artefacts, corresponding in type to the "growing plants" of the well-known "silica garden," and are due, like these latter, to surface-tension phenomena limiting the diffusion of the dissolved iron or other salts.

The above constitutes my attempt to answer the questions set at the beginning of this paper. I would beg to sum up as follows.

1. Silicosis is a result of the local action of hydrated silica upon the pulmonary tissue. This action is of a physico-chemical nature, and the speed of its development,

other things being equal, depends upon the rapidity with which fresh silica hydrosol is formed and brought into contact with pulmonary tissue.

2. Substances which favour the formation of silica hydrosol from silica, when added to the silica dust, accelerate the development of silicosis—for example, the alkalis. Substances which retard or prevent the formation of hydrosol from silica, or which coagulate the hydrosol when formed, retard or prevent silicosis—for example, carbon, coal dust, clays, and probably many other substances.

3. The action of silica in producing the nodular pulmonary fibrosis which we term "silicosis" has not been paralleled so far by any non-siliceous substance.

4. Silica is a normal constituent of plant and animal cells; its presence seems essential in certain tissues, and its absence from the food of the organism disastrous.

5. The study of the role of silica in biology suggests that many of the processes of cell metabolism belong to the realm of colloidal physics.

6. Some characteristic cellular phenomena are explained most simply by regarding the living cell as a polyphase colloidal system.

7. Silica has a place in therapeutics comparable to that of lime.

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METHODS FOR THE REDUCTION OF HUMAN TUBERCULOSIS OF BOVINE ORIGIN.*

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THE subject is so large that to cover it adequately it will be necessary for me to deal with parts of it by bald statements of ascertained facts, without giving in detail the evidence upon which these facts and estimates are based. I do so the more readily because this evidence is now obtainable without trouble in my recently published book, *The Prevention of Human Tuberculosis of Bovine Origin*.

THE AMOUNT OF HUMAN TUBERCULOSIS OF BOVINE ORIGIN.

The following table, from the work of a number of English pathologists (F. Griffith, Eastwood, and particularly A. S. Griffith), represents findings up to the end of 1927, as kindly summarized for me by Dr. A. S. Griffith. This represents English results, and the findings from Scottish cases give rather a higher percentage of bovine cases.

Cobbett, using the figures of the Registrar-General for 1915, arrived at the figure of 6 per cent. of all human tuberculosis deaths as of bovine origin. With the 1927 figures my calculations give rather over 5 per cent. bovine. This gives about 1,960 calculated deaths in 1927 as due to the bovine tubercle bacillus in man, the majority of deaths being in children.

* Read in opening a discussion in the Section of Public Health at the Annual Meeting of the British Medical Association, Manchester, 1929.

TABLE.

Variety of Tuberculosis.	No. of Cases	Children under 5 Years.		Children 5-15 Years.		Cases 15 Years and Over.	
		Human.	Bovine.	Human.	Bovine.	Human.	Bovine.
Cervical Glands...	112	3	16	28	25	31	9
Lupus ...	176	23	36	48	51	15	3
Scrofuloderma ...	54	7	6	17	10	13	1
Bone and joint ...	511	60	24	277	65	81	4
Genito-urinary ...	23	—	—	2	1	17	3
Pulmonary ...	202	—	—	10	0	19	2
Meningeal...	30	2	1	11	7	9	0
Post-mortem cases*	181	72	31	49	8	23	3
Totals ...	1,289	167	114	442	167	379	25

169 of the 181 Post-mortem Cases Classified as Regards Portals of Entry.

Alimentary entry	40	4	27	2	5	1	1
Respiratory ...	98	46	1	32	0	19	0
Double portal ...	25	15	0	10	0	—	—
Uncertain ...	6	2	0	3	0	1	0

* A series of unselected post-mortem tuberculosis cases. Five were cases of mixed infection and are entered twice—that is, as both human and bovine. These are 2 in 0-5 years, 1 in 5-15 years, and 2 in 15 years and over.

A study of the death returns shows, as we know, a marked decline in the death rate from tuberculosis. When we consider respiratory and non-respiratory deaths separately, the decline in the latter group is considerably more in evidence. For example, if we take 1912 as a standard year, respiratory tuberculosis deaths have declined by 22.6 per cent., non-respiratory tuberculous deaths by 48.3 per cent. It is reasonable to deduce a decline in bovine tuberculous infections greater than in tuberculous infections due to the human tubercle bacillus.

Probably not more than 2,000, or possibly 2,300, deaths from human tuberculosis each year are now due to the bovine tubercle bacillus, but we do not know how many infections occur not resulting in death.

THE EXTENT OF BOVINE TUBERCULOSIS.

Since the infections under consideration are entirely derived from tuberculous animals, and, for practical purposes, almost all from the consumption of milk or milk products containing tubercle bacilli, it is unscientific to consider their prevention, or even the reduction of this type of human tuberculosis, without having regard to the extent of tuberculosis in bovines and particularly in cows. Certain particulars may be more or less dogmatically stated. A large proportion of cows are infected with the bovine tubercle bacillus and give a positive reaction to tuberculin. The percentage varies widely in different areas, and is particularly influenced by the age constitution of the herd. Taking the country as a whole, veterinary data indicate that about 40 per cent. are affected.

The great majority of these cows are non-infectious to other animals or to the milk supply, and never become infectious. Others progress and become "open" cases—that is, they shed out tubercle bacilli into their surroundings. There are no reliable statistics as to the percentage of these "open" cases at any one time throughout the herds of Great Britain. A detailed study of the results of routine veterinary inspection of cows in particular areas suggests that cows which can be clinically diagnosed as suffering from tuberculosis are from 0.4 to 0.6 per cent. of the whole. These are all "open" cases, and to these have to be added cows shedding out tubercle bacilli, but unrecognizable by clinical means. At the most we can put the total percentage of "open" cases in herds of cows as not more than 1 per cent., probably less. This is considerably lower than figures often suggested, and is much lower than percentages recorded, for example, in Germany. From the human standpoint the most important type of "open" tuber-

culosis is that disease affecting the udder, and here a study of detailed inspections suggests 0.3 per cent. as a maximum, and in some areas considerably less.

REDUCTION METHODS NOW IN USE.

Theoretically we might consider separately those measures the aim of which is to reduce bovine tuberculosis, and those the object of which is to reduce the risk of human infection from milk containing tubercle bacilli. The two problems are so interrelated that it is impracticable to consider them apart. We can group the different procedures as follows:

1. The Elimination of All Tuberculous Cattle.

By this is meant the testing of all animals with tuberculin and the destruction of those giving a positive reaction, the so-called "reactors." Apart from the fact that a great many of these animals are not infectious and never will become infectious, their wholesale destruction is entirely impracticable. It can be successfully done in small areas—for example, in the Channel Islands. It is also the official plan in the United States of America, and in 1927 as many as 207,830 tuberculous cattle were slaughtered. It is possible in the United States because their percentage of reactors averages 3.3, and in different years only fluctuated between 2.9 and 4.9. It is impracticable in England, with more than ten times as high a percentage of reactors.

2. Building up Herds Free from Tuberculosis by Selection.

By making use of the simple procedure advocated by Professor Bang this is theoretically easy. There are, however, many administrative difficulties, and the building up of tuberculosis-free herds along these lines has never been much utilized in this country, and even in Denmark, its original home, its use seems to be declining. This method deserves more employment than it receives. In England the same principle has been followed, but along different lines, and in designated milks we can follow the production of tuberculosis-free herds. Two of the types of these designated milks—that is, Grade A (tuberculin tested), and Certified Milk—are from herds entirely free from tuberculosis, and they are able to advertise this fact.

Their growth has been of the slowest, and after six years' working there were only 152 "Certified" Milk and 207 Grade A (tuberculin tested) producers at the end of September, 1928. This, of course, is an entirely insignificant proportion of producers. In Somerset, with at least 7,300 producers, there were only eleven producers of these two types of milk at the end of 1928. As a practical solution of our problem these two types of milk can be neglected. Apart from these designated herds there are a good many herds the owners of which maintain them free from tuberculosis by careful selection, repeated testing, etc.

3. The Elimination of Particular Classes of Tuberculous Cows.

On theoretical grounds it is a sound policy to eliminate all infectious cows and so reduce both the spread of infection to bovines and the risks of tubercle bacilli in the milk supply. This is the aim of two separate procedures—the Tuberculosis Order, 1925, and routine veterinary inspection of dairy cattle. Under the Tuberculosis Order three types of bovines have to be reported, and, if the diagnosis is confirmed, destroyed, compensation being payable. For practical purposes these types correspond to "open" cases of tuberculosis. If these animals were all reported, or could all be reported, so soon as they became "open" cases, and if the disinfection and other steps in the Order were efficiently carried out, it is evident that this procedure could be an efficient weapon to reduce bovine tuberculosis and to protect the milk supply. In fact, however, partly from administrative defects, but mainly from scientific difficulties which are only removable to a limited extent, these desirable objects are not being attained. For example, these "open" cases are only being notified and destroyed so long after they have become infectious that most of the harm they are capable of doing has been done before they are destroyed. The finding of these cases

is not being followed up by a systematic examination of the other animals. Of particular importance from the human standpoint, cases of tuberculosis of the udder are not being detected, or are only reported when the disease is advanced and the milk supply has been affected for long periods before detection.

A scheme of systematic veterinary inspection of dairy cattle is legally in force in Scotland, is permissive in England, and is being carried out in a few areas. The scheme is being stressed by most members of the veterinary profession as the one urgent method by which to tackle these problems. It is an advance on the methods in the Tuberculosis Order, in that under the Order the cow-owner is instructed to report conditions which he has not the knowledge to detect, so that only the advanced cases are reported. Under this scheme the expert will go to the cowsheds and himself detect these infectious animals, so that theoretically the elimination of "open" cases will be prompt, thorough, and complete.

Unfortunately there are serious difficulties in the way of obtaining these theoretical results. The first is the inability of even the ablest veterinary inspector to detect these infectious animals in their early stages. Also these pathological conditions may advance in the cow with considerable rapidity, so that fairly frequent inspection is necessary. Financial and staff considerations limit severely the frequency of inspection. The wider the interval between the inspections the greater the number of animals which in the meanwhile will have developed open lesions and be a source of infection before their recognition. Dairy herds are unstable combinations, and additions and abstractions from the herds are constantly taking place. Veterinary inspection at its best under practical conditions can only hope to remove the comparatively gross cases of infective animals.

This raises the supremely important point as to the susceptibility of the cow to tuberculous infections. I emphasize its importance because in my opinion the administrative validity of any scheme of veterinary inspection of cows turns upon this question. In man there is evidence of some reliability that removal of cases of advanced tuberculosis diminishes the intensity of infection amongst contacts. With the physiologically overworked cow, subjected to the heavy strain of frequent calf-rearing, and so often kept under grossly insanitary conditions, the same may not be true. Put quite simply, routine veterinary inspection of our cattle will remove gross cases of tuberculosis, but will not remove all sources of infection. Will the removal of such infectious sources as it can effect play any decisive part in reducing the amount of bovine tuberculosis? The figures that we have from places where routine inspection has been in vogue for years do not show any such reduction.

Clearly this procedure can only reduce very partially, not remove, the risk of tubercle bacilli in the milk supply, and for that degree of reduction alone it is not worth the heavy expense entailed. I calculate the cost of a reasonably adequate system of veterinary inspection as rather over £300,000 a year, while it would press heavily in individual areas—for example, in Somerset it would cost about £13,500 a year.

I consider that this procedure must stand or fall on its merits as a means of reducing bovine tuberculosis. If it can be shown to accomplish this, and so reduce tuberculosis in bovines year by year to manageable proportions, it is a true preventive measure and thoroughly worth the price. I suggest to my veterinary friends that the onus is on them to demonstrate its ability to reduce bovine tuberculosis. Up to the present they do not even consider this point, for at the important discussions in June, 1928, at the World's Dairy Congress, not a single one of the distinguished veterinary surgeons discussing this matter paid the slightest attention to this problem, although it was discussed from almost every other angle.

4. Measures Directly Aimed at Reducing the Amount of Tubercle Bacilli in Milk.

These are of two kinds—bacteriological milk examinations and heat treatment of the milk. Although extensively employed and of considerable utility the value of bacterio-

logical examinations is almost entirely educational; they do nothing effective to protect the milk supply of any particular community. Take, for example, any town or city, it is only possible to bacteriologically test a quite insignificant proportion of the milk supply. When tubercle bacilli are detected it is feasible in something like 60 per cent. of the cases to find an infective animal and eliminate her. Clearly that amounts to nothing as regards protection of the milk supply. It is a system of spot sampling, such as we use for chemical milk testing. Spot sampling for chemical purity is effective, because a proved deficiency constitutes a statutory offence and fear of publicity and a penalty is the deterrent. When tuberculosis is found there is no penalty, but, on the contrary, public money is freely spent to provide free veterinary assistance and additional bacteriological examinations, while compensation is paid when the tuberculous cow is detected.

Pasteurization of the milk supply is along an entirely different line. In effect it assumes that none of our existing measures give us adequate protection from the risk of consuming tuberculous milk, and the only way we can achieve that protection is by heat treatment to eliminate the risk of their presence. It is impossible for me, in my limited time, to cover the large question of pasteurization. All I wish to say is that I am prepared to agree that, as carried out in the laboratory, pasteurization will very largely eliminate the dangers of tuberculous milk. Between laboratory results and a practical efficient working system there is a wide gulf, which, however, can be bridged. I do not think its opponents have demonstrated that, when efficiently performed, it does any material damage to any known nutritional qualities of milk, but there remains the possibility that it may destroy other valuable properties at present unknown. There are very considerable objections to a compulsory system of pasteurization on other grounds related to the various problems of clean milk, and if we have to adopt it as the best available method of protection from tuberculous milk I should regard it as a confession of failure, and the acceptance of a second best procedure, only to be adopted with very adequate precautions.

5. Immunization of Cows against Tuberculosis.

Theoretically practical, this method still remains experimental. Calmette's B.C.G. vaccine is on trial and should be very fully tested, but later results are not very favourable. It is a short cut to a solution of this difficult problem, and we can only hope it will not share the failure of all other short cuts for the treatment of tuberculosis.

SUGGESTIONS AS TO LINES OF REDUCTION TO ADOPT.

In the above account I have aimed at a summary of the rather bewildering number of remedies advocated, or utilized, to deal with this complicated problem. We can say at once that all methods specifically aimed at preventing tubercle bacilli from gaining access to milk are only palliatives, and not true preventive measures, in that they do nothing to reduce the need for their continuance by reducing bovine tuberculosis. Admittedly the operation of such measures as the Tuberculosis Order, or a scheme of veterinary inspection of cows, will effect some reduction in the risk of tuberculous milk. Administratively the question is whether this reduction is worth the price to be paid for it if such measures do not also effectively reduce tuberculosis in bovines. If we could be sure of two things—that is, that the risk of all gross infection with tubercle bacilli is removed by these measures and that only gross human infection matters—there would be a great deal to be said for their utility, but, as has been shown, they do not remove all gross infection or anything like it, while our pathologists are not in a position to assure us that moderate infections by way of the tonsils, etc., are negligible.

I consider that the value of these measures really turns upon their efficiency as agents for the reduction of bovine tuberculosis. Taking the long view, I suggest that the real problem is one of the reduction of bovine tuberculosis. Tuberculosis in dairy cattle has never received adequate consideration on broad preventive lines, but has been dealt with by the application of special procedures of limited scope, which fail, and, in my opinion, must fail,

because they are not part of a broad comprehensive scheme. Abundant illustrations might be given, but taking the latest of the remedies advanced—the routine veterinary inspection of dairy cattle—it is advocated as a thing worth introducing by itself, or to protect the milk supply, and never with a realization of the need to fit it into a wide comprehensive scheme. By itself I regard it as not worth doing, but it occupies quite a different place as part of a comprehensive attack on bovine tuberculosis.

As part of such a comprehensive scheme certain changes seem to me to be essential requirements. One is a radical alteration in the environmental conditions of the cow. There seems no reason that the agriculturists have advanced why the usual practice of keeping cows all the winter in insanitary cowsheds should not largely give place to their living under much more open-air conditions, the sheds possibly being used for milking or housing under exceptionally severe conditions.

A second step is the development of adequate measures to prevent or at least limit the spread of infection. The partial abolition of the cowshed will materially reduce risks of infection, but, in addition, more direct measures are necessary. One is a more active educational campaign. A second is to place part of the onus of preventing infection upon the cow-keeper. Since a material part of the cost of bovine tuberculosis now falls upon the central and local public health authorities, it is but logical they should have some powers to limit their expenditure by insisting that cow-owners should exercise due precautions to prevent infection. Cow-keepers who, by wilful failure to take due precautions, add to the nation's bill for tuberculosis should be penalized.

Problems of feeding and other factors affecting tuberculosis in cows all merit careful consideration in any well-thought-out programme.

Into such a scheme can profitably be fitted immunization experiments, the formation of tuberculin-free herds, the operation of a modified Tuberculosis Order, the routine veterinary inspection of cows, etc. Veterinary inspection of cows would be most valuable as part of such a scheme and might be made a most helpful procedure.

It will be noted that in any such scheme I give a prominent place to the active co-operation of the cow-owner, and regard that as essential. Any comprehensive attack on bovine tuberculosis is ultimately for the benefit of the farmer and the stock-owner. The present measures, in use or advocated, whereby a great deal of public money is spent on an attempt to diminish bovine tuberculosis without insisting on his active co-operation, are not only illogical but, in my opinion, likely to effect comparatively little. Considerable financial assistance to the farmer is necessary, since the difficulties of eradication are so considerable, and no one who appreciates these difficulties would wish to reduce the assistance or belittle its need. At the same time it is logical to ask that, as some return for that assistance, there should be a very active co-operation on the part of the stock-owner.

While such a scheme has as its primary aim and object the reduction of bovine tuberculosis, incidentally it would do a great deal to reduce the dangers of milk being infected with tubercle bacilli. This particularly applies to certain parts of it, such as routine veterinary inspection of dairy cattle, if bacteriology is adequately utilized in connexion with such inspection.

If the agricultural community decides that it is not prepared to co-operate actively (for that is what it amounts to) in the measures of the State and of local authorities to reduce the incidence of bovine tuberculosis; that, while willing to receive rate-aided assistance, tuberculosis is not of sufficient moment to agriculture to warrant the considerable disturbances to existing practice which are required, then another line of procedure is necessary. In that event I do not think it worth while, for the small measure of reduction of human tuberculosis which will accrue, to continue these partial measures, such as the Tuberculosis Order, an inadequate system of veterinary inspection, or occasional milk sampling for the tubercle bacillus. The extent of their success is not likely to be commensurate with their cost—at least, as regards the human side of the problem. It is better for those con-

cerned with the human infection side to face their own problem in their own way: to leave bovine tuberculosis to those concerned with animal diseases, and to protect the milk supply by an efficient and adequately controlled system of pasteurization. It is a confession of failure, the second best instead of the best. It has extensive drawbacks, and cannot be advocated without combination with other procedures, the aim of which is to minimize these drawbacks as far as possible.

In view of these drawbacks and other inherent objections to pasteurization, I greatly prefer the adoption of the preventive measures indicated to deal with bovine tuberculosis, but if these are not attainable, pasteurization seems less of an evil than the present tinkering procedures. Pasteurization will give a more effective protection to the milk supply than any incomplete scheme under existing conditions.

A CLINICAL STUDY OF ACUTE RHEUMATISM.

BASED ON WORK AT THE RHEUMATISM SUPERVISORY CENTRE,
ROYAL BOROUGH OF KENSINGTON.

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JUVENILE rheumatism is a disease characterized by its protean manifestations, its tendency to relapses, and its proneness to attack the heart. The aim of a rheumatism supervisory centre would be, were it possible, the prevention of rheumatic disease of the heart. Unfortunately the physician's hands are tied by ignorance of the exact cause of rheumatism, by possessing no specific remedy for its cure, and by having no sure or ready means for protecting the heart from its attacks. It has been said that the prevention of rheumatic heart disease can only be attained when rheumatism itself can be prevented, and, while we are not able, with our present knowledge, to prevent either rheumatism or rheumatic involvement of the heart, yet there is good reason to believe that relapses may be avoided by the employment of certain preventive measures. Put briefly, these measures consist in providing for the rheumatic child management and surroundings as near the ideal as possible, remembering that he cannot be neglected without risking exacerbations.¹ When the heart is already affected careful supervision may do much to enable the child to attain a degree of physical fitness sufficient to enable a return to a normal occupation. Thus the primary object of a rheumatism supervisory centre is twofold: the prevention of relapses and the after-care of those children whose hearts are already involved. In the latter group of children these two objects are inseparable; the best guarantee that a damaged heart will make a satisfactory recovery being to ensure that no further bouts of rheumatism occur, maintaining during the healing stage of rheumatic heart disease a careful supervision of all physical exertion.

With these principles in mind we decided that the functions of the rheumatism supervisory centre† should be: first, to make use of all the measures available for preventing relapses in rheumatic children, and, secondly, to supervise the after-care of children already the victims of rheumatic heart disease. Not directly related to either of these functions, but rather in the hope of adding something, however little it might be, to the knowledge of rheumatism, we have, by keeping careful records of the cases, been investigating juvenile rheumatism along clinical lines.

Prevention of Relapses.

The lines on which recurrences of rheumatism may best be prevented are: (1) correction of unsuitable environmental conditions; (2) attention to general health; (3)

* Working with a grant from the Medical Research Council.

† Established in connexion with the rheumatism scheme of the Royal Borough of Kensington.