Pulmonary Tuberculosis among Woodworkers as seen in National Service Recruits to the Royal Air Force.

by

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CONTENTS.

Introduction.

It has been for many years the policy of the Royal Air Force to examine by X-ray the chests of all Entrants to any branch of the service. This undertaking is carried out by the Chest Radiography Section, which has units, with mass miniature equipment, at the intake centres through which the great bulk of recruits enter the service.

The figures on which this thesis is based were collected while I was in charge of No. 4 Chest Radiography Sub-section, which was then located at the intake centre through which all National Service Conscripts passed when they were called up for their two year period of service.

The main object of the Chest Radiography Section was to prevent men with infective pulmonary tuberculosis from entering the service, and all such cases discovered by the various sub-sections were rejected at once, by the medical officers in charge. Active tuberculosis was not the only reason for which a man could be rejected for service. As will be shown, many were turned down due to non-tuberculous pulmonary infections, cardiac, orthopaedic and various miscellaneous acquired and congenital lesions. These were all such that, they either would have prevented the man from performing his duties in a satisfactory manner, or could have been worsened by overseas conditions, or/

/or were liable, in the case of infective lesions, to break down and become active again.

The origin of this thesis lies in the rejection of a number of woodworkers, due to pulmonary tuberculosis, in a relatively short period. This made me wonder if there was any known increase in the incidence of pulmonary tuberculosis among woodworkers. A search of the medical literature, available to me at that time, failed to reveal any suggestion of an association between woodworking and pulmonary tuberculosis. I then examined the case records, held on the unit, of the men who had been rejected in the previous nine months, to find whether these showed any link between woodworking and pulmonary tuberculosis. The numbers in this series were not large enough to be conclusive, but they gave a definite indication that there was an increased incidence of tuberculosis among the men who had worked with wood before being called up. This finding prompted me to enlarge the series until I had obtained a number which was definitely significant. This enlarged series also showed an increased incidence of pulmonary tuberculosis among the woodworkers, and it is the figures of this second series which are considered in this thesis.

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Chapter I.

Material and Methods.

In the period covered by this survey, No. 4 Chest Radiography Sub-section X-rayed 166,000 National Service Conscripts, of whom 900 were rejected for service due to lesions discovered by the section.

The period during which these men were X-rayed was approximately three years, and during this time, the Section was under the charge either of my predecessor or myself.

I chose this period because I was initially trained for the job by my predecessor, and also because we had a very similar approach to the clinical problem of acceptance or rejection in doubtful cases, and hence I feel that there is clinical continuity in the outlook of the men who have been in charge of the Section over this period. Further, in this period, the number of men X-rayed by the Section was sufficiently large to give the figures significance.

It would have been quite simple to have further increased the number in the survey either by including men X-rayed by the Section between the time of its formation and the start of this survey, or by including men X-rayed by the other units of the Chest Radiography Section.

I did not feel justified in adopting either of these courses, because there could have been no certainty of continuity of clinical outlook in the figures from No. 4 Chest Radiography Sub-section in the period during which the unit was being run by men who were unknown to me/

/me, and there could have been no continuity of outlook if other units were involved.

The other units of the Chest Radiography Section handled volunteers. The question of medical differences, particularly psychiatric, between conscripts and volunteers is recognised, and was summarised during the War by Curran (15), who dealt with the differences between the volunteers to the Royal Navy and the conscripts which the other forces received.

It must be made clear that the men in this survey are by no means representative of their age group in the population as a whole, because the proportions of each year of age in the total intake vary very widely, and the men who reached the intake centre had already been passed as fit for service by the pre-service medical boards of the Ministry of Labour and National Service, within the preceding few months; also the intake to the Royal Air Force is selected to some degree on educational grounds, this being well illustrated by the fact that 27.34% of the intake were either full time students or school-leavers, at the time of their call up.

A control series was obtained by the method of statistical sample of the intake passing through the unit.

Enquiry was necessarily limited, as the unit dealt with large numbers of men, and the normal rate of working had to be maintained if a serious bottle-neck was not to develop in the induction procedure, The only three enquiries which could be made of the recruit were - age, occupation at the time of call up <u>or</u> occupation in which he had spent most/

/most time since leaving school, and the period of time spent in this occupation.

The control series, so derived, consisted of 8,558 men, who had spent an average of 3.14 years in their jobs prior to being called up, the students and school leavers being excluded from this figure.

The numbers and percentages in each year of age are:-

Age.	Number in control series.	Percentage.
17	44	0.51
18	4,981	58.20
19	965	11.27
20	520	6.07
21	1,388	16.22
22	434	5.07
23	194	2.28
24	28	0.33
25	3	0.04
26	1	0.01

As a general rule, the occupation as described by the recruit was accepted, unless it was very vague or it seemed highly improbable. In these cases, the man was contacted and adequate information obtained. On some occasions, when an extravagant claim was made, it was quite evident what the man's occupation really was, as when an eighteen year old laboratory assistant described himself as a "nuclear research physicist".

The/

The occupations of the men in the control series, and the number in each occupation, are:-

Actor	3
Asbestos worker	2
Baker	14
Ballet dancer	1
Bath attendant	1
Bookbinder	11
Boot repairer	8
Boxing	1
Note: The use of professional sport as an occupation was only accepted where the man had no other fixed occupation which he had held for at least six months.	
Bricklayer	38
Brickmaker	2
Bus conductor	2
Cabinet maker	13
Carpet layer	1
Caterer	9
Note: Includes snack bar assistant - sandwich cutter.	
Chef	12
Clerk	2,300
Note: Includes civil servants - inland revenue officer - local government officer - cashier - secretarial worker.	
Coachbuilder	17
Commercial artist	21
Note: Includes advertising artist.	
Commercial traveller	13
Concrete worker	1
Cricketer	3
Die sinker	2
Draughtsman	331
Driver	55
Note: Includes chauffeur.	
Electrician	285
Note: Includes electrical engineer.	
Engineer	240
Note: Includes Mechanical engineer - maintenance engineer - engineering apprentice.	
Engraver	8
Factory hand	125
Farming	169
Note: Includes ploughman - market gardener - shepherd.	

Fireman (Railway)	62
Fishing	5
Fitter and turner	220
Footballer	10
Forestry	9
French polisher	3
Glassmaker	11
Golfer	2
G.P.O. engineer	116
G.P.O. sorter	2
Hairdresser	4
Hotel worker	8
Note: Includes hotel porter - receptionist - bell boy - boots.	
Joiner and carpenter	97
Laboratory assistant	484
Note: Includes dental technician.	
Labourer	35
Laundry worker	1
Library assistant	12
Locomotive cleaner	12
Mechanic	109
Note: Includes only garage hands.	
Meteorology assistant	22
Metal worker	76
Note: Includes wire workers - steel workers - sheet metal workers - bodybuilders - blacksmith.	
Miner	2
Merchant Navy	15
Musician	3
Newspaper worker	33
Note: Includes copy boy - news reporter.	
Office worker	108
Note: Includes typist - office boy - comptometer operator.	
Packer	5
Painter	49
Paper maker	1
Pattern maker	17
Photographer	34
Physiotherapist	1
Plasterer	4
Plater	5
Plumber	48
Police cadet	38
Porter (B.R.)	7
Postman	46
Note: Includes telegraph boy.	

Pottery worker	3
Printer	123
Note: Includes type setter - compositor - letter press operator.	
Projectionist	9
Quarryman	3
Radiographer	1
Radio mechanic	46
Saw mill labourer	3
Scaffolder	2
Sculptor	2
Shop Assistant	306
Shunter	1
Signalman	7
Slater	4
Spinner	1
Student	2,340
Note: Includes school leavers and all forms of full time study at technical colleges, commercial colleges or universities.	
Surveyor	43
Tailor	2
Teacher	35
Tennis pro.	1
Toolmaker	51
Unemployed	19
Upholsterer	8
Waiter	7
Warehouseman	90
Note: Includes storekeeper - storeman.	
Watchmaker	3
Weaver	1
Welder	1
Window cleaner	2
Window dresser	6
Woodworker	27
Note: Includes sawyer.	
Wood yard worker	7

At the time this work was carried out, men were accepted for service only if they were fit to serve in any part of the world.

Men who had pulmonary tuberculous lesions of doubtful activity were rejected for service, unless a series of films, covering at least two years, and showing no change in the lesions in this time, could be produced. Under certain conditions, described in the next chapter, men might be rejected for service even if their lesions were demonstrated to be inactive in this manner.

The organisation and administration of the Royal Air Force mass X-ray units is developed from that described by Traill (67) and used by the original units.

No. 4 Chest Radiography Sub-section was equipped with two four valve machines. All the films were taken by a qualified radiographer, and the dark room work was carried out by trained photographers, so that a high standard was maintained both for full size and miniature film.

On the station where we were located was a small hospital, where tomography, sputum testing, blood counting or erythrocyte sedimentation rate examinations could be carried out. Despite these facilities, however, the assistance and advice of both service and civilian consultants and hospital facilities were occasionally called on before a final decision was made as to the acceptance or rejection of a particular man.

If a man were recalled for a large film and a definite lesion demonstrated, he could be investigated as an in-patient in the camp hospital/

/hospital, or as an out-patient, or merely be retained in a reserve flight while films taken previously were obtained for comparison with our films, or be rejected for service on the evidence of the single examination. Despite these facilities, a large proportion of the cases of pulmonary tuberculosis, who were rejected for service, were "presumed" to be either active or inactive, without being fully investigated to prove whether or not the lesion was in fact active or quiescent.

This is due to two factors. Firstly to a desire to get all cases of obviously active tuberculosis off the station in the shortest possible time, in order to minimize the risk of spread of infection. Secondly, as all the cases who were rejected were referred to their own doctor, in order that he might arrange the further care required by the patient, any investigation which we might have done would have been duplicated by the man's local chest clinic. For this reason, there was no point in retaining a man for investigation when his lesion was such that he would obviously be rejected for service, whether or not it was active.

The comparison of these figures derived from the records of No. 4 Chest Radiography Sub-section with those from any other source cannot be carried out without many reservations. The mass miniature units of the Ministry of Health have done, and recorded, a great deal of work, but their figures cannot be compared with those presented here with any degree of accuracy for the following reasons:-

(a)/

(a) The people X-rayed by the Ministry of Health units were all volunteers, whereas the men who were done by this unit were simply marched up and told that they were being X-rayed, unless they had any objection on grounds of conscience. Since the units of the Ministry of Health began working, there has been a great change in the approach of the general public to having their chests X-rayed. In recent years, the response to appeals and campaigns has been very great, as was demonstrated in the Glasgow Campaign of 1957, but this happy state of affairs was seldom, if ever, met in the early days of mass radiography. Stanford (62), writing of mass radiography in 1942, quotes the remark "If I've got T.B., I don't want to know it", which represents a frame of mind often encountered in the days when the average layman regarded tuberculosis as incurable. The same point was made a year earlier by Hall (33), instancing the unsatisfactory response to campaigns in individual factories. This wide difference in the response of the public over the years makes comparison of figures from these units with those from No. 4 Chest Radiography sub-section of very doubtful value.

(b) The age groups, as presented in the reports of the Ministry of Health, are different from the age group with which I am concerned here, and the occupational groups as published are not sub-divided into age groups at all, although they are broken down to some degree by the pathological conditions discovered.

(c)/

(c) Figures reported from other service sources by Brookes (9), Evans (23), and Traill (67) are based on surveys of men who have been in the forces for some time, and, therefore, are not comparable with conscripts in that serving personnel have been subject to regular medical examinations for some time before the occasion of their X-ray and also have been living under different conditions from men in their own homes. Clive (14) has published the only figures of intake X-rayed after passing a clinical examination, but they are of women entering the Women's Auxiliary Air Force, and so are not comparable, as there is the normal variation in incidence between the sexes at this age to be considered.

(d) The standard laid down by the Royal Air Force for the acceptance of any man with an apparently healed lesion in his lung, which could not be proved to be healed, is much more stringent than that used by many civilian chest clinics to indicate inactivity.

I have attempted to obtain a comparable series from the records of the Victoria Infirmary of Glasgow by selecting the case sheets of male patients in the relevant age group admitted in one calendar year, then discarding all cases, which, on the findings recorded, seemed unlikely to have been able to pass their pre-service medical examination, e.g. cases of diabetes, pulmonary tuberculosis (where this was known to be present before admission or was suspected on clinical grounds and not merely picked up by chance on X-ray), clinically obvious heart disease, etc. Thus I was left with a group who were comparable with the intake which/

/which was examined by No. 4 Chest Radiography Sub-section in that:-

(a) They were exactly the same age group.

(b) They had their chests X-rayed not by their own seeking, but because of some injury or coincidental illness, which had caused their admission to hospital.

(c) They were likely, on the findings recorded in their case sheets, to have been able to pass their pre-service medical examination.

When I examined the resultant group, it quickly became evident that even this method had not produced a group who were really comparable with the intake in this series, because the percentages in each individual year of age in the two groups are very different, being:-

Age.	17	18	19	20	21	22	23
Victoria Infirmary figures.	21.07	10.36	13.21	12.89	13.21	11.78	17.50
Air Force intake figures.	0.51	58.20	11.27	6.07	16.22	5.07	2.28

Also the proportions of the various occupations were very different in the two groups.

As the numbers, both among those rejected and among the intake sample in each individual occupation, are too small to be significant, I have grouped the occupations according to their working conditions under four headings, which are defined in Chapter III, and which are,

i) Students.

ii) Dust free workers.

iii) Dust exposed workers.

iv) Wood workers.

Comparison/

Comparison of the percentages of these four groups of occupations showed the following differences in the figures from the two sources:-

	Victoria Infirmary figures.	Air Force intake figures.
Students	9.74	27.34
Dust free workers	72.08	66.71
Dust exposed workers	9.74	3.83
Wood workers	8.44	2.12

The increased percentage of the "Dust exposed workers" and "Woodworkers" in the hospital series is due in part to the much smaller percentage of students in the hospital figures raising the value of the other three groups, and partly to the number of admissions to the orthopaedic department as a result of accidents from these two groups.

For all these reasons, any close comparison between the figures derived from the intake of National Servicemen to the Royal Air Force and any other source would be of very dubious validity, and has not been attempted in this work.

The method I have used in this investigation is to list - in Chapter II - the details of the 900 men rejected for service.

In Chapter III, each of the occupational groups is examined in detail, both as to their composition and as concerns the percentage of the group to be rejected for service.

In/

In Chapter IV, I have examined the social background of the four groups, as obviously it must be shown that there is no significant difference in this respect before their occupations may be blamed for the discrepancy between them. I have also examined in this chapter the circumstances of their work, excluding only the materials with which they work.

I have searched the medical literature and also that of the wood-working trades for information about the nature of the dust produced by processing wood, but without finding any adequate information. For this reason, Chapter V is concerned with the physical nature and the chemistry of wood dust in so far as it concerns this thesis.

In Chapter VI, the findings tabulated in the earlier chapters are examined, and my explanation for the increase in the percentage of woodworkers to be rejected for service is advanced.

Chapter II.

Details of men rejected.

The 900 men rejected for service have been grouped into twenty four classifications, as under, by the pathological conditions which caused their rejection. The classification used here is based on, but is not identical to, that used by the Chest Radiography Section.

Classification.	Diagnosis.	Number of men.
1	Active pulmonary tuberculosis - sputum positive.	42
2	Active pulmonary tuberculosis - sputum negative.	24
3	Presumed active pulmonary tuberculosis.	187
4	Primary adolescent pulmonary tuberculosis.	6
5	Pleural effusions.	17
6	Pulmonary tuberculosis proved inactive.	50
7	Pulmonary tuberculosis presumed inactive.	363
8	Calcified nodules and glands of tuberculous aetiology.	1
9	Pleural thickening.	25
10	Enlarged hilar glands.	11

Classification.	Diagnosis.	Number of men.
11	Recurring spontaneous pneumothorax.	3
12	Post-pneumonic fibrosis of lung.	64
13	Bronchiectasis.	62
14	Chronic bronchitis.	6
15	Collapse of lung (Partial).	4
16	Undiagnosed pulmonary lesion.	1
17	Congenital pulmonary lesions.	4
18	Cardiovascular lesions.	11
19	Diaphragmatic lesions.	3
20	Skeletal lesions.	8
21	Mediastinal lesions.	5
22	Sarcoidosis.	1
23	Hodgkin's disease.	1
24	Malignant neoplasia.	1

It/

It is evident that the men in classifications number 17 - 24 inclusive have been rejected, due to conditions which, with the exception of the four men with congenital conditions, in classification 17, do not arise in the lung, although they may in some cases have arrived at a stage where the disease manifests itself in the lung.

CLASSIFICATION I.

Active pulmonary tuberculosis - sputum positive.

Number of cases: 42.

Occupations of rejected cases:

Clerk	5
Electrician	4
Factory worker	2
G.P.O. engineer	1
Hotel worker	1
Joiner and carpenter	1
Laboratory assistant	2
Labourer	2
Mechanic	3
Metal worker	3
Office worker	2
Painter	3
Photographer	1
Plumber	1
Radio mechanic	1
Shop Assistant	3
Student	2
Unknown	5

CLASSIFICATION 2.

Active pulmonary tuberculosis - sputum negative.

Number of cases: 24.

Occupations of rejected cases:

Cabinet maker	1
Clerk	6
Coach builder	1
Factory worker	2
Hotel worker	1
Joiner and carpenter	1
Labourer	1
Laundry worker	1
Metal worker	3
Office worker	1
Pattern maker	2
Shop assistant	2
Student	1
Toolmaker	1

Note: Proof of activity in these cases consisted of either change in the lesion, as shown by comparison with a recent film taken by a non-service unit, or in an elevated erythrocyte sedimentation rate, for which no other reason could be found when the activity of the chest lesion was already suspect.

CLASSIFICATION 3.

Presumed active pulmonary tuberculosis.

Number of cases: 187.

Occupations of rejected cases:

Bricklayer	2
Cabinet maker	2
Clerk	51
Coach builder	2
Cotton carder	1
Draughtsman	9
Driver	2
Electrician	12
Engineer	3
Engraver	1
Factory worker	3
Farmer	3
Fireman (Railway)	1
Fishing rod maker	1
Fitter and turner	9
Glassmaker	1
Golf professional	1
G.P.O. engineer	5
G.P.O. sorter	1
Hairdresser	1
Joiner and carpenter	12

CLASSIFICATION 3.
(Continued).

Labourer	3
Laboratory assistant	5
Laundry worker	1
Library assistant	1
Mechanic	4
Metal worker	1
Meteorology assistant	1
Miner	1
Office worker	5
Painter	4
Pattern maker	2
Physiotherapist	1
Porter	1
Postman	1
Projectionist	1
Shop assistant	6
Slater	1
Student	11
Toolmaker	2
Unknown	5
Warehouseman	2
Watch maker	1
Window cleaner	1
Window dresser	1
Wood machinist	1
Wood worker	1

CLASSIFICATION 4.

Primary adolescent pulmonary tuberculosis.

Number of cases: 6.

Occupations of rejected cases:

Printer	1
Projectionist	1
Student	1
Surveyor	1
Warehouseman	1
Window dresser	1

CLASSIFICATION 5.

Pleural effusions.

Number of cases: 17.

Occupations of rejected cases:

Asbestos worker	1
Clerk	4
Draughtsman	2
Driver	1
Engineer	1
Laboratory assistant	3
Merchant Navy	1
Plumber	1
Projectionist	1
Shop assistant	1
Watch maker	1

Note: All effusions, unless overlying a pneumonic process, were assumed to be tuberculous.

CLASSIFICATION 6.

Pulmonary tuberculosis, proved inactive.

Number of cases: 50.

Occupations of rejected cases:

Bricklayer	1
Clerk	4
Commercial artist	1
Draughtsman	2
Driver	2
Electrician	3
Factory worker	2
Fireman (Railway)	1
Fitter	2
Joiner and Carpenter	4
Labourer	1
Metal worker	2
Mechanic	2
Painter	1
Plumber	1
Postman	2
Printer	1
Radio mechanic	1
Sculptor	1
Shop assistant	5
Student	3

CLASSIFICATION 6.
(Contd.)

Tailor	2
Toolmaker	1
Unknown	2
Upholsterer	1
Warehouseman	1
Window dresser	1

Note: The cases in this classification showed no change in their lesions when previous films were compared with those which we had obtained of the recruit. Their clinical examinations were within normal limits, but they were rejected for service as it was felt that there was a substantial risk of the condition breaking down, due to the size and nature of the lesion.

CLASSIFICATION 7.

Pulmonary tuberculosis, presumed inactive.

Total cases: 363.

Occupations of rejected cases:

Baker	3
Bookbinder	1
Bricklayer	5
Cabinet maker	1
Caterer	1
Chef	1
Clerk	85
Coach builder	2
Commercial artist	1
Die sinker	1
Draughtsman	10
Driver	11
Electrician	21
Engineer	7
Engraver	2
Factory worker	8
Farming	4
Fireman (Railway)	3
Fitter and turner	23
Furniture remover	1

CLASSIFICATION 7.
(Continued).

G.P.O. engineer	1
G.P.O. sorter	2
Hairdresser	1
Joiner and carpenter	19
Laboratory assistant	11
Labourer	2
Laundry worker	1
Locomotive cleaner	1
Mechanic	9
Metal worker	7
Meteorology assistant	1
Merchant Navy	2
Miner	1
Newspaper worker	2
Office worker	5
Painter	11
Pattern maker	5
Photographer	2
Plumber	4
Postman	7
Printer	3
Projectionist	1
Saw mill labourer	1
Shop assistant	24
Spinner	1

CLASSIFICATION 7.
(continued).

Student	22
Tailor	1
Toolmaker	2
Unemployed	1
Unknown	9
Upholsterer	1
Waiter	1
Ward Porter	1
Warehouseman	3
Welder	2
Window cleaner	1
Window dresser	1
Woodworker	1
Wood machinist	2

Note: The reason for the rejection of the cases in this classification is that no films proving that the lesion had not altered in the preceding two years could be produced, and hence these men were not acceptable for service under the regulations then in force. In some cases, where the lesion was large and it was felt that there was a substantial risk of reactivation, the man was rejected for service without any attempt being made to obtain previous films.

CLASSIFICATION 8.

Calcified nodules and glands of tuberculous aetiology.

One case only. Occupation - Clerk.

Note: Rejection due to recurring pneumothoraces.

CLASSIFICATION 9.

Pleural thickening.

Number of cases: 25.

Occupations of rejected cases:

Caterer	1
Clerk	3
Draughtsman	1
Driver	2
Electrician	1
Fireman (Railway)	1
Fitter and turner	1
G.P.O. engineer	1
Joiner and carpenter	1
Painter	1
Pattern maker	1
Plumber	1
Postman	2
Printer	2
Student	2
Upholsterer	1
Warehouseman	2
Weaver	1

CLASSIFICATION 10.

Enlarged hilar glands.

Number of cases: 11.

Occupations of rejected cases:

Bricklayer	2
Clerk	3
Driver	1
Fireman (Railway)	1
G.P.O. engineer	1
Mechanic	1
Painter	1
Printer	1

Note: These cases had no clinically demonstrable lymphadenopathy in any other part of the body, and had normal blood pictures. They were assumed to be of tuberculous aetiology.

CLASSIFICATION 11.

Spontaneous pneumothorax (Recurring).

Number of cases: 3.

Occupations of rejected cases:

Clerk	1
Electrician	1
Shop assistant	1

Note: These cases comply with Kjaergaard's (47) criteria for "Spontaneous pneumothorax in the apparently healthy". None was rejected for what appeared to be the first pneumothorax.

CLASSIFICATION 12.

Post-pneumonic fibrosis of lung.

Number of cases: 64.

Occupations of rejected cases:

Box maker	1
Clerk	17
Coach builder	2
Cotton carder	1
Driver	1
Electrician	1
Factory hand	2
Fireman (Railway)	1
Fitter and turner	3
French polisher	1
G.P.O. engineer	2
Hairdresser	1
Kennel man	1
Laboratory assistant	2
Merchant Navy	1
Metal worker	2
Mechanic	2
Photographer	1
Plumber	1
Postman	2
Shop Assistant	9

CLASSIFICATION 12.
(Continued).

Student	4
Tailor	1
Unknown	1
Weaver	1
Welder	2
Woodyard worker	1

CLASSIFICATION 13.

Bronchiectasis.

Number of cases: 62.

Occupations of rejected cases:

Clerk	20
Draughtsman	3
Driver	3
Electrician	1
Electroplater	1
Engineer	1
Factory hand	4
Farming	2
Fireman (Railway)	3
Fitter and turner	2
G.P.O. engineer	1
Joiner and carpenter	4
Labourer	1
Mechanic	2
Newspaper worker	1
Painter	1
Postman	2
Shop assistant	3
Student	3

CLASSIFICATION 13.
(Continued).

Toolmaker	1
Unknown	1
Welder	1
Window dresser	1

Note: The cases in this group were confirmed by bronchogram, unless the history plus the clinical and X-ray findings placed the diagnosis beyond doubt. If bronchiectasis was suspected but not confirmed, the case was placed in either classification 12 or 14, depending on the history and the clinical findings.

CLASSIFICATION 14.

Chronic bronchitis.

Number of cases: 6.

Occupations of rejected cases:

Bricklayer	1
Clerk	1
Shop assistant	2
Student	1
Warehouseman	1

CLASSIFICATION 15.

Collapse of lung (partial).

Number of cases: 4.

Occupations of rejected cases:

Fitter	1
Postman	2
Unknown	1

CLASSIFICATION 16.

Undiagnosed pulmonary lesion.

There was only one man in this group, a clerk of eighteen, who had his left lower lobe consolidated. Bronchogram and bronchoscopy both failed to reveal the aetiology of the condition, and he was discharged from hospital at this stage, as he was obviously unacceptable for service.

CLASSIFICATION 17.

Congenital pulmonary lesions.

Number of cases: 4.

Type of lesion and occupation:

Pleural cyst - one case- Joiner.

Cystic disease of the lung - three cases.

Clerk	1
Projectionist	1
Shop assistant	1

CLASSIFICATION 18.

Cardiovascular lesions.

Number of cases: 11.

Congenital lesions: 7.

Type of lesion:

Coarctation of aorta	3
Patent ductus	2
Septal defect	2

Occupations of rejected cases:

Bricklayer	1	Shop assistant	1
Labourer	1	Student	1
Pattern maker	1	Tailor	1
Window cleaner	1		

Acquired lesions: 4.

Type of lesion:

Mitral stenosis	2
Mitral and aortic incompetence	1
Auricular flutter plus gross cardiac enlargement	1

Occupations of rejected cases:

Farming	1
Shop assistant	1
Unknown	2

CLASSIFICATION 19.

Diaphragmatic lesions.

Number of cases: 3.

Type of lesion:	Diaphragmatic hernia	2.
	Eventration of left hemi-diaphragm	1.

Occupations of rejected cases:

Clerk	1.	Unknown	1.	Welder	1.

CLASSIFICATION 20.

Skeletal lesions.

Number of cases: 8.

Type of lesion:	Chondroma of scapula	1
	Simple spina bifida	2
	Spina bifida with fusion of vertebrae	1
	Scoliosis of thoracic spine	3
	Scoliosis of thoracic spine, plus wedging of T.9	1

Occupations of rejected cases:

Clerk	1	Journalist	1
Electrician	1	Student	1
Fitter and turner	1	Unknown	3

Note: The men in this group were seen by an orthopaedic specialist, who recommended their rejection for service.

CLASSIFICATION 21.

Mediastinal lesions.

Number of cases: 5.

Type of lesions: Retro-sternal thyroid 2.

Undiagnosed mass 3.

Occupations of rejected cases:

Artist	1
Clerk	1
Engineer	1
Student	1
Welder	1

CLASSIFICATION 22.

Sarcoidosis.

One proved case in a clerk of 18.

CLASSIFICATION 23.

Hodgkin's disease.

One proved case in a toolmaker, aged 18.

CLASSIFICATION 24.

Malignant neoplasia.

One proved case of secondary seminoma in a clerk, aged 18.

CHAPTER III.

Analysis of the numbers rejected.

Out of a total of 900 men rejected for service in the period of this survey, 726 were rejected for pulmonary tuberculous infection, either active or inactive; 140 due to non-tuberculous pulmonary infection, and the remaining 34 due either to congenital lesions or disease having its origin in other than the respiratory tract. This last group are not considered beyond this point, as obviously their occupation can have played no part in the aetiology of the condition which caused their rejection for service.

The composition of the occupational groups, together with the numbers in each group to be rejected, is listed below.

STUDENTS:

This group consists of all school leavers and all those who, at the time of their call-up, were engaged in full time courses of study at technical or commercial colleges or universities.

The numbers in this group both among those in the intake sample and those rejected are:-

	Number in group.
Intake sample	2,340
Tuberculous pulmonary infection rejects	42
Non-tuberculous pulmonary infection rejects	8

My/

My reasons for treating the students as a separate group are that, due to the limited nature of the enquiries made of the intake sample, no knowledge is available concerning the home background of any of the students. I believe that, as a group, they have a very different type of background to the other men in the survey for the following reasons:-

(1) They have, in the majority of cases, been protected from economic stress, in that their families have been able to support them, either unaided or with the help of bursaries or scholarships.

(2) Those parents who accept the burden of maintaining their children in a course of full-time education, beyond the permissible school leaving age, are likely to attend adequately to the minor illnesses, from which so many chest conditions can develop. It is not only parents whose children have higher education who take care of their children's health, but those who are able, and much more important, have the desire to ensure that their children are given a good educational start in life, will be relatively more painstaking in safeguarding the health of their children than those who, not for reasons of economy but merely from lack of interest or forethought, allow their families to drift into whatever occupation may first present itself, whether there be any future to the job or not.

(3) There is little opportunity for students to develop pulmonary infections in the short time between their pre-service medical examination and the time when they report for service, as their medical examinations are usually delayed until they have completed their/

/their courses and are available for call-up. Men who are deferred for other reasons, as apprentices or on compassionate grounds, are usually granted their deferment of call-up on application made at the time of their medical examination, and so have a longer period in which they can acquire infections before they report for service.

(4) Those who come straight from school have had the advantage of the regular physical training and gymnastic periods of a school curriculum, and in many cases of participation in organised school sports, to maintain them in fairly good physical condition. The full time students, while not having in all instances the regular periods of physical training and gymnastic work which they had at school, do as a rule have easy access to gymnasium facilities, and also have the stimulus of college or university teams and colours to strive for. Both these groups are, therefore, in a much better position to maintain their physical fitness than lads who leave school at 15, and go into shops, offices or factories, and who have no opportunities for recreation, unless they join a youth club, or are fortunate enough to be employed by a firm which provides sports facilities for its employees.

(5) There is also the question of the differences in temperament to be considered, as very few lads will continue in full time study - particularly beyond school standard - unless they wish to do so and are not merely being urged to do so by their parents.

(6) The fact that medical students have been shown to acquire a significant amount of tuberculous infection during their training (53) is of no significance in this series, as all doctors entering the

service/

/service, after qualifying, passed through a different centre from the one with which I am dealing. Any medical students who might be called-up before completing their course and so pass through No. 4 Chest Radiography Sub-section could only constitute a very small fragment of the student group.

By separating the students from those employed in some wage earning capacity at the time they were called up, comparison can be made among the groups of occupations without the risk of any distortion being produced by the different background of the "Student" group.

DUST EXPOSED WORKERS.

This group consists not only of the occupations which are accepted as causing the various recognised occupational "dust diseases", but also several other occupations which involve exposure to a considerable concentration of dust in the atmosphere.

The numbers in the control sample and among those rejected for service in this occupational group are:-

	Intake sample.	Tuberculous infection.	Non-tuberculous infection.
Asbestos worker	2	1	0
Brickmaker	2	0	0
Concrete worker	1	0	0
Cotton carder	0	1	1
Die sinker	2	1	0
Engraver	8	3	0

Fireman (Railway) /

Fireman (Railway)	62	7	4
Fitter and turner	220	35	6
Locomotive cleaner	12	1	0
Miner	2	2	0
Plasterer	4	0	0
Quarryman	3	0	0
Sculptor	2	1	0
Upholsterer	8	3	0
Welder	1	2	3
	329	57	14

I have taken the step of introducing these other occupations into this group for the following reasons:-

(a) The numbers in the occupations recognised as causing pensionable "dust diseases" are far too small to be significant.

(b) The occupations in this group, as it is constituted, are all such as to involve exposure to a fair concentration of dust, and, with the exception of railway firemen and quarrymen, are indoor occupations. That quarrying may be hazardous, depending on the type of stone involved, is recognised. In sandstone workers, for instance, it has been shown that as high a proportion as 25% may have silicosis (64). Sandstone itself contains from 75% to 95% of free silica, and granite also is hazardous, containing 65% to 75% of silica (40), while limestone is harmless (37). In the/

/the case of the firemen, on considering the degree of protection provided by the footplates of modern locomotives, and particularly tank locomotives, I believe that the atmosphere in which these men are working is not very different from that of many dusty indoor occupations, in so far as particulate matter in the respired air is concerned. The occupation of railway fireman does not convey any deferment of call-up, so that the men in this occupation are called up at eighteen years of age, when they are still comparatively junior. This is important, as junior members of footplate crews are mainly employed in shunting and local train working, where tank engines, with their high degree of footplate protection, are mostly to be found. A further justification of their inclusion in this group is that they begin their careers as locomotive cleaners, in which capacity they encounter very dirty and dusty conditions, especially in cleaning the smoke boxes of steam locomotives.

(c) By producing this group, I have been able to obtain, albeit rather artificially, a group who differ from the intake as a whole in that they have been exposed to dusty atmospheric conditions at work. According to Perry (56), they are, for this reason, to be regarded as being exposed to a potential lung irritant, and the fact that they figure more largely among those who have been rejected for service than do those in dust free occupations, supports this opinion.

(d) The biggest single occupation in this group is that of fitter and turner, and Hueper (36) has stated that there is evidence that/

/that the petroleum mist, which is produced in lathe turning, is carcinogenic, while Breslow (7) in over 400 serial examinations of patients with lung carcinoma found that the disease appeared with increased frequency in turners, welders, cranemen and fire service workers. The men employed as die sinkers and engravers will also be exposed to this type of mist. While the only known case of malignancy in the series was a seminoma, and no primary lung neoplasm was discovered, this does not mean that a potentially irritating effect of the petroleum mist may not have played some part in the development of the pulmonary lesions for which some of these men have been rejected.

WOODWORKERS.

This group consists of all the men in the series who were employed in the processing or handling of wood in either a skilled or unskilled capacity. Their numbers are:-

	Intake Sample.	Tuberculous infection.	Non-tuberculous infection.
Box maker	0	0	1
Cabinet maker	13	4	0
Coach builder	17	5	2
Fishing rod maker	0	1	0
Joiner and carpenter	97	38	4
Pattern maker	17	10	0
Saw mill labourer	3	1	0
Woodworker	27	4	0
Wood yard worker	7	1	1
	181	64	8

DUST FREE WORKERS.

This group consists of all men in the survey who have not been included in the three groups above. Their numbers are:-

	Number.
Intake sample	5,709
Tuberculous pulmonary infection	563
Non-tuberculous pulmonary infection	110

As stated earlier, the total intake of national servicemen included in this survey is 166,000. The statistical sample forming the control numbers 8,558 men. The numbers and percentages of each occupational group in the control series are:-

	Number in intake sample.	Percentage of intake sample.
Students	2,340	27.34
Dust free workers	5,709	66.71
Dust exposed workers	328	3.84
Woodworkers	181	2.11

The actual number of men rejected for chest infections in each of the four groups are:-

	Tuberculous.	Non-tuberculous.
Students	42	8
Dust free workers	563	110
Dust exposed workers	57	14
Woodworkers	64	8

By/

By calculation from the percentages of each of the four groups in the control series and the total number of men to pass through the unit during the survey (166,000), the number in each of these groups in the total intake can be calculated. Using this figure for each separate group plus the figures belonging to the group in the above table, the actual percentage of the intake of each occupational group to be rejected, due to the two types of infection, can be calculated, and these results are set out below.

	Intake.	Tuberculous rejects.	Non-tuberculous rejects.
Students	45,386	0.09%	0.02%
Dust free workers	110,738	0.51%	0.10%
Dust exposed workers	6,374	0.89%	0.22%
Woodworkers	3,502	1.83%	0.23%

The group - "Dust free workers" - is engaged in occupations which do not involve any inhalational hazard to health. It is, therefore, a good standard with which to compare the other employed groups. If the percentage of this group who have been rejected due to each type of infection is increased to unity and the percentages of the other groups are increased in proportion, the resulting figures, in the table below, show the ratio in which these other groups have been rejected compared with the "Dust free worker" group.

Students/

	Tuberculous rejects.	Non-tuberculous rejects.
Students	0.18	0.18
Dust free workers	1.00	1.00
Dust exposed workers	1.76	2.22
Woodworkers	3.58	2.58

It is evident that the percentage to be rejected in the "Woodworker" group, due to tuberculous infection, is substantially larger than in the "Dust exposed worker" group, although the difference between the percentage rejected in the two groups, due to non-tuberculous pulmonary infection, is too small to be of significance.

Before it is possible to attribute this increased incidence of tuberculous chest infection to the man's occupation, it must be shown that his social background - in its widest possible sense - does not differ significantly from that of the other employed groups. This question is examined in the next chapter.

CHAPTER IV.

Comparison of Social Backgrounds and Working Conditions.

In any survey of this type, the fact that one occupational group is found to be rejected in a markedly higher percentage than the other employed groups may have its origin in any of four sources:

(1) From coincidence, where conclusions are drawn from inadequate numbers.

(2) From the social background, in the widest possible sense, of the men in the group with the increased reject percentage.

(3) From the working conditions of the group.

(4) From the materials which are handled by the group in their work.

The first of these hypotheses is not tenable in this instance, as there is little opportunity for coincidence to distort the results derived from a series of 166,000 men.

The second and third hypotheses will be considered, in detail, in this chapter, as they apply to this series, and the materials handled by the woodworker group in the next chapter.

SOCIAL BACKGROUND.

As state earlier (p.3), all that could be found out about the background of the men in this series was their occupation at the time of call-up. The assessment of a group of people from a socio-economic standpoint, working only from their occupations, has been investigated by workers from the University of Columbia. It has been shown by Gillen (27) that this is a practical method of comparison between cities which are widely different, both in size and character, as well as between those which closely approximate in both these respects. Gillen bases his assessment of a city, not on the nature of that city's industries, but on the proportion of various categories of occupations, ranging from the professions to unskilled workers, found among the workers living in that city. Such a method of comparison means that cities with industries whose raw materials and end-products are very different may have a similar distribution of the various occupational categories. It also follows from this method of assessment that, as the various grades of workers are found in all types of industry, a comparison of the background of various industrial groups may be made by this method. I believe that it will give a satisfactory basis for the comparison of the three employed occupational groups, as defined for the purposes of this thesis.

The objections which may be raised to the use of this method in this particular instance are :

(1) The important occupation in determining the background of a man of 18 to 24 years of age is his father's and not his own.

(2) The method takes no account of factors outwith the family's control but affecting their children, such as school conditions, efficiency of school medical services or availability of satisfactory housing in the area where the family lived, when it is applied to an occupational group who are dispersed throughout the country.

(3) As most of the men in this survey were born between 1930 and 1935, their childhood was affected by the war.

I do not believe that these objections are valid in the case of this survey for the following reasons.

It is the natural desire of most parents to place their children in as advantageous a position in life as they can manage. For this reason, in all the occupational groups, there will be a proportion of men whose occupation will be superior to their father's from the viewpoint of earning power and social classification. The desire for betterment is not limited to one group of occupations or to any one social or economic level, and so a raising of the standard of a proportion of the men will occur in all the occupational groups, and because of the common distribution of this factor, is likely to be equal in all the groups. Gillen's work has shown that mobility of workers at one level or between different levels is not unique to any one type of city (28), and hence there is no reason to suppose that it will be unique to any one occupational level.

The standard used in this work to compare the occupational groups

is/

is the social classification to which the men comprising the group are allocated, by reason of their occupation, by the Registrar-General's co-relation of occupations with social classifications (32). He describes five classifications, viz:

Classification.	Types of occupation included.
1	Professional, etc. occupations.
2	Intermediate occupations.
3	Skilled occupations.
4	Partly skilled occupations.
5	Unskilled occupations.

and allocates all occupations to one or other of these.

As these classifications are of necessity wide, the difference between the occupations of the men in this series and their fathers will not be great enough, in the majority of cases, to produce any difference in the classification to which the two men would be allocated. Even this small potential error is likely to cancel out when the occupational groups are compared, in view of the large numbers involved. For these reasons, in comparing the occupational groups, the standard of the man's occupation prior to call-up will reflect the background of the group as a whole.

The school conditions which any man may have encountered and the efficiency of the school medical services in his area, are factors which would require to be assessed on a geographic basis, and in a country which/

/which has its industries as dispersed as Great Britain, these factors cannot affect any one occupational group, drawn from all parts of the country.

Using a standard of one-and-a-half persons per room, in any given house, Gillen has shown that the standard of occupation is directly related to the proportion in satisfactory living conditions, in that occupation (29). The average standard of housing available at any given economic level in any particular area, will depend on the amount of modern building which has taken place in that area. Therefore, any variations in the quality of housing available at any given economic level will operate on a geographic basis, and so distortion between the occupational groups due to the availability, or lack, of satisfactory housing in the district in which any single family lived, need not be feared, as on a nation-wide level the standard of housing in each occupational group will average out the local discrepancies, and hence the standard may be assessed from the occupation.

The effects of war-time conditions on the men in this series may result from the call-up which would affect their fathers, and so, either temporarily, or permanently, alter their family circumstances. Here again is a factor which will apply equally to all the occupational groups in this series. The war-time call-up affected the less skilled men far more than the craftsmen, and, as shown below (p.61), the occupational groups have a very similar proportion of skilled and unskilled men, so this/

this factor would affect each group to a similar degree. The war-time measure of rationing imposed a very uniform diet on all in the country, as far as the essentials were concerned, regardless of economic position. While the more well-to-do could obtain more expensive extras in the way of unrationed foods or "black market" supplies, this is not likely to have raised the standard of the diet of any complete group to a level significantly better than the others. The full employment of the war years, plus the well balanced basic diet, ensured that no group would be at a disadvantage in relation to the others in this respect.

The other variable factor which cannot be assessed on an occupational basis is the size of the family in relation to its income. In the figures published in the Report on the Census of 1951 ((31), concerning a representative sample of households of the various social classifications, the percentage of each size of household within each social classification is listed. They are :

Classification.	Total number of households.	Persons in household.	Percentage of total households.
I	411.4 *	1	4.4
		2	30.2
		3	27.6
		4	22.3
		5	9.3
		6+	6.2
II	2263.1	1	8.3
		2	29.9
		3	26.8
		4	19.7
		5	9.1
		6+	6.2
III	6111.0	1	6.1
		2	26.8
		3	27.2
		4	21.5
		5	10.4
		6+	8.0
IV	2028.3	1	8.2
		2	25.1
		3	24.3
		4	20.0
		5	11.3
		6+	11.1
V	1523.4	1	10.1
		2	26.5
		3	22.7
		4	16.5
		5	11.2
		6+	13.0

<u>NOTE</u>: All figures in this column require to be multiplied by a factor of 1,000.

There is a division evident in the pattern which the percentages

assume/

/assume between groups I, II, III and groups IV and V, with a definite increase in the larger households in the latter groups. It is also shown in the Census of 1951, Housing Report (30) that, as the size of a household rises, the ratio of earners to persons for that household decreases. An abstract of the figures given is quoted below:-

Persons in household.	Ratio of Earners : Persons.
All sizes	0.45
1	0.41
2	0.52
3	0.49
4	0.43
5	0.40
6+	0.39

When these two tables are taken in conjunction, it is evident that not only are the families of men in classifications IV and V larger than the other classifications, but that they are less well provided for, both because one wage earner has to support more people than in the other classifications, and because, being less skilled, he will be paid a lower wage. In the case of this survey, this effect is offset to some degree by the make-up of the employed occupational groups. Of the "Dust free workers", 6.8% fall into classifications IV and V, while the corresponding figures for the "Dust exposed workers" and the "Woodworkers" are 25% and 5.5% respectively. (See table on p. 59). The difference between the "Dust free workers" and the "Woodworkers" is not of significance in this respect, and the "Dust exposed workers", who are at a severe disadvantage from this source in comparison to the "Woodworkers", have/

/have a reject percentage, due to tuberculosis, which is less than half that of the "Woodworkers". For this reason, I cannot believe that the size of the family is, per se, an important factor influencing the percentage to be rejected, due to tuberculous pulmonary infection, as far as this series is concerned.

The question of how boarding school life might affect the health of those whom it involved is not relevant in this series, as the relatively small number of men educated in this manner are most unlikely to appear in any of the employed groups, and could only form a most insignificant proportion of any such group. They will be, almost without exception, in the "Student" group, as they would not leave school until an age when they would be liable for call-up, unless they were accepted by a college or university.

The fact that some of the men had their chests X-rayed as part of their pre-service medical examination, while others did not, cannot affect any one occupational group, as this factor must operate solely on a geographic basis, depending only on the centre which the man attended for examination.

Exposure to infection from cases of active tuberculosis is common to all occupational groups, although the severity of the risk is connected to the standard of housing, and is much more severe where overcrowding exists. As stated above, the standards of housing present in each occupational group are likely to be related to occupation. When the groups are considered on a national level, the fact/

/fact that the woodworkers are not at any marked disadvantage when the occupational groups are compared by the Registrar-General's social classification (p. 59), means that they will not be living in less satisfactory housing conditions than the other employed groups, and so there is no reason to assume that they are exposed to a greater risk of infection in their homes, than the other employed occupational groups.

It has long been known that there is a lower incidence of pulmonary tuberculosis in rural than urban areas. This fact does not affect the validity of any of the conclusions drawn in this thesis, as no one occupational group is entirely rural or urban in its constituent occupations. The group with the largest proportion of men likely to be employed in rural surroundings are the "Woodworkers", which has the highest incidence of tuberculosis of any group.

The belief that the race to which a man belongs is, per se, a factor in influencing the incidence and severity of pulmonary tuberculosis has been questioned by Myers (52). He has suggested that the conditions under which the more primitive races live are the responsible agents in increasing the morbidity produced by tuberculosis among them. He produces figures concerning the North American Indian in support of this view, and is supported in this by Bogen (5) with figures concerning negroes in Los Angeles. Robins (58) also supports this view with figures from the Harlem district/

/district of New York. The men in my survey were British by birth, although in a few cases they had been born abroad, due to their parents' occupations, so that any difference which may occur in racial resistance to tuberculosis cannot be important in this survey.

The comparison of the groups on an occupational basis involves the separation of each occupation in each group into its appropriate classification, as tabulated by the Registrar-General (32), and once this has been done, the comparison of the proportions of each classification to occur in each occupational group. This classification allows comparison of the groups mainly on the grounds of economic status, and while this is of undoubted importance, it does not give, by itself, a completely satisfactory index of the environment which has surrounded the man in his home. Whether or not a particular man has been determined enough to face a prolonged apprenticeship or training, and has been encouraged to do so by his parents, despite the financial burden incurred thereby, reveals those parents who are willing to accept privations and possibly hardship, to give their children a good start in life. I believe that families of this type will provide a more reliable and stable background during the formative years of their children's lives : that they will provide adequate care, food, clothing, housing and medical attention, when this is required, to the limits of their ability, and that in such an environment their children are not subjected to the mental and physical stresses produced by lack of parental interest and affection. It is, of course, not only in the families/

/families whose children train for the professions, as tradesmen, or as skilled workers, that these advantages are to be found. They are, however, less likely to be found among those who live only for the present, and who are not prepared to accept the temporary disadvantage of the years spent in an apprenticeship to reap the benefit of higher earning power and security in later life.

Comparison by Registrar-General's classification.

The percentages within each occupation group of each of the classifications are shown below:

Classification.	I	II	III	IV	V
Dust free workers	0.8	7.5	84.9	6.0	0.8
Dust exposed workers	-	-	75	24.1	0.9
Woodworkers	-	-	95.4	-	5.5

Of the five classifications, the occupations comprising numbers IV and V are not only the least skilled, but are also the group who are likely to be poorest paid and to have the least security in their jobs. Group III consists of people who have some skill, and have a reasonable degree of security, in that if one firm should require to pay off men in this type of occupation, they are likely to be able to obtain similar employment without very much difficulty and without any major loss of earnings. Classifications I and II comprise the better paid occupations, with a fair degree of security in the tenure of their jobs. For these reasons, comparison of/

/of the total percentage of classifications I, II and III in each occupational group seems to offer a fair comparison of the proportion of men in each group whose families had a secure and reasonably adequate income during the formative years of life of the men in this survey, i.e. during the war years, when skilled men were at a premium.

	Classifications I, II and III.
Dust free workers	93.2%
Dust exposed workers	75%
Woodworkers	94.5%

These figures demonstrate that the "woodworker" group is in a better social and economic position than the "Dust exposed worker" group, and, from the point of view of adequacy of income, is not at any marked disadvantage compared to the "Dust free worker" group, in so far as the essentials will be concerned, although this latter group does contain some occupations belonging to classifications I and II. The increased percentage of men in the "Woodworker" group to be rejected cannot, therefore, be attributed to their being on a lower economic level than the other two employed groups.

Comparison/

Comparison by apprenticeship or training.

The percentages within each employed occupational group who are in occupations calling for a period of training, either as a recognised apprenticeship, or in some other form, and which would be either poorly paid or unpaid, and those in jobs for which no such training is required are shown below:-

	Apprenticeship.	Unskilled.
Dust free workers	72.9	27.1
Dust exposed workers	74.3	25.7
Woodworkers	79.6	20.4

These figures demonstrate that the percentage of men to complete a training period in the "Woodworker" group is higher than in either of the other employed groups. For this reason, they are unlikely in the aggregate to have a poorer quality of family background than the other groups for the reasons advanced on p. 58, and in all probability are a little better off than the "Dust exposed workers" group in this respect.

As already stated, the intake to the Royal Air Force is to some degree selected on educational grounds, and this will result in the percentage of men who have a skilled trade or whose occupations belong to either classification I, II or III being rather higher than would/

/would be found in a true cross section of men in this age group.

The results of these methods of comparison between the employed occupational groups show that their home backgrounds are very similar. The differences which do occur cannot be responsible for such a substantial increase in the percentage to be rejected among the "Woodworker" group, as has been shown to occur. For this reason, I will now proceed to examine the conditions under which the various groups perform their work.

Working conditions.

The comparison of the working conditions of the three employed occupational groups will be carried out under three headings, these being:

(a) Hours of work.

(b) Conditions of work.

(c) Machinery used at work.

Hours of work.

As it was impossible to question each recruit about his working hours, there are only two ways in which comparison may usefully be made between the different groups. These are the proportions/

/proportions of the various groups which perform, firstly, shift working and, secondly, overtime working, as a normal routine occurrence.

Any group with a marked increase in the proportion of men either doing shift work or engaged in overtime working is likely to be at a disadvantage from a health point of view, compared with a group which does not normally work in this manner. Of the two factors, that of shift working is likely to impose the more severe strain on health, due to its irregularity of routine. Overtime working does at least have economic advantages to offset the physical strain involved - if the extra income earned in this manner is sensibly used. In the table below, only occupations which normally involve either shift or overtime working have been included in the percentages given; those occupations where it is only an occasional occurrence being excluded.

	Normal shift working.	Normal overtime working.
Dust free workers	2.3%	6.1%
Dust exposed workers	22.6%	19.5%
Woodworkers	9.4%	11.1%

In respect of both these factors arising from the hours of work, the "Woodworkers" are in a better position that the "Dust exposed workers", although the "Dust free workers" group are in a much superior position to either of the others.

It/

It is, therefore, not the working of long or erratic hours which has caused the increase in the percentage of the "Woodworkers" to be rejected. This is especially true, as the "Dust exposed workers" group have a much greater increase in these types of working, while their reject percentage, due to pulmonary tuberculosis, is less than half that of the "Woodworkers".

Conditions of work.

The assessment of the conditions under which the various groups work in a manner which will allow of comparison between them is a rather difficult problem. There are not only physical aspects to this comparison, such as ventilation, lighting, heating, protective measures, wide variations in temperature, and the like, but also less easily measured factors, such as working to the speed of a conveyor belt, working to very fine limits of accuracy, the incidence of nervous strain, due to responsibility or intricate processes.

The yardsticks which I have chosen to employ as being those lending themselves most satisfactorily to accurate assessment by occupation alone, are by comparing the percentage of men in each occupation group who have jobs which:-

(a) Are normally performed indoors in well heated and well lit conditions.

(b)/

(b) Are normally carried on out of doors as well as indoors and which are not "fair weather only" in so far as the outside working is concerned.

(c) Normally involve a man in working to a high degree of accuracy.

It is a fundamental assumption in this comparison, and one which I believe to be justified, that the provisions of the various Factories Acts will eliminate unnecessary or avoidable hazards to health, in so far as this is possible without interfering with the performance of the man's job, and will impose conditions of work which will be very uniform for all men doing the same job in different factories.

The results of this comparison are set out below:-

	Percentage of men whose jobs involve:		
	Satisfactory heating and lighting.	Outside in all weathers.	High degree of accuracy.
Dust free workers	86.7%	7.4%	6.7%
Dust exposed workers	73.1%	21.9%	67.6%
Woodworkers	40.9%	3.9%	7.2%

From these figures, it seems that the "Woodworkers" are at a definite disadvantage as regards the percentage working in well heated and lit conditions. There is, however, unlikely to be as big/

/big a difference between them and the other employed groups as the figures would at first sight imply. The "Joiners and carpenters", which single occupation comprises 53.5% of the "Woodworker" group, have been included in the group not having adequate heating and lighting. While those employed on building sites certainly have no heating and no lighting, other than daylight, until a late stage in the construction of a building, many joiners work indoors either in workshops, where the standards of heating and lighting are governed by the Factories Acts, or in repairing or altering completed and inhabited property, where the conditions of heating and lighting will be quite satisfactory.

Variations, such as this, in working conditions within any one occupation, must either be ignored in calculating the percentages in the tables above, or the number in the occupation divided to try to reach an assessment of the numbers in favourable and unfavourable working conditions. I have not felt justified in taking this latter course, as it would be pure guess work as to how many men within any single occupation should be put into each group, and the possibility of error would be very large indeed. Where I have been in doubt because of this type of variation, I have counted the occupation into the group at a disadvantage in the factor under consideration, and so, by painting a uniformly blacker picture than may be the true one, I hope to avoid influencing any single occupational group in a manner which/

/which would interfere with its comparison with the other groups.

The proportion of "Woodworkers" who are outside in all weathers is smaller than that of either of the other occupational groups, therefore the question of repeated exposure to inclement weather cannot adversely affect this group.

The question of nervous tension produced by working to very high degrees of accuracy does not affect the "Woodworker" group adversely, as very few of its members have to work to fine limits, and even those few have very wide limits of tolerance compared, for example, with lathe turners, die sinkers or draughtsmen.

It was found in Northampton (63) that no co-relation could be shown between the hygienic standards of various factories and the incidence of pulmonary tuberculosis among their employees, but that there was a clear association between the number employed in a factory and the incidence of tuberculosis, the disease being found much more frequently in large factories. This factor is not likely to apply to woodworkers, as labour forces in this type of occupation are relatively small.

<u>Machinery used at work.</u>

Except in very small workshops, it is now rare for men to encounter the inhalational irritant of the fumes from one of the old type of oil engines/

/engines used to drive machinery, power being now almost always derived from electric motors. In all the workshops visited in the Glasgow area during the investigation of the inhalational hazard problem, as applied to "Woodworkers", electricity was the only power source which I saw. Even in the few cases where the old type of oil engine may still be in use, it is placed in a corner of the workshop and the various machines driven from it by belts or rods, so that the men are not near the source of the potential irritant.

The type of oil mist produced by lathe turning, and referred to by Hueper (36), is less likely to be encountered by woodworkers than almost any other type of machine user. The same is true of every type of dust arising from the machinery itself, ignoring for the moment the question of dust arising from the material being processed. One important source of such material are the discs used on "sanding" machines, either of the portable or fixed workshop type. It is very probable that a serious risk lies in the use of the small portable power units, which have inter-changeable sanding discs, drills, etc., and which can be used almost anywhere, whether or not there is adequate ventilation to carry away the dust so produced, and which are extensively used by joiners or carpenters. While many of the paper backed discs sold for use on this type of portable unit are silica free, this is not true of all makes of disc, and Bergman (4) has shown that some discs contain up to 9.57% of silica.

To/

To set against this is the fact that not one of the men in the "Woodworker" group to be rejected showed the least evidence of a pneumoconiotic process, such as might have been expected, where a silica-containing dust to have found its way into the lung. Some of the films of men in this group are reproduced in plates 14 to 21 . These films have been selected as being those where the markings in the lungs are heavier than would normally be found associated with the type of lesion present, but they do not in the least resemble a pneumoconiotic process. Also, from the practical viewpoint, even the hardest woods are relatively soft in comparison with metals, so that the concentration of dust removed from the abrasive by wood will be very much less than would occur with men working with metal, and hence the risk to the "Woodworkers" will be much smaller. Some practical observations on this point are recorded in the next chapter (p. 90).

I believe that the various considerations dealt with above refute any suggestion that the differences between the social background and working conditions of the three employed groups are sufficient to explain the large increase in the proportion of "Woodworkers" to be rejected due to pulmonary tuberculosis.

This being so, the responsible agent, or agents, must lie among the materials which the woodworker handles in the course of his work. I have searched extensively in the publications of the woodworking and building/

/building trades, as well as in those from medical sources, for accurate information concerning the potential hazards to which woodworkers are exposed, but apart from references in dermatology texts to the ability of various woods to produce dermatitis, the action of Mansonia wood (Sterculiacea Altissima) in producing bronchial spasm, described by Bridge (8), the effect of South African Boxwood (Gonioma Kamassi) in producing a syndrome resembling cardiac asthma and reactions to Katon wood (Sandoricum), which acts similarly to mansonia wood, both described by Merewether (49), and cases of asthma due to Western Red Cedar (Thuja Plicata), described by Doig (22), I have found little definite information.

In the next chapter, the various materials with which the woodworker comes in contact are discussed and some investigations into them described.

CHAPTER V.

MATERIALS HANDLED BY WOODWORKERS.

The materials with which woodworkers come in contact during their work include various preservatives, stains and paints, and contaminants of wood, as well as various synthetic boards, plywood and solid woods.

Some of the materials can be eliminated from the search for the agent responsible for the increase in the incidence of pulmonary tuberculosis among the woodworkers, for one or both of two reasons. Either because of what is known of their action on man, or because they are handled by such a small fraction of the woodworking group that they could not appreciably influence the incidence of tuberculosis in the woodworking trades as a whole.

The various types of material will be considered in turn.

WOOD PRESERVATIVES AND INSECTICIDES.

These fall into two main types. Those which are used on standing timber, and those which are used on cut wood and wooden structures.

The former group can only reach the bark and leaves of the

tree/

/tree and as these are rapidly stripped off when the tree is felled or in the lumber yard, they simply do not reach the men who ultimately process the wood. The few men who may come in contact with this type of chemical are the sawmill labourers and woodyard workers, which occupations have a lower percentage rejected on account of pulmonary tuberculosis than the woodworker group as a whole : 1.03% as against 1.83%. This type of chemical is, therefore, not the agent responsible for the increased percentage of the group as a whole to be rejected due to pulmonary tuberculosis.

The second group of preservatives are those used on cut timber, and they fall into three categories (12):-

(a) Oil preservatives : e.g. coal tar or creosote.

(b) Water soluble salts : e.g. arsenicals, magnesium silico-fluoride, sodium fluoride, and, less commonly in Great Britain, corrosive sublimate.

(c) Oil soluble preservatives : e.g. light oils, such as naphtha, containing zinc or copper naphthenates, beta napthol or pentachlorphenol.

I do not believe that these agents are of importance in this survey, as, while many require careful handling because of their effects on the skin, none is known to cause any pulmonary irritation, although they have been extensively investigated because of their dermatological/

/dermatological action. Also the extent to which preservatives are applied to wood after it reaches the saw-mill, and before the manufacturing processes are completed, is minimal, and in the case of the products of the pattern maker and cabinet maker non-existent. Only joiners apply preservatives to wooden structures, especially to those being built outside, and it is unlikely that this factor plays any part in the development of tuberculosis, as they are rejected in a much lower percentage (2.02) than the pattern makers (3.04), who are not exposed to this type of chemical.

WOOD STAINS AND PAINTS.

The chance of a man in the woodworking trades coming in contact with materials of this type is even less than that of their contacting any of the chemical preservatives.

In all the works of any size, the polishing and painting shops are apart from the woodworking section and manned by a separate staff.

In small joiners' establishments, where the men may occasionally stain wood, contact with stains which contain isoamylalcohol may occur, and this has been shown by Wittich (74) to produce asthma in some men, but there is no suggestion that it/

/it predisposes to tuberculosis.

Here again, the fact that only a small proportion of the woodworking group come in contact with this type of chemical justifies it being regarded as not of significance in causing the increase in tuberculous infection.

CONTAMINANTS OF WOOD.

There are three possible types of contaminants of wood:-

(a) Chemicals.

(b) Bacteria.

(c) Fungi.

Chemical contamination: The question of chemicals applied deliberately has already been considered. It seems highly unlikely that accidental contamination of the wood handled by these tradesmen need be feared, as this is new wood. If the men worked with old wood, such as might be recovered from the demolition of old buildings, an entirely different position would arise, as such wood may have almost anything spilled on it. This wood is not, however, processed to any extent, so this hazard need not be feared.

Bacterial/

Bacterial contamination: An extensive search in publications from medical and trade sources has failed to reveal any bacterial organism which is pathogenic to man and which occurs in association with wood. There is no doubt that wood which has lain in woodyards in populous areas must become contaminated with bacteria-containing dust. Such contamination of any material which lies uncovered is universal wherever man lives and works, and cannot for this reason be regarded as significant factor in increasing the risk of acquiring pulmonary tuberculosis to the men in the woodworking trades.

Fungal contamination: Fungal disease of the lung as a primary infection is not common in Great Britain, and none of the woodworkers who were rejected for service had ever lived in a country where pulmonary fungous disease is more common. According to Davidson (18), only three fungi are found as pathogens in primary pulmonary fungus disease in Great Britain. These are aspergillosis, moniliasis and actinomycosis, and I have been quite unable to find any reference suggesting an association between these diseases and wood.

The only fungal diseases known to be occupational hazards in woodworking are chloroblastomycosis and sporotrichosis, both of which occur among woodworkers in North America (59). It is possible that both of these fungi could reach Great Britain in consignments of/

/of softwood, which is the type most commonly infected, from North America, which was the source of 33.8% of British imports of sawn softwoods in the period from 1947 to 1951 (65). It is, therefore, possible that some of the men who were rejected were in contact with one or other of these fungi. These diseases, however, are uncommon in North America among woodworkers, where all the softwood used may be contaminated, and so the hazard in this country, where only a third, or thereby, of the imported wood may be infected, and where none of the home produced wood will be involved, will be very slight indeed, and also a skin infection is by far the commonest form of these diseases.

The question of allergy to fungi, which are normally non-pathogenic to man, but found in association with wood, is not easily dismissed. Frankland and Hay (24) in a series of one hundred patients, who were known to be allergic subjects, showed that twenty of them reacted to an extract of merulius lacrimans, the fungus of dry rot, although only three of the twenty had ever lived in houses known to have been invaded by the fungus. It is a logical conclusion that contact with this fungus is not limited to people who have been closely in contact with infected wood, and the findings pose the question as to how far contact with such fungi as normally infect wood occurs in the general population, and whether it is likely to be significantly greater among woodworkers, bearing/

/bearing in mind that woodworkers rarely handle anything but new wood, while fungal contamination is commonest in old wood.

Sensitivity to the fungus, Coniosporium Corticola, which is occasionally found in the bark of trees, is known to occur among lumbermen (42) employed in stripping the bark. The condition manifests itself by inhalational allergic symptoms, but as the hazard is removed with the bark, it cannot be of importance to the woodworking group as a whole.

It is unlikely that pulmonary fungus infection need be regarded as a hazard of woodworking in Great Britain, although the occurrence of allergic reactions to otherwise non-pathogenic fungi must be considered.

SYNTHETIC BOARDS.

These are made from various sizes of wood chips and coarse sawdust.

In principle, the manufacturing process consists of five steps:

(1) Reduction in size of the wood fragments.

(2) Screening of the fragments to sort them to size.

(3) Passage through a drying plant to ensure a uniform and suitable moisture content.

(4) Mixing with the resin to be used as the binding agent.

(5) Pressing to shape.

During this last process, the pressure varies from 110 to

170/

/170 pounds per square inch, depending on the type of board. The temperature to which the board is raised while in the press is dependent on the adhesive in use, varying from 250° F. to 340° F. when phenolformaldehyde is used and from 200° to 220° F. for ureaformaldehyde. (25). These are the two resins in most common use.

The temperatures employed are such as to destroy any sensitising agent of complex molecular structure, according to the results obtained in the manufacture of insulating board from bagasse, by Castleden and Hamilton-Paterson (13).

The behaviour of synthetic boards when machined, in so far as particle production is concerned, is considered on p. 90 , along with the particles of solid wood.

Synthetic boards of the "Formica" type were encountered in only one of the cabinet works which I visited in the course of the investigations described below. They were not applied to the furniture by the cabinet makers themselves, but by the men employed in the polishing and finishing shop, and so are handled by such a small fraction of the woodworking group that they cannot form an appreciable hazard to the group as a whole.

PLYWOOD/

PLYWOOD AND VENEER.

The essential difference between plywood and synthetic boards is, that in plywood the wood is still recognizable. There are many types of plywood, but the basic principle of manufacture is the same for all. The various component layers are arranged along with the adhesive to be employed, most commonly either a blood albumen or a casein derivative or a resin, and then subjected to considerable pressure at high temperature, e.g. with resins to 300 pounds per square inch at a minimum temperature of 266° F. (75), and with albumen or casein derivatives to around 225° F. (76). Here, as with the synthetic boards, the temperature is high enough to decompose most complex molecules capable of acting as sensitising agents, and so no action, other than that of an inert foreign body, need be feared from dust produced by machining plywood and inhaled. The physical nature of this dust is considered on p. 90 below.

WOOD.

I have found no satisfactory data in either trade or medical journals concerning the nature, either from a physical or chemical viewpoint, of the dust which is produced by machining wood.

For this reason, I have undertaken a limited investigation into the nature of wood dust, in so far as it may constitute an inhalational hazard to the men working in an atmosphere contaminated by it.

No/

No pretence is made that the subject has been completely investigated, but I have attempted to obtain answers to the following relevant questions:-

(1) What is the smallest size of wood particle produced by machining wood?

(2) Does the concentration of these particles in the air breathed by men in woodworking shops reach a significant level?

(3) What is the morphology of a small wood particle?

(4) In sanding wood, is the abrasive used liberated into the air in fine particle form in sufficient amount to constitute an inhalational hazard?

(5) Can the small content of nitrogenous material in wood be liberated from fine wood particles by a fluid which is not specifically a protein solvent?

(6) If so, can the amount extractable, either of such material or of any other sensitising agent, in such a fluid produce sensitisation in experimental animals?

The macroscopic nature of wood dust is well known, and the fact that much of it is very large indeed is obvious to even a cursory inspection. In the dust produced by a large rip saw, fragments of wood of up to one inch in length are common, with much larger particles occurring frequently, and it is very difficult indeed to/

/to find any very small particles. As saws with smaller teeth are used, or as the speed of a circular saw is increased, the average size of particle produced becomes smaller.

The first, rather crude, investigation which I carried out was to collect from around the blade and bench of a circular saw with a medium-sized tooth and working under average conditions as far as ventilation and rate of revolution were concerned, the dust produced from two separate woods. These were obechi and Baltic white wood, and the two samples were then passed separately through wire screens of progressively finer mesh, as listed below. The percentage, by weight, of the total sample to be stopped by each filter is shown below, together with the percentage to pass the finest filter.

	Obechi.	Baltic white wood.
Stopped by 10 mesh	15.5	8.0
" " 18 "	15.5	21.0
" " 34 "	22.0	45.0
" " 44 "	18.0	16.0
" " 70 "	22.4	8.0
" " 120 "	4.4	1.5
Passing 120 mesh	2.2	0.5

The sample which had passed the 120 mesh screen was then examined/

/examined in two ways. Firstly, by passing it through a cascade impactor and examining under the microscope, the slide which had been behind the finest impaction slit. Secondly, by suspending some of the sample in alcohol and dropping the suspension on to a previously warmed slide, then putting on a coverslip and sealing around with wax as soon as the alcohol had evaporated. Examination of the slides so obtained showed that particles of the order of 4 microns diameter and upwards were present.

The accuracy of this method is very low, especially where small particles are concerned, as they tend to become adsorbed on to the larger ones. It does, however, demonstrate that the heavier and closer grained of the two woods, i.e. obechi, produced more small particles than the lighter and coarser grained wood when cut under exactly the same conditions, and also that particles as small as 4 microns diameter can be produced by the circular saw. No wood particle under 4 microns diameter was identified in dust produced by a saw.

The next procedure undertaken was to examine, by sampling with a thermal precipitator, the airborne dust in the region of sanding machines. From this point onwards, the emphasis in sampling and sizing was laid on the particles produced by sanding machines, as such particles are very much smaller than those produced by a saw, and/

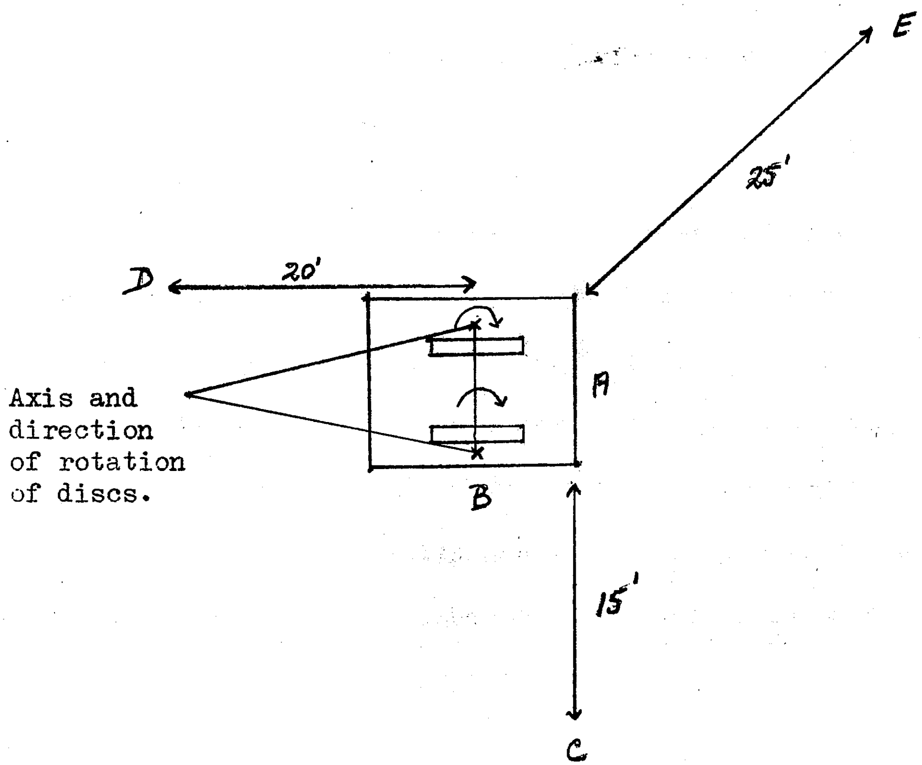
/and so will be more easily aspirated into the lung. Also the use of sanders is very widespread, and all the woodworking shops which I visited had at least one in use. The extent to which they are used may be judged from the fact that 3% of all wood waste from cabinet works is sander dust (26).

Counts were taken in various woodworking shops at various distances and angles from the sanding machines. In all cases, sampling was done at mouth level for men working in that particular position. Two basic types of sander were encountered, the first consisting of revolving abrasive discs, and the second of a flexible belt coated with an abrasive.

In the woodworking shops which I visited, the disc type of sander was found to be in use in pattern shops, joiners' shops and in coachbuilding, while the belt type sander was only encountered in cabinet works. It is also interesting to note that the disc type sander can usually be approached on at least three sides, and frequently stands in the centre of the working space, whereas the belt type sander can only be approached from one direction, and is usually sited along the side of the shop.

In cabinet works, one group of operators do all the sanding, and the various pieces are brought to the sanding shop or bay for processing, and, for this reason, the dust counts have only been taken at the operator's working position, as the other employees are not in the same/

/same shop or working bay. In the case of the disc type sanders, the men making the various articles bring the component parts to the machine and do the sanding themselves. They are normally working at benches situated around the machine, and so are exposed to the dust produced by sanding operations carried out by others. For this reason, counts have been taken at various positions in the working area, as well as at the sanding machine itself. These positions, relative to the sanding machine, are shown in the composite diagram below.



The average counts obtained in each position, of particles between 0.5 and 20 microns maximum diameter, were:

Position	A	-	1,455 particles per c.c. of air.
"	B	-	1,320 " " " " "
"	C	-	1,299 " " " " "
"	D	-	1,217 " " " " "
"	E	-	1,112 " " " " "

In the cabinet works, the samples were taken only in front of the machines and the average counts were:

876 particles between 0.5 and 5 microns in maximum diameter per c.c. of air.

1,223 particles between 0.5 and 20 microns in maximum diameter per c.c. of air.

In all counts of samples taken by the thermal precipitator, no particle over 20 microns in maximum diameter has been counted, as the efficiency of this instrument drops off rapidly for particles above this size and only a small proportion of them appear on the slides. The fact that this introduces an inaccuracy in counting the total numbers of particles present is fully recognised, but as this error will cause the number of particles to be underestimated, the figures above cannot exaggerate any respiratory hazard which may be present.

I have not been able to obtain satisfactory counts of the airborne/

/airborne particles in the range above 20 microns in diameter. Particles of this size can be collected on slides coated with some suitable oily film and the morphology of these particles examined, but it is not possible to collect all the particles present in a known volume of air by this method, and hence accurate counting is impossible.

The Hexlet dust sampler will collect all the dust in a known volume of air, but as this method is based on the principle of the soluble thimble collector and subsequent illutriation in liquid, it is impracticable for wood dust.

It has been possible to determine that the morphology of the particles in the range above 20 microns in diameter conforms generally to that of those in the range below 20 microns, but I have been unable to find a way of counting those above 20 microns with an acceptable degree of accuracy. As it is very unlikely that particles of over 20 microns can penetrate into the respiratory tree to any significant extent, this lack of an accurate figure for the number present in the air in woodworking shops is not of major importance for the purposes of this thesis. Further, the proportion of the particles on the thermal precipitator slides above ten microns in maximum diameter is only 18.7% of the total particles on these slides. This indicates that the bulk of the larger particles settle out of the air very rapidly/

/rapidly and before reaching the worker's mouth or nostrils. The maximum velocity at which a spherical particle settles, in a gaseous or liquid medium, is governed by Stoke's Law, which may be written:

$$V = \frac{2}{9} \frac{a^2 \quad (p^1 - p) \quad g}{y}$$

where : V - Final velocity of the particle.

a - Radius of the particle.

p^1 - Density of the particle.

p - Density of the medium.

g - Gravity.

y - Viscosity of the medium.

From this it is evident that the larger the particle the more rapidly it will settle out of a gaseous medium. While no comparable formula exists governing the behaviour of irregular particles, such as wood dust, it is known that the larger the particle the more quickly it settles from the air. In view of the limited proportion of the particles between 10 - 20 microns maximum diameter present on the slides from the thermal precipitator, and the increased rate of settling of larger particles, it is certain that those over 20 microns in diameter will settle sufficiently quickly to reduce the number of them to reach a position where they could be inhaled by the worker, to a degree where they will not form a significant inhalational hazard.

In some of the samples taken near the sanding machines, electron microscope grids were used in the thermal precipitator instead of the glass/

/glass coverslips, and some of the electron micrographs obtained from these samples are reproduced in plates 1 to 13. The general morphology of the dust particles in the range of the electron microscope shows features common to all the samples taken, these being :

(1) The shape of the particles is very irregular, and there are usually one, or more, "tails" present.

(2) Most of the particles are very thin in part, if not in all, of their area.

(3) There are many particles on all the samples with a spongy structure, and these show considerable variation in size. (See plate 9, where two separate particles of this type occur, one being 1.6 microns in maximum diameter, and the other 8.6 microns.)

(4) In consequence of the above features, the surface area of the particles, relative to their volume, is very large.

Some particles from the abrasive agent were found on the grids, but it was possible to differentiate them from the wood dust by their outline and refractive pattern. Such particles were very few in relation to the numbers of wood particles present, and it is highly unlikely that sufficient of them are present either to form an appreciable inhalational hazard by themselves, or to influence, to a significant degree, the particle counts done on the projection microscope, where it was not possible to differentiate the wood from the abrasive particles. In all the electron micrographs reproduced only wood particles have been photographed, with the exception of plate 13, which is of an abrasive particle.

To/

To study the morphology of the wood particles more readily, some samples were taken of the dust deposited around the sanding machines, on lamp fittings, shelves, ledges, etc., above the level of the machines. Collecting these samples from above the level of the machines ensured that the larger and heavier particles were eliminated. These samples were suspended in butyl-alcohol and sprayed on to electron microscope grids. The morphology of the particles on the grids prepared in this way was identical to those taken directly by the thermal precipitator. There is a difference in the percentages of the various sizes of particle between the specimens prepared in the two ways, and it is clear that in the samples which were allowed to settle and then re-dispersed, adsorption has taken place, and reduced the number of free and recognisable particles in the very small size ranges. There is also the possibility that some of the particles have absorbed sufficient of the fluid used to suspend them, to increase their size. The percentage of particles below various maximum diameters encountered on representative electron micrographs prepared by re-dispersion and direct thermal precipitator sampling are listed below :

	Thermal Precipitator	Sprayed
Under 1 micron in maximum diameter	9	4.7
" 2.5 " " " "	36.4	28.6
" 5 " " " "	63.6	61.9
" 10 " " " "	81.3	90.4
" 15 " " " "	91.6	95.2
" 20 " " " "	100	100

In/

In some of the workshops where the samples, described above, were collected, both plywoods and veneers, as well as synthetic boards and solid wood, were being sanded. This occurred almost without exception in the cabinet works and only a minimal amount of plywood or synthetic board was seen to be used elsewhere, and none at all in pattern shops. In the cabinet works, where a large amount of plywood and veneers were encountered, as well as other synthetic boards, the morphology, concentration and size distribution of the resultant particles was not found to differ from that found in shops where only solid wood was in use. The heat treatment to which wood fragments or sheets are subjected during the manufacture of plywood or synthetic boards does not, therefore, alter the type or size of particle produced by the sanding machines.

Chemistry of wood dust.

There has been a considerable amount of knowledge collected by botanists, working on plant physiology, on the nature and size of wood cells, and on the various chemicals contained in their walls and cytoplasm. According to Desch (20), the size of a wood cell varies from 0.001 to 0.02 inches (25.4 to 508 microns). This means that the particles produced by sanding wood are well below the size of the wood cell, and hence the cell membrane must have been ruptured, and so whatever chemicals may be present in the cell will be free to escape into the surrounding fluids without having to pass through a membrane.

The proportion of nitrogen in wood varies with the part of the

tree/

/tree from which the sample is taken. In the cambial layer the nitrogen may be very high. According to Wise and Jahn (73), the cambium of common ash contains 29.4% protein, that of elm 30% and Scottish Pine 20.8%. The sapwood of these same trees contains only a fracture of these amounts, the values being 1.73, 1.37 and 0.83% respectively. These figures are based on the assumption that, provided there is no alkaloid content in any particular wood the nitrogen present may be considered to be virtually all in the form of protein. The exact size of the non-protein fraction of the total nitrogen, in a wood not containing alkaloid, has not been precisely determined. The protein content of wood has been very little studied, and various authors report a series of non-related facts about different woods, many of them of rather exotic varieties of little commercial interest, which are not relevant here. Alkaloid in wood is not a common finding and is confined almost entirely to tropical woods, which are seldom used in this country.

It is unlikely that the atmospheric dust in a saw-mill, handling newly felled wood, could contain a high proportion of nitrogenous material, as the cambial layer of the wood is relatively thin and lies around the periphery of the trunk. Hence, in sawing the wood a very thin layer of cambium will be cut along with a thick layer of sapwood. In any case, the dust produced by the circular saw is much coarser than that from the sander, and so is a much less dangerous material from the point of view of inhalation.

As has been shown above (p. 90), the majority of wood cells in

sander/

/sander dust have been ruptured, and so there will be no interference from the cell membrane with the liberation of the chemicals contained in the dust, either in the lung or in the experiments described below.

Before any chemical present in inhaled wood dust can cause any effect on man, it must first pass into either solution, or suspension, in the fluid present on the respiratory mucosa.

I have measured the ability of nitrogen-containing chemicals in wood dust to pass into fluid, which is not specifically a protein solvent, in the following manner. The weight of nitrogen present in three samples of approximately one gramme of mixed sander dusts, from several sources, was accurately determined. Three samples of this same dust were soaked in water for 48 hours, the wood dust filtered off, and the weight of nitrogen present in the water after this time determined. From this was calculated the weight of nitrogen to pass into the water per gramme of wood soaked, and hence the fraction of the nitrogen contained in the wood sample to pass into the water can be calculated. The nitrogen content was determined by a modification of the Kjeldahl method, and the technique used is fully described in Appendix "A".

The nitrogen content of three samples of sander dust was found to be :

Sample A - 0.00214 grammes of nitrogen per gramme of sander dust.
" B - 0.00231 " " " " " " " "
" C - 0.00245 " " " " " " " "

These/

These figures give an average nitrogen content for the mixed sample of 0.0023 grammes nitrogen per gramme of wood.

The nitrogen extracted from each sample of wood was equivalent to :

Sample X - 0.000805 grammes of nitrogen per gramme of wood.
" Y - 0.000836 " " " " " " "
" Z - 0.00081 " " " " " " "

Using the averaged figure of 0.0023 grammes for the nitrogen content of each gramme of wood extracted, the percentage of nitrogen to pass from the wood to the water in which it was soaked was :

Sample X - 34.74%
" Y - 35.39%
" Z - 34.95%

The same procedure was carried out using a mixture of samples of sawdust instead of sander dust, and the following figures were obtained :

Sample 1 - 0.00220 grammes of nitrogen per gramme of sawdust.
" 2 - 0.00211 " " " " " " "
" 3 - 0.00214 " " " " " " "

The average of these three figures is 0.00215 grammes of nitrogen per gramme of sawdust.

The nitrogen extracted from each sample of sawdust which was soaked was :

Sample 1/

Sample 1	-	0.00051 grammes of nitrogen per gramme of sawdust.
" 2	-	0.00048 " " " " " " "
" 3	-	0.00046 " " " " " " "

Using the averaged figure for the total nitrogen present in the sawdust samples, these figures represent the following percentages of nitrogen passing from the sawdust to the water in which it was soaked :

Sample 1	-	23.7%
" 2	-	22.3%
" 3	-	21.8%

This represents a substantial proportion of nitrogen passing into the solvent, and there is no reason to suppose that, with the considerable retention of wood dust which will occur in the lung due to its hygroscopic properties (p. 107), the proportion of nitrogen-containing substances to reach the mucous membrane of the lung will not be as high.

Once this stage had been reached, a similar suspension of wood dust in distilled water was prepared by the method described in Appendix B, for injection into guinea-pigs.

Four guinea-pigs were injected with this aqueous extract, each animal being given 1 c.c. intraperitoneally. These animals weights were :

Guinea-pig Number	Weight
230	800 grammes
231	750 "
232	830 "
233	750 "

Two weeks later these animals were given a second injection of 1 c.c. of the aqueous extract by the intraperitoneal route, quite without upset, none of them showing the slightest ill-effects at the time of the injection or thereafter.

An attempt was made using two rabbits to obtain a Schwartzman reaction. The animals were given an intra-dermal injection of a culture of human tubercle bacilli, of the strain H 37 RV, and 24 hours later they were given 1 c.c. of the aqueous extract intravenously. No reaction was produced by this procedure.

The next step was to prepare two more wood extracts, by the same method as before, but using normal solutions of sodium hydroxide and sulphuric acid in place of the distilled water, and with the additional step of neutralising the solutions before filtration.

These solutions were injected intraperitoneally into four guinea-pigs, as detailed below, each animal, in this instance, being given 0.75 c.c. due to their lesser body weight as compared with those given the aqueous solution. There was no reaction in any of the animals at, or following, the injection of either solution.

Guinea-pig number	Weight	Extract Given
306	680 grammes	Alkaline
307	585 "	"
308	600 "	Acid
309	555 "	"

Two/

Two weeks later these same animals were given a second injection of 0.75 c.c. of these extracts. Guinea-pigs numbers 308 and 309, which had had the acid extract, showed no reaction during or following the second injection. Guinea-pigs numbers 306 and 307 both reacted strongly to the second injection of the alkaline extract, this reaction reaching its height one hour after the injection, and neither animal returning to normal, in so far as behaviour and feeding were concerned, for 48 hours thereafter.

In view of the reaction in the animals which had been given two injections of the alkaline extract, two of the four guinea-pigs which had been given two injections of the aqueous extract, were given 1 c.c. of the alkaline extract intraperitoneally, and the other two were given a like dose of the acid extract, as shown below :

Guinea-pig number	Extract
230	Alkaline
231	"
232	Acid
233	"

The object of this step was threefold :

(1) To confirm the results obtained with guinea-pigs numbers 306 to 309.

(2) To test whether any sensitisation might have developed in the period since these animals had had their injections of aqueous extracts.

(3)/

(3) To determine whether the alkaline extract had undergone any change, since the time of the first injection, which would have made it act as a primary irritant.

The fact that none of these animals showed any reaction to their first injections of either of these two extracts dismisses both questions two and three above. A further injection of these two extracts was given to these animals two weeks later, and once again no reaction occurred in the animals which had had the acid extract, while those which had had the alkaline extract reacted in the same manner as the other two.

The work described in this chapter has given definite answers to the questions concerning the nature of wood dust which I set myself to solve (p. 80).

First, it has been shown that particles as small as four microns in maximum diameter can be produced by a conventional circular saw, and where sanding machines are in use particles of sub-micronic size will be encountered.

Second, the concentration of particles present in the air of wood-working shops does reach considerable and significant levels.

Third, the morphology of the small wood particle has been described. (p. 88).

Fourth, the abrasive is liberated only to a very limited extent and will neither form an appreciable inhalational hazard by itself, nor distort the accuracy of the counts of the wood particles.

Fifth, a considerable proportion of the nitrogen in wood dust can be/

/be liberated by no more efficient a solvent than water.

Sixth, there is a sensitising agent in wood which is capable of passing into an alkaline medium and producing sensitisation in laboratory animals.

Chapter VI.

Discussion.

The figures tabulated at the end of Chapter III show that, in the group of 166,000 young men dealt with in this thesis, those who had worked with wood have a much higher incidence of pulmonary tuberculosis than those employed in other types of occupation. The size of the series is such that coincidence cannot seriously be considered as the explanation. The various aspects of the social backgrounds, and working conditions of the various groups have been considered in Chapter IV. They do not show any difference sufficient to explain the degree by which the incidence of tuberculosis is increased among the woodworkers. The factor, or factors, responsible must therefore lie in the materials handled by the woodworkers.

While it has been known for some time that wood dust could produce asthma when inhaled by sensitive subjects (50), it has, in general, been regarded as a physiologically inert material, and one which, if inhaled into the lung produced no pathological change therein. Nor has it been suggested that the men who were sensitive enough to wood dust to sustain asthmatic attacks when they inhaled it, were any more liable to develop pulmonary tuberculosis than any other workers. This viewpoint was endorsed in 1956 by Hinshaw and Garland (34), who instanced workers in furniture factories who inhale vast quantities of powdered wood cellulose over many years, without its producing any lung lesion "so far as is known".

I/

I believe that the possible pathological effects of inhaling wood dust have not been fully recognised because of several factors:-

(a) The recognised pulmonary dust diseases, such as silicosis or asbestosis, have unique, and typical, clinical and radiological pictures. In the case of the woodworkers, there is an increase in the commonly found diseases, and particularly of tuberculosis, without any special or unusual finding common to this group, or to a major portion of the group, and dissimilar to that found in the rest of the intake.

(b) The men in the occupations in the woodworker group are spread throughout the entire country. The joiners and carpenters, which single occupation comprises over 50% of the woodworking group, are to be found in every community regardless of size. It is, therefore, only under exceptional conditions that any one person, chest clinic or X-ray unit can see enough of these men to form a series large enough to be significant.

(c) The numbers employed in the occupations comprising the woodworker group, who are employed in individual works or factories, are small in comparison with the large labour forces employed in the type of works where silicosis, byssinosis or siderosis occur. The recognition of occupational chest disease among miners or textile workers has also been facilitated by the tendency of these people to congregate in mining areas or in the textile towns of the Midlands.

(d) The men employed in the various woodworking establishments which I visited/

/visited, all considered that wood dust did no harm to men in their particular trade. It was interesting to hear from three separate sources, in all cases pattern makers, the opinion that there were more chest diseases among cabinet makers than among other woodworkers or men employed outside woodworking. This opinion is not supported by the figures of this series in so far as comparison with the other woodworking trades is concerned. The reluctance of the men in these trades to admit the possibility that the wood dust to which they are exposed could be harmful may well have caused less attention to be paid to this dust than to that in other dusty occupations where the risk has been recognised for many years.

I have searched extensively in the medical literature for any definite record connecting woodworking with infective chest disease. There is very little material on this point, and I have only been able to trace four references which support the belief that there is a link between woodworking and such disease. These references are, Oliver (55) in 1902, The Annual Report of the Chief Medical Officer of the Ministry of Health for 1919-20 (1), Bergman, Rukstinat and McNally (4) in 1943 and the Registrar-General's Decennial Supplement for 1951 (England and Wales) (57).

Oliver's figures, those from the Chief Medical Officer and those from the Registrar-General are concerned with the mortality from pulmonary tuberculosis, or phthisis as it was called in the first two instances. Extracts from their tables are shown below:-

Oliver's figures:-

Occupation.	Comparative mortality figures from phthisis.	Ratio.
Agriculturist	106	100
Stone quarrier	269	254
Cotton manufacturer	202	191
Cooper and wood turner	250	236
Mason	225	212

The Chief Medical Officer's figures:

Occupation.	Comparative mortality figure from phthisis.					
	1890 - 1892		1900 - 1902		1910 - 1912.	
Agriculturist	175	(100)	155	(100)	156	(100)
Cotton manufacturer	303	(173)	362	(233)	256	(164)
Cabinet maker	373	(213)	409	(264)	412	(264)

The Registrar-General's figures:-

	Carpenters Joiners.	Cabinet makers.	Packing-case makers.	Pattern makers.
Population at Risk aged 20 - 64 (Census 1951)	199,675	24,499	7,747	11,631
Standardised mortality rate; ages 20 - 64 (based on 1949 - 53)				
from ALL CAUSES	91	106	102	89
from RESPIRATORY TUBERCULOSIS	90	109	115	100
from CANCER of LUNG and BRONCHUS.	104	132	87	66

(Standardised mortality rate, all males, 100)

The increased incidence of carcinoma among the cabinet makers is not relevant to this series, as the age group involved in it is much too young. Similarly, the mortality rate quoted in these figures is likely to be higher than in my series because of the different age distribution.

The figures produced by Bergman and his co-workers are concerned, in part, with morbidity, and, although they do support the theory of a link between woodworking and pulmonary tuberculosis, they are not conclusive, both because they are drawn from many sources where different standards may be applied, and because the numbers of people with whom they deal are not sufficiently great.

The figures quoted above show that an increased incidence of tuberculosis among woodworkers is not confined to my series, despite the dearth of references to this finding in the literature.

I do not consider that the increased percentage of the woodworking and dust-exposed groups to be rejected due to non-tuberculous chest infections is in any way connected with occupation. The increase, both as a percentage and as an absolute number of men is very small. It is important to note that the disease involved in almost 50% of the cases in the two occupational groups is bronchiectasis; in four out of eight woodworkers and in six out of fourteen dust exposed workers1 This condition requires a period of time to become fully developed. The men in this series had only spent an average of 3.14 years in their jobs prior to call-up, the corresponding figure for the woodworking group alone being 4.54 years, and so it is highly unlikely that the man's occupation is of any/

/any importance in the development of this disease, as far as this series is concerned.

The consideration of the materials handled by the woodworkers, which has occupied Chapter V, allows some of them to be eliminated from the search for the agent responsible for the increased incidence of tuberculosis among woodworkers. Wood preservatives, insecticides, paints and wood stains may be eliminated, mainly because very few of the woodworkers handle them, but also because what is known of their action suggests that there is no respiratory hazard connected with their use, so far as tuberculosis is concerned. It has been shown that it is extremely unlikely that either chemical or bacterial contamination of the wood need be feared. As only a fraction of the imported wood may be contaminated with pathogenic fungi, this cannot be a significant cause of respiratory disease in the United Kingdom. Synthetic boards of the "Formica" type may also be eliminated, as so few men handle them. This leaves only the other types of synthetic boards, plywoods and solid woods as agents likely to affect the entire woodworking group, and about which little is known, in so far as their action in the human lung is concerned.

I have examined the woodworking group who were rejected for service due to tuberculosis specifically to find whether there was any difference between them and those rejected in other occupations. There are indications of two differences. If the men in the three employed groups, who were rejected due to tuberculosis, are divided into the active and inactive cases, then the following figures are obtained:-

	Active tuberculosis.		Inactive tuberculosis.	
	Number of cases.	Percentage of total.	Number of cases.	Percentage of total.
Dust free workers	120	21.3	343	78.2
Dust exposed workers	14	24.5	43	75.5
Woodworkers	27	42.2	37	57.8

The numbers here are not large enough to be conclusive, but they indicate that there may be a larger proportion of active cases among the woodworkers.

The large films taken of the rejected woodworkers have been lent to me from service records. Rescrutiny of these shows that in a third of the cases, the broncho-vascular markings in the lower part of the lung fields are more pronounced than would have been expected, in so young an age group, if the type of lesion for which they were rejected had been the sole agent acting on the lung. Some of these films, or parts of them, are reproduced in plates 14 to 28 . I have considered the possibility of mistaken diagnosis among the rejected woodworkers, but have not found any reason to change the original diagnoses, made at the time the man was examined. The only differences between my opinion at rescrutiny and that at the time of the original examination, occurred in three cases who had been classified as "presumed inactive tuberculosis", and whom I would now consider as potentially active cases. As this does not affect the total number of cases of tuberculosis, I feel that this discrepancy is/

/is not important for the purposes of this thesis, especially as the distinction between active and inactive cases of pulmonary tuberculosis, at a single examination, is notoriously difficult.

The lesions for which the woodworkers were rejected were of the reinfection type. This is demonstrated by the distribution of the lesions in the lung. According to Schinz, Baensch, Friedl and Uehlinger (61) the localisation of a primary tuberculous complex, as shown by fluoroscopy, in two separate series, was :

	Right.	Left.	Right.	Left.
Upper zone	0.6%	-	1.8%	1.8%
Middle zone	11.7%	20.8%	8.8%	18.4%
Lower zone	59.4%	7.4%	65%	4.4%

These figures give an average for each zone, as is shown below:

	Right.	Left.
Upper zone	1.2%	0.9%
Middle zone	10.2%	19.6%
Lower zone	62.2%	5.9%

The figures for the distribution of the lesions in woodworkers in this series are:

	Right.	Left.
Upper zone	47.6%	47.6%
Middle zone	4.8%	-
Lower zone	-	-

These figures demonstrate a completely different distribution of the lesions/

/lesions from that found in the primary form of the disease, and according to Kerley (46), they are typical of the distribution of the reinfective type of lesion.

Before the dust produced by machining wood, plywood and synthetic board may be considered to have any action in the lung, it must first be shown to be capable of entering the lung.

It is generally accepted that particles under five microns in maximum diameter can penetrate far into the bronchial tree. The total lung retention is a function of the particle size, and it has been shown by Brown, Cook, Ney and Hatch (10) that for five micron particles this is about 90%, and that the retention falls off steadily as the particle size diminishes, being 85, 75 and 55% for four, three and two micron size particles, and only about 25 - 30% for particles of under 0.25 microns. The work done by Van Wijk and Patterson (69) agrees with these figures. There is general agreement that particles of one micron, or thereby, can reach the alveoli, and Dautrebande, Beckman and Walkenhorst (16) have shown that particles of one micron produce maximum alveolar deposition, and that this deposition, like the whole lung retention, decreases with particle size. That Dautrebande's figures will apply to the percentage of the wood particles to be retained in the respiratory tree is unlikely, as the work done by this group was with particles of coal, carbon black and iron oxide. None of these materials will absorb moisture from the alveolus or the alveolar air, while it is probable that wood particles will do so. It has been shown by Millburn, Crider and Morton (51) that the lung retention of/

/of aerosols of rehydrating materials is increased over that of otherwise comparable non-rehydrating particles.

It has been shown (p.90) that the size range of the particles of wood dust begins at a sub-micronic level, the smallest found having a diameter of 0.75 microns, and progresses upwards to a level where they are too large to enter the bronchial tree.

It is, therefore, certain that some fine wood particles will reach and will be retained in all parts of the bronchial tree, and nasal passages.

There are several possible ways in which a wood particle can act once it has been inhaled and retained in the lung. Its access to the lung is dependent on its size, and, once lodged in the lung, its action will depend on its size, its shape, its ability to absorb moisture from its surroundings, any contaminants it may carry and its chemical composition.

Whatever the action of the wood particle may be, it will obviously be more pronounced the longer it remains in the lung. Wood dust will be retained in the lung to a greater degree than mineral dust of the same particle size, due to its hygroscopic properties (51). The experiments of Lengerova, Lerger, Esslova, Tuscany and Volfova (48) showed that round particles are phagocytosed preferentially to long ones. They estimate that the surface area of a long particle is 50% greater than that of a round particle of similar mass, and suggest that the larger surface area allows the particle to carry more adsorbed impurity than can a round particle of similar mass. They suggest that such an impurity is chemotactically/

/chemotactically negative to the phagocytosing elements. The surface areas of the fine wood particles, relative to their volume, has been shown to be very large (p. 88) and hence their ability to adsorb impurities must similarly be very great. The experiments of Belt, Friedman and King (3) with asbestos fibres and coal particles, confirmed that asbestos fibres over 2.5 microns in length were not phagocytosed to any extent, while phagocytosis of the smaller particles, which they found to be largely fibrous, began in forty-eight to seventy-two hours. Their figures showed that 50% of the smaller asbestos fibres remained within reach of the phagocytes throughout the experiment without being phagocytosed. They also showed that asbestos fibres had little, or no, toxic effects on living cells or tissue cultures. The growth of fibroblasts was neither accelerated nor retarded, there was no necrosis of cells in contact with asbestos, and fatty change occurred more slowly in phagocytes containing asbestos than in those containing coal particles. It is relevant to note that the fibrous asbestos particles are less toxic to the phagocytes which ingest them than are the coal particles. If this toxicity were to depend solely or even mainly, on the adsorption of chemical agents, the larger area of the asbestos fibres would result in a greater concentration of toxins on each particle, and so the degree of toxicity would be higher. As it was found that the asbestos fibres were less toxic than the coal particles, it is unlikely that adsorption of toxin plays any important part in the inhibition of phagocytosis which was found to occur in these experiments, and it may be that it is the physical nature of/

/of the asbestos fibre which is responsible for the retardation of phagocytosis which occurs with these particles. If the delay in phagocytosis is due only to the physical nature of the fibre, as appears likely, then the phagocytosis of wood particles will be similarly delayed, as many of them, even in the small size ranges, are fibrous.

Here then are two reasons, in their hygroscopic action and their fibrous shape, why wood particles will persist in the lung to a greater extent than mineral dusts of the same size.

The possible modes of action of the dust are, as a chemically inert foreign body, with the possibility that the physical nature of the particle may modify the consequent reaction. Alternatively, its action may be purely as a vehicle of a bacterial, chemical or fungal pathogen. Finally, its action may depend on some chemical constituent of the wood, which may be either a systemic poison, a local primary irritant or a sensitising agent.

It is unlikely that the dust in the lung acts as a chemically inert foreign body. If it did act in this manner and produced sufficient irritation, merely by its presence, to cause the increase in the proportion of woodworkers with tuberculosis, then the dust which the dust exposed workers inhaled ought to have been able to produce a comparable increase in the amount of tuberculosis in this group. That the unusual, and somewhat fibrous, shape of the wood particles could modify the reaction in some way must be considered. There is evidence that/

/that asbestosis is due to the shape of the asbestos fibre, and not to its chemical constituents. Hunter (41) summarises evidence that the fibrosis of asbestosis is caused by fibres exceeding 2.5 microns in length. It is suggested that the action is due to the flexibility of the fibres, a quality not possessed by other foreign bodies. With the movement of the lungs in respiration, these fibres cause friction within the alveoli and terminal bronchioles, and this friction causes fibrosis. If this is so then may not wood dust cause fibrosis by the same mechanism, since most of its particles are fibrous? It may do so to a degree which is inadequate to produce a dyspnoeic state which would be noticed by the patient. This is suggested by the findings on plates 14 to 28, where the increase in the bronchovascular markings already referred to on p.105 is recorded. In some cases there is a suggestion of a fine fibrosis similar to that which is found as the first radiological sign of asbestosis (45, 60). This fibrosis does not progress to a disabling degree, or it would inevitably have been discovered long ago. It is quite possible that this may be prevented by the wood particles being broken down in the lung by the action of the fluids in the bronchioles and alveoli. If not completely broken down, then they may become so saturated with fluid that they lose any spring or flexibility that they had originally possessed. This possibility is supported by the findings of Derbes and Windsor (19) that inhaled flour particles are broken down in the lung with the production of lactic acid, which acts as an irritant. It is unlikely that an action, on the principle of the mechanical theory of/

/of asbestosis, could be of importance in the development of tuberculosis in woodworkers. An association between tuberculosis and asbestosis does occur, according to Davidson (17), but to a much lesser extent than between silicosis and tuberculosis. The few men in this series who showed basal markings suggestive of asbestosis did not develop their lesions in the affected areas. For these reasons, it seems unlikely that the wood dust can produce a degree of fibrosis, by the mechanical process which has been suggested for asbestos, which is capable of influencing the incidence of tuberculosis among the woodworkers in this series.

The presence of the wood particles must traumatise the respiratory mucosa, and such abrasions will facilitate the implantation of bacteria, whether or not any irritant is produced by a breakdown of wood tissue. Such abrasions may occur in all areas and cause insufficient irritation to produce even minimal signs on the films. The fact that the lesions among the woodworkers have not occurred in the areas where the increased markings are to be found does not, of itself, mean that there are no abrasions present in the mucosa at the site of the lesions. The unusual and irregular shape of the wood particles may well increase their ability to abrade the mucosa above that possessed by a simple fibrous particle.

It has been suggested by Vorwald (70) that a cause of the massive degree of fibrosis, often seen where silicosis is complicated by tuberculosis, is that adsorption of toxin from the tubercle bacilli by the inhaled particles causes a concentration of the toxin, which in turn leads to the extensive fibrosis. Any such action is highly unlikely with/

/with the wood particles, as, were they capable of acting in this manner, the degree of fibrosis to be found would almost certainly be much more definite than does occur, and would be likely to occur in a higher proportion of the cases.

It seems from this evidence unlikely that wood dust can cause any important effect in the lung by acting simply as a chemically inert foreign body, although it is not possible to discount the possibility of the unusual shape of the wood particles being able to cause rather more abrasions to the respiratory mucosa than will occur with non-fibrous particles.

The consideration given in the last chapter (p.74) to the question of contamination of the wood justifies the rejection of chemical or bacterial contamination as of any importance to woodworkers in this country. Fungal contamination, with a fungus which is a primary pathogen, is also not a likely hazard in the United Kingdom, although the possibility that sensitisation to an otherwise non-pathogenic fungus could occur cannot be eliminated.

The possibility that wood dust could have some constituent chemical capable of causing systemic reactions when absorbed by the respiratory mucosa is not likely with the majority of woods. It does occur with South African Box-wood (49), but is not known to occur with any other wood. There has been no suggestion that the incidence of tuberculosis among/

/among people who have been affected by this wood is increased when compared with other woodworkers, although it is most unlikely that sufficient men have been exposed to this wood for adequate figures to be obtainable on this point. Far too few men handle this wood for it to be able to cause any significant increase in the incidence of tuberculosis among the woodworking group as a whole, even if it did predispose to tuberculosis.

A chemical constituent of wood capable of causing systemic reactions of the severity of those due to South African Boxwood would not have been likely to have remained undiscovered until the present time. The responsible factor in South African Boxwood is known to be an alkaloid (49). Alkaloids are not a very common constituent of wood, and McNair, who is quoted by Wise and Jahn (72), examined 285 families of gynosperms and angiosperms, finding only 57 to contain any alkaloid, and of these woods, 43 were predominantly tropical in their distribution. Alkaloids occur mainly in tropical woods where their presence is known, and this knowledge, combined with the fact that most woods do not contain toxic alkaloids, means that an uncontrolled hazard to health need not be feared from this source in workshops in the United Kingdom.

No wood is known to have an irritant action comparable to that of Mansonia or Katon woods. These two woods produce both symptoms and signs in a very short period of exposure. It is unlikely that a similar action, by any other wood, which is handled to any appreciable extent commercially, could have remained unnoticed until the present. The consequences of such an exposure in one individual to any wood having an action similar

to/

/to that of either Mansonia or Katon woods, could be mistaken for a sensitisation reaction of the "hay fever" type. Mild reactions of this type may thus occur and simply be ascribed to "hay fever" without any thought of their being related to the man's work arising, provided they do not occur frequently. If such a reaction were to occur with any frequency, particularly at times of the year when most of the agents capable of causing hay fever are minimal or absent, then I cannot believe that a relationship with the wood involved would not be suspected fairly quickly. These woods do not produce their action by sensitisation, but by some primary irritant which they contain. For this reason, it is unlikely that only one man in a woodworking shop would be affected by the irritant. Multiple cases even of typical hay fever occurring in men working in one workshop, or even one trade, at a time of year when this is normally a rare occurrence, would be bound to direct attention to the responsible material. For these reasons, I cannot believe that woods, other than Mansonia and Katon, can act as primary irritants, unless they are handled only very rarely commercially. This degree of restriction in the number of woods capable of acting as primary irritants, if such an action were not to be readily apparent, means that very few men would be exposed to them. There is no evidence that men who have been exposed to either Mansonia or Katon woods are any more liable to develop pulmonary tuberculous lesions than are other woodworkers. It would be difficult in view of the limited use made of these woods to find sufficient men who have been in contact with them to form a series. Even if some increase in the incidence of tuberculosis among the men exposed to this type of wood/

/wood does occur, the fact that exposure is so unusual, means that such an action could not affect the woodworker group, as a whole, to a sufficient degree to affect the incidence of tubercular disease in the entire group. I do not, therefore, consider that a primary irritant action of a constituent chemical of the wood is a responsible factor in increasing the incidence of tuberculosis among the woodworkers in this series.

The possibility that the increased incidence may be related to a sensitisation reaction to some component of the wood dust is more likely.

There is substantial evidence that many materials of vegetable origin can produce sensitisation. Probably the best known of these are the various woods which can cause dermatitis, a subject which has been extensively recorded. In 1937, Weber (71) listed forty-eight woods capable of causing dermatitis. In 1943, Becker and Obermeyer (2) listed one hundred and six such woods, but their list did not include eight of the woods listed by Weber. To this total, Hunter (38) has added a further five, making a total from these three authors of one hundred and nineteen woods capable of causing dermatitis. Some of these woods are primary irritants, while others act by sensitisation. It is difficult to differentiate clearly between the two types of wood, as many of them which, in high concentration, act as primary irritants, will cause sensitisation reactions in lower concentrations in men who have previously handled the wood. Although these woods can cause dermatitis by primary irritant action, I do not consider it likely that they will cause comparable irritation when inhaled into the lung. The concentration to reach/

/reach the bronchioles is not likely to be enough to produce other than the sensitisation type of reaction. It is also possible that the action of these woods on the skin may be of a different nature from that of Mansonia or Katon woods on the respiratory mucosa. I have been unable to find any reference which cites Katon wood as a cause of dermatitis. Mansonia wood is an infrequent cause of dermatitis. It is not listed by either Weber (71), Becker and Obermeyer (2) or Hunter (38), but has been shown by Honer (35) and Bourne (6) to be an infrequent cause of dermatitis in this country. The fact that these two woods which are well known for their irritant action in the lung are not equally well known as skin irritants, while none of the many woods which are commonly skin irritants are recognised as causing pulmonary symptoms in other than a few hyper-sensitive subjects, raises the question of whether the woods capable of acting as skin irritants can cause pulmonary irritation in other than rare cases. I feel that they do not do so with any frequency, if at all, or their action would inevitably have been noticed long ago.

It is known that many woods can cause asthmatic attacks when inhaled by sensitive subjects. According to Merewether (50), probably any vegetable dust may produce asthma through a process of sensitisation, and he cites woodworking as one of the occupations where cases of this type occur.

Allergic reactions to tree pollens have been investigated by Hyde (43), whose evidence shows that these substances are weak sensitisers. He suggests that the weak action may be due to variation in the dates at which/

/which pollen is liberated into the air from year to year. It is difficult to see why irregularity in exposure to an allergen, which is of such infrequent occurrence, should weaken its allergenic action. It is much more likely that the weakness of the action is due to the size of the pollen cell, about 20 microns in diameter (39), preventing its penetrating into the respiratory tract beyond the nasal mucosa, plus the fact that the membrane of the pollen cell will still be intact when the cell is inhaled. Any chemicals present in the pollen cell will, therefore, have to pass this membrane before they can produce any action in the lung. According to Wittich (74), the active antigens in pollen cells have been shown to contain complex polypeptides, and a molecule of this relatively large size may well be slow to pass a membrane such as a cell wall. This is reflected by the proportion of nitrogen to pass into water from sawdust and sander dust, the proportion from the sawdust being appreciably lower than that from the sander dust, where most of the cells have been ruptured (p. 92).

In the cases of Red Cedar poisoning described by Doig (22), the period between the commencement of exposure and the appearance of symptoms was relatively short, varying from a few weeks to a maximum of five months, a much shorter period than the average exposure which the woodworkers had prior to call-up (p.103). In this instance also the wood was being processed and hence many of the cells would be ruptured. Unfortunately the size of the Red Cedar dust is not recorded, but from my own investigations it is a reasonable assumption that some would be of the order of 5 - 6 microns, even if no sanding machines were in use.

Whatever/

/Whatever their size may have been, the Red Cedar particles penetrated into the respiratory tract to an extent adequate to produce an allergic state which persisted in one of the cases for seven years.

The ability of allergy to this wood to persist for such a long period, plus the ability which many other woods possess to produce allergic asthma, suggests the possibility that all woods may be capable of acting as sensitising agents. They may do so and only produce clinical symptoms when inhaled by sensitive subjects, the reaction to them in the majority of people remaining at a sub-clinical level.

The occurrence of similar reactions to those described by Doig are reported, in a series of six people who worked with coffee, by Bruun (11). In all his cases, the symptoms were co-terminous with exposure, and either patch testing or intra-cuntaneous injection of coffee bean, coffee grounds or extracts made from these produced marked reactions. There was no reaction if the extract, or the material from which it had been made, were boiled for three minutes. This resembles the finding by Castleden and Hamilton-Paterson (13) that the sensitising agent present in bagasse could be destroyed by heat. It may be inferred from these two findings that the sensitising agent is of complex molecular extract and possibly a protein.

At one time it was held that asthma and pulmonary tuberculosis never, or only very rarely, occurred in the one patient. This has been shown to be untrue by the figures published by Tocker and Davidson (66), which show that there is neither more nor less asthma among tubercular patients than in/

/in the general population. A number of authors have supported the theory of a link between asthma and pulmonary tuberculosis. Urbach and Gottlieb (68) summarise much of the evidence on this point, but it is not conclusive.

There is evidence of a direct link between a personal history of allergy and the presence of the tracheo-bronchitic form of tuberculosis, in the figures published by Oatway, Gale and Mowry (54). They showed that patients with tuberculous tracheo-bronchitis did not react to tuberculin skin tests more strongly than did other tuberculous patients. They reacted more strongly to routine allergen skin tests than did tuberculous patients with other types of lesions. This increase in tuberculous tracheo-bronchitis in patients who both have a history of allergy and who react more strongly to routine allergen testing, does not imply that there will be an increase in the incidence of other forms of tuberculosis in these patients. The increase in the tracheo-bronchitis may well be due to increased secretions, plus paroxysms of coughing consequent on the asthmatic state which arises from the allergic background. Such attacks could facilitate the spread of tubercle bacilli along the bronchi from an already established pulmonary focus, without assisting in the original establishment of that focus.

The clinical evidence that many materials of vegetable origin, including wood, may cause allergic reactions when inhaled by man is very great, and it has been shown that there is some antigen present in the fine/

/fine wood dust given off in modern industrial processes, which is capable of causing sensitisation reactions in experimental animals. The overt cases of asthma which occur among woodworkers may quite possibly be confined to sensitive subjects, but it is entirely possible that reactions to repeated inhalation of fine wood dust may occur at a sub-clinical level in many men working in atmospheres where this material is present.

Such a sub-clinical action could well explain why there are more cases of pulmonary tuberculosis among the woodworkers than the other National Service recruits.

Two important points must be borne in mind about the nature of the increase in the incidence of tuberculosis among the woodworkers. These are, the indication that there may be more active cases among the woodworkers than in the other occupational groups (p.105), and, more important, that it is the reinfection type of tuberculosis which is encountered among the woodworkers (p.106).

I believe that the increase in the incidence of pulmonary tuberculosis among woodworkers may be explained by the following hypothesis. If men who have had and have healed a primary tuberculous infection, and in consequence have a degree of allergy to tuberculo-protein, as well as a partial resistance to the tubercle bacillus, are employed in woodworking, then some of them will develop an additional sensitivity to allergens in the wood. At this stage, the men may acquire a reinfection with the tubercle bacillus in the lung, and the intake to the forces is of such an/

/an age that the incidence of the reinfection type of tuberculosis in the two or three years prior to call-up is normally fairly high. The outcome of this reinfective focus is normally dependent on the size of the reinfection, the patient's general health at the time, and the balance between the immunity and allergy resulting from his primary infection. If at this stage a second agent to which the man is sensitive is introduced into the lung, at the site of the reinfective focus, then this agent may upset the interaction of these factors to the patient's detriment. Such an action would explain the increase in the number of cases found at the intake centre among the woodworkers. It also fits with the reinfective type of lesion which is found to occur and would explain, in part, the fact that woodworking has not been regarded as a dangerous trade, as mere delay in healing of the focus, without any increase in mortality sufficient to attract attention readily, would account for the figures found in this series. Such an action would also explain the suggestion that there is a higher proportion of active cases among the woodworkers.

The evidence in support of this theory is substantial. There is clear evidence that many vegetable materials, including wood, can cause sensitisation, and that in some subjects this can be severe enough to produce clinical asthma. That there is an antigen in the fine particles of wood dust capable of causing sensitisation in laboratory animals has been shown. It has also been shown that modern machinery produces fine enough wood particles to be inhaled into the terminal bronchioles and alveoli, and experimental evidence has been adduced to show that such particles/

/particles are likely to be retained in the lung to a very considerable degree.

According to Dietenfass (21), it is well established that allergy predisposes to and aggravates many diseases of the upper and lower respiratory tract. Suggestions that allergy might affect the course of pulmonary tuberculosis have been made. The work already cited by Oatway, Gale and Mowry (54) suggests that the reactions, due to the allergic state, may facilitate the spread of tubercle bacilli throughout the bronchial tree. The work of Judd and Henderson (44) showed that improvement could be produced in the clinical and radiological findings, in cases of tuberculous pneumonia, by the administration of anti-histamines. This improvement, however, was not maintained after the therapy was stopped. They also showed that the improvement which was produced was accompanied by the patient's Mantoux reaction becoming less strongly positive, but that this also reverts to its previous level after the drug is discontinued. It is also noted that the longer established and more chronic the lesion, the less effect could be produced by the anti-histamines.

These findings indicate that allergy may play a part in influencing the nature of the tuberculous lesion occurring in any given patient. I believe that this finding leads to the conclusion that the presence of a second material in the lung to which the patient is sensitive will assist in the establishment of a reinfective type of tuberculous focus, where the patient is already sensitive to tuberculo-protein. Further, once this infection is established, it seems likely that, in the more sensitive type of subject, the wood dust may produce an asthmatic type of reaction which,/

/which, by purely physical means, will facilitate the spread of tubercle bacilli in the lung tissues.

The presence of allergy to otherwise non-pathogenic fungi contaminating the wood, the possibility of which has already been discussed (p.76), could act in a comparable manner to that to the antigenic substances present in the wood dust itself.

Much work remains to be done before the substantial evidence which can be adduced to support this theory becomes conclusive. This work will, however, require to be done over a period of time and with a considerable number of animals. It will involve detailed histology of many lung sections where the changes found will, in many cases, be minimal and the interpretation of which will call for an experienced pathologist. This undertaking is altogether beyond the scope of a single person, although it is to be hoped that it will be possible to interest others in this line of research, and that I may be able to help in carrying it forward.

APPENDIX 'A'.

ESTIMATION OF NITROGEN.

The materials whose nitrogen content was to be estimated were samples of sander dust of approximately one gramme, and the filtrate obtained by soaking approximately two grammes of sander dust in about 100 c.cs. of water for forty eight hours, then filtering out the wood particles.

The modified Kjeldahl method was:-

(1) The sample was placed in a Kjeldahl digestion flask, along with 0.2 g. of selenium and 10 g. of anhydrous sodium carbonate.

(2) These were well mixed, then 30 c.cs. of pure sulphuric acid was added and a light drop shaped stopper placed in the neck of the flask. The flask was then placed in an inclined position, with the neck in a suction device to remove the acid fumes.

(3) The mixture was then heated gently till frothing ceased, then vigorously until the fluid cleared, a matter of four to five hours.

(4) Once the fluid had cleared, it was allowed to cool, then water was added, and the contents of the digestion flask transferred to a one litre boiling flask. Several washings of the digestion flask were transferred to the boiling flask, and the total contents of this made up to about 400 c.cs. with water.

(5)/

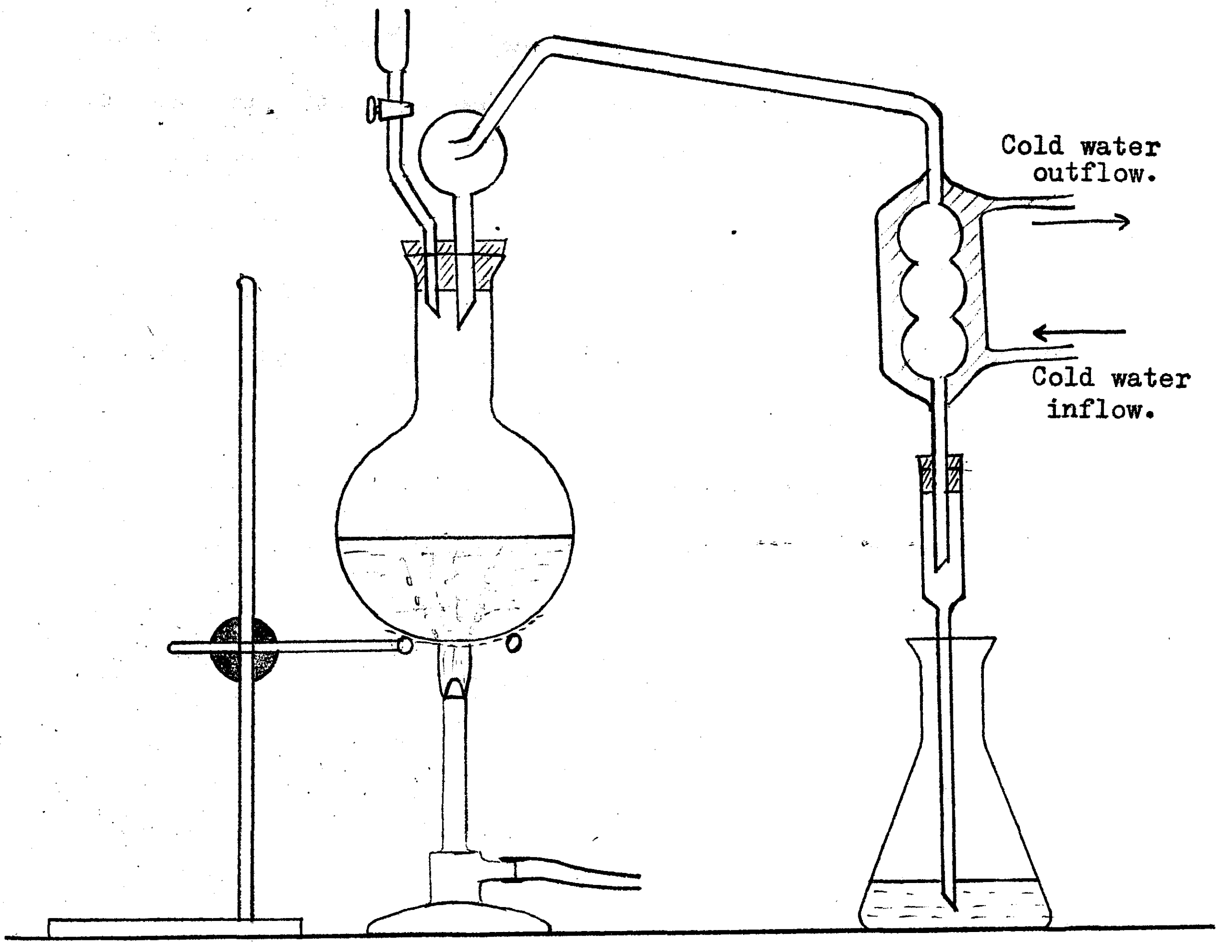
(5) The boiling flask was then fitted with a funnel, with a cock, and with a splash-trap extending to a bulbed tube in a condenser jacket, and to a tail-piece, which led into a conical flask.

(6) Into this conical flask was put 20 c.cs. of 0.1 N. hydrochloric acid and two drops of methyl-red indicator, the level of this being adjusted, so that the end of the tail-piece was dipped into the fluid.

(7) When the apparatus was so arranged, 130 c.cs. of a 40% aqueous solution of sodium hydroxide were added to the boiling flask via the funnel, the cock closed, and boiling begun.

(8) Boiling was continued until about 250 c.cs. had been distilled over, when the contents of the conical flask were titrated against 0.1 N. sodium hydroxide to discover how much acid had been neutralised by the distillate, and from this, the nitrogen content of the sample was calculated.

(9) An estimation, as above, was carried out without wood or wood extract present to determine the amount of .1 N. hydrochloric acid neutralised by the reagents in the distillate, plus any nitrogen contamination of the reagents.



DISTALLATION APPARATUS.

APPENDIX 'B'.

Method of preparation of extracts for animal injection.

(1) The sander dust was soaked in the medium in which the extract was to be made for forty-eight hours.

(2) The dust was then filtered off, using an ordinary chemical filter paper.

(3) As the likelihood of the extract producing a sensitisation reaction depends on the presence of complex chemicals, which are likely to be able to be decomposed by heat normal sterilizing methods were not possible. The filtrate from stage two was, therefore, passed through a sufficiently fine Seitz filter to remove any bacterial organism which might have been present.

(4) The extract was stored in refrigerated conditions until required, and between experiments.

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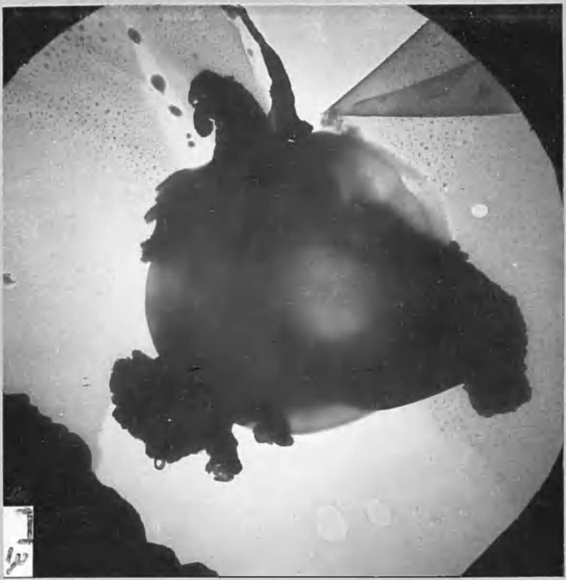


Plate 1.

Electron Micrograph.

Magnification - 4,000 times.

Wood Dust.

Thermal Precipitator Sample.

Plate 2.

Electron Micrograph.

Magnification - 4,000 times.

Wood Dust.

Thermal Precipitator Sample.

Plate 3.

Electron Micrograph.

Magnification - 4,000 times.

Wood Dust.

Sprayed Sample.

Plate 4.

Electron Micrograph.

Magnification - 4,000 times.

Wood Dust.

Sprayed Sample.

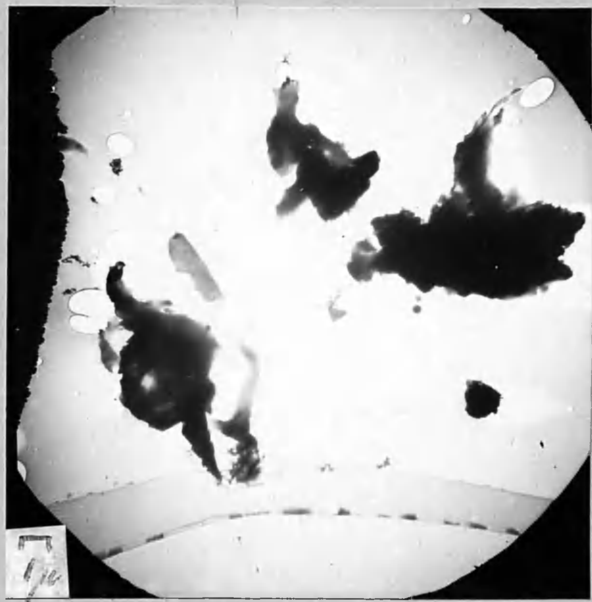


Plate 5.

Electron Micrograph.

Magnification - 8,000 times.

Wood Dust.

Sprayed Sample.

Plate 6.

Electron Micrograph.

Magnification - 4,000 times.

Wood Dust.

Sprayed Sample.

Plate 7.

Electron Micrograph.

Magnification - 8,000 times.

Wood Dust.

Thermal Precipitator Sample.

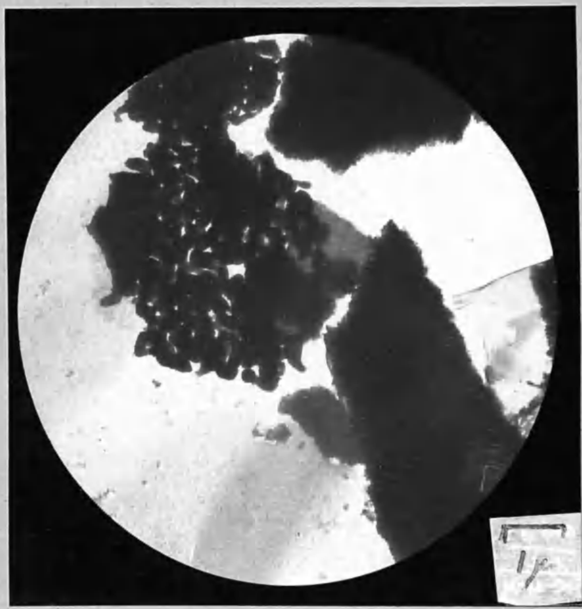


Plate 8.

Electron Micrograph.

Magnification - 8,000 times.

Wood Dust.

Thermal Precipitator Sample.

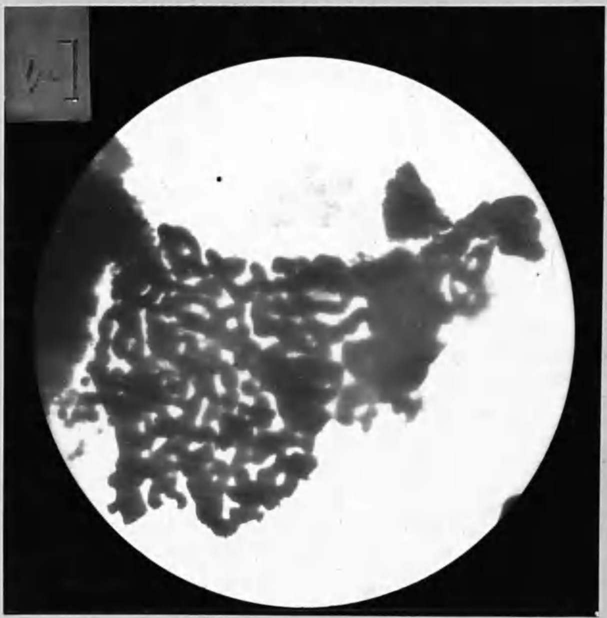


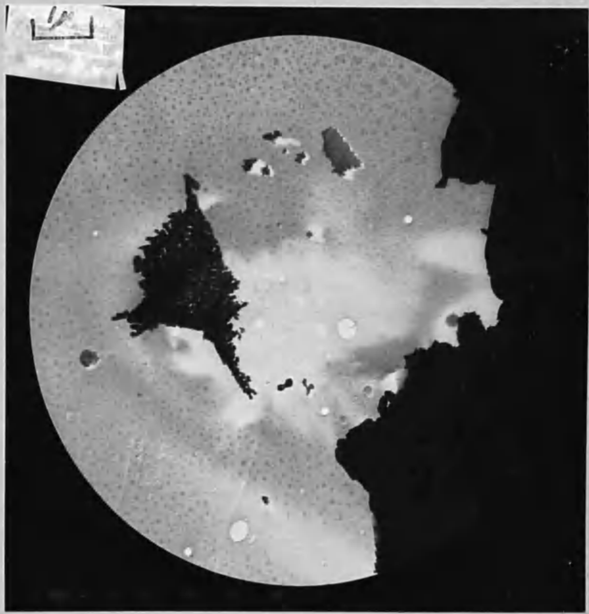
Plate 9.

Electron Micrograph.

Magnification - 8,000 times.

Wood Dust.

Thermal Precipitator Sample.



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Electron Micrograph.

Magnification - 8,000 times.

Wood Dust.

Thermal Precipitator Sample.

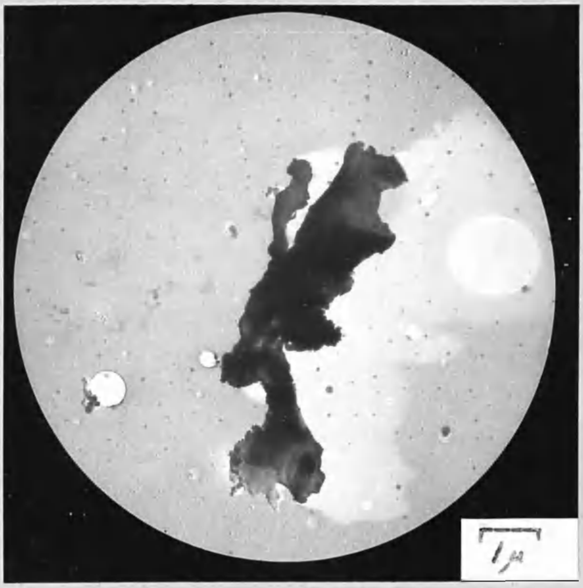


Plate 11.

Electron Micrograph.

Magnification - 8,000 times.

Wood Dust.

Sprayed Sample.

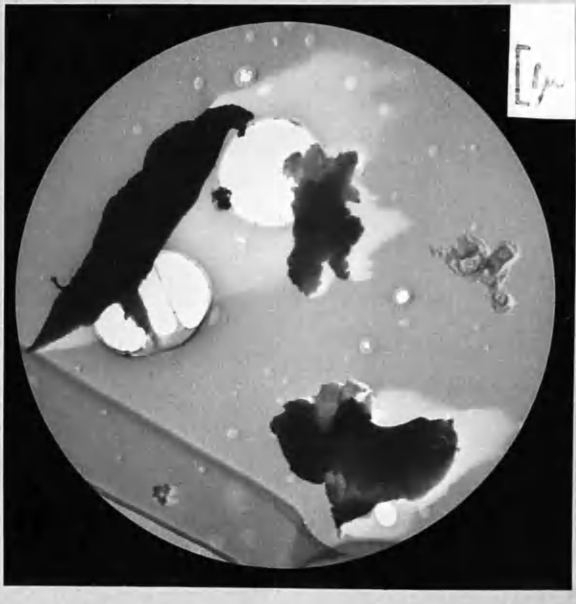


Plate 12.

Electron Micrograph.

Magnification - 8,000 times.

Wood Dust.

Sprayed Sample.

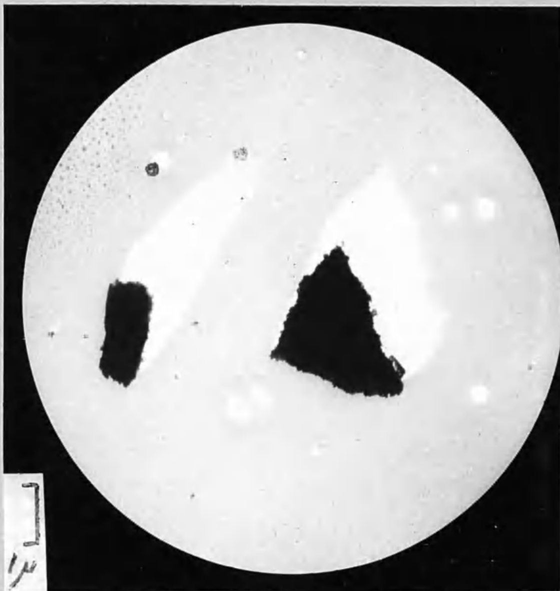


Plate 13.

Plate 14.

Electron Micrograph.

Magnification - 8,000 times.

Abrasive Particles.

Thermal Precipitator Sample.

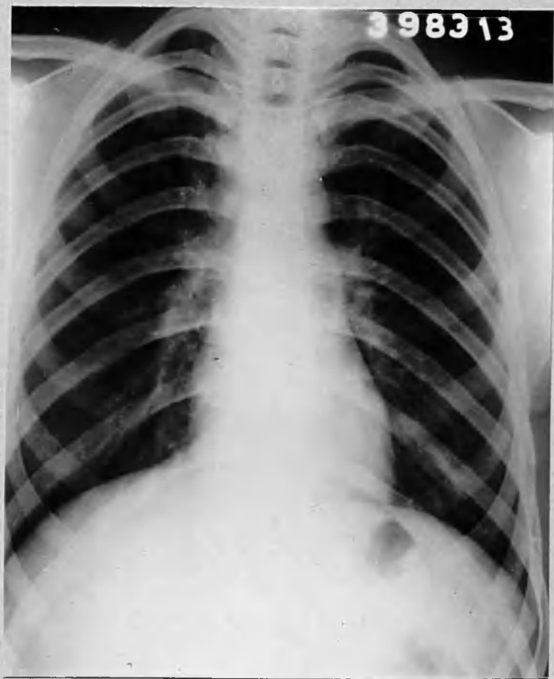


Plate 15.

Plate 16.

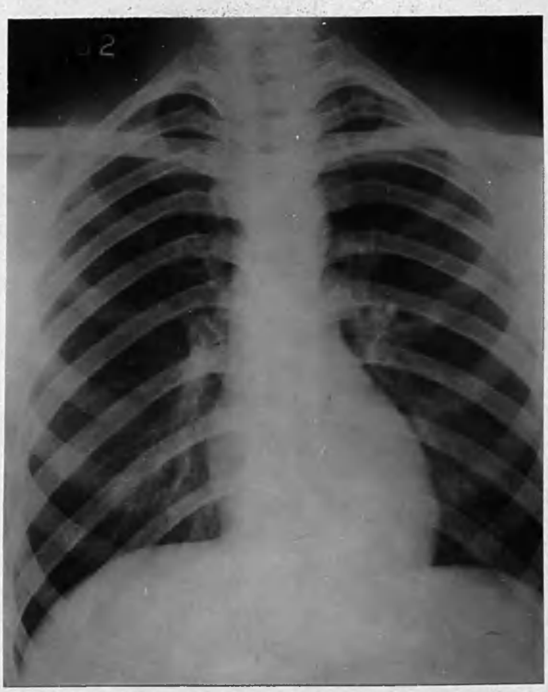


Plate 17.

Plate 18.

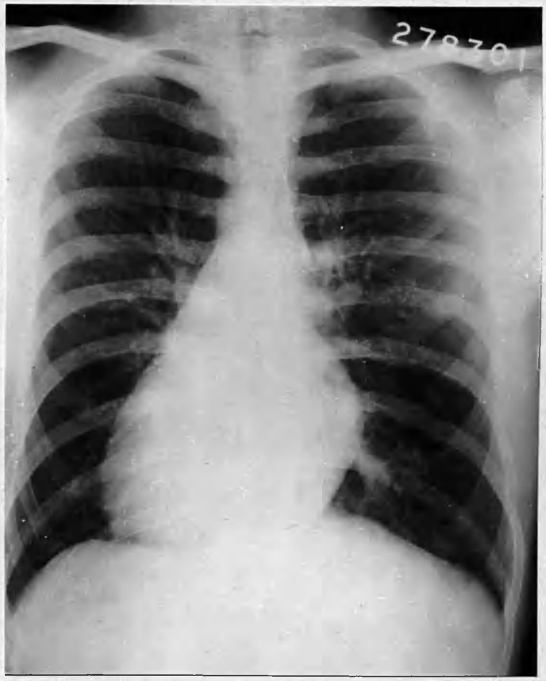


Plate 19a.

Plate 19b.

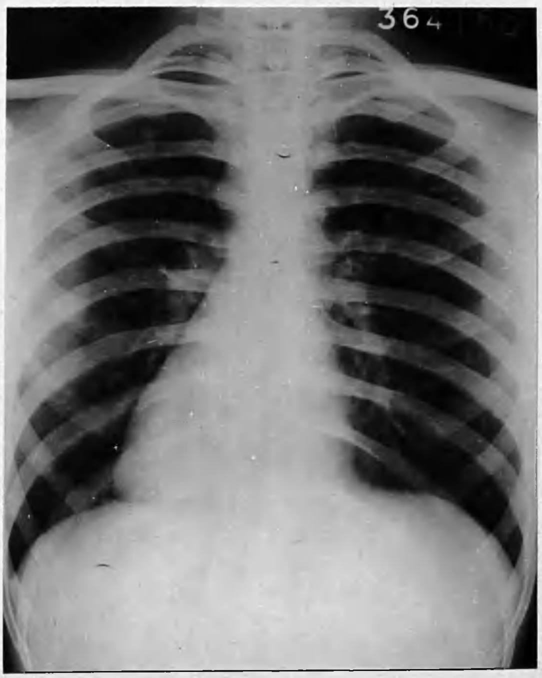


Plate 20a.

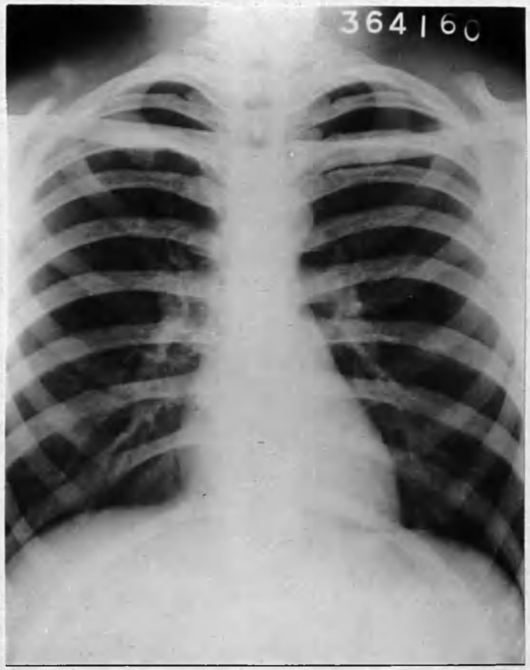


Plate 20b.

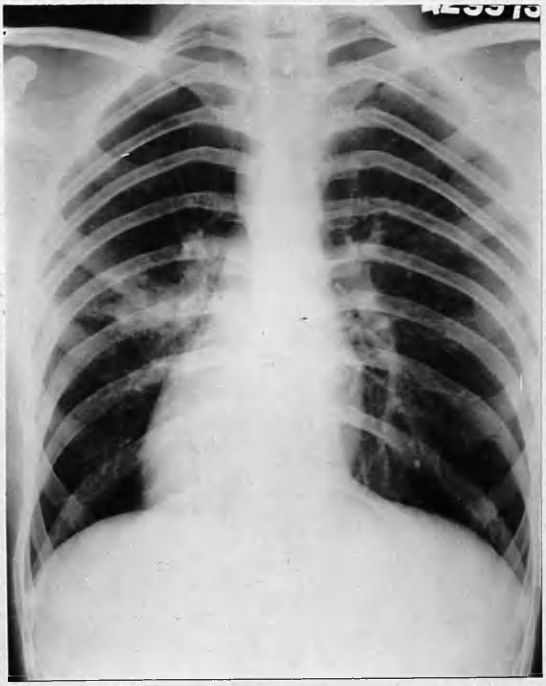
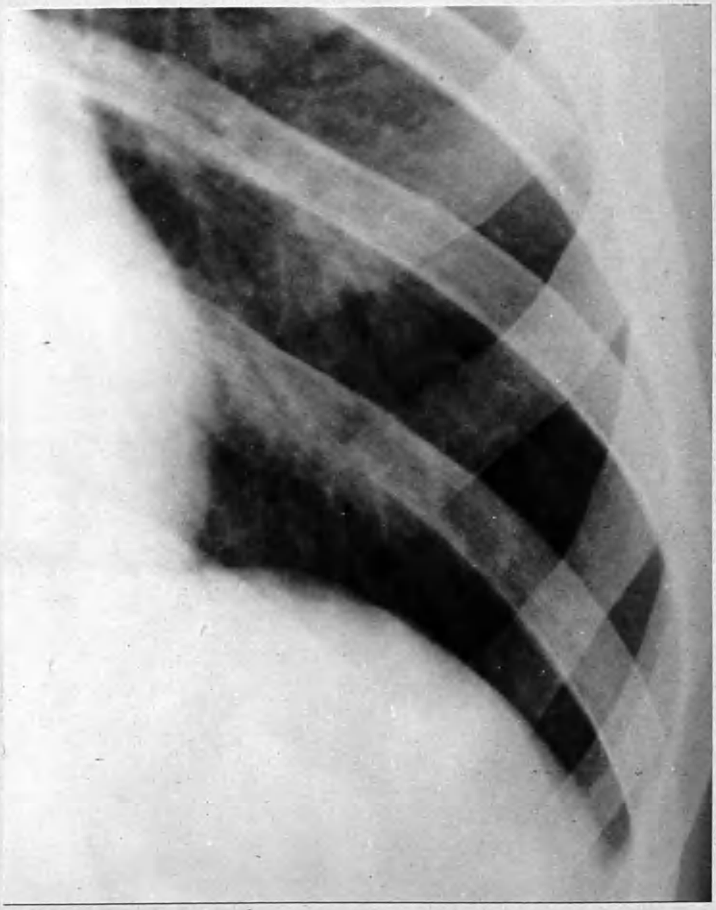


Plate 21a.

Plate 21b.



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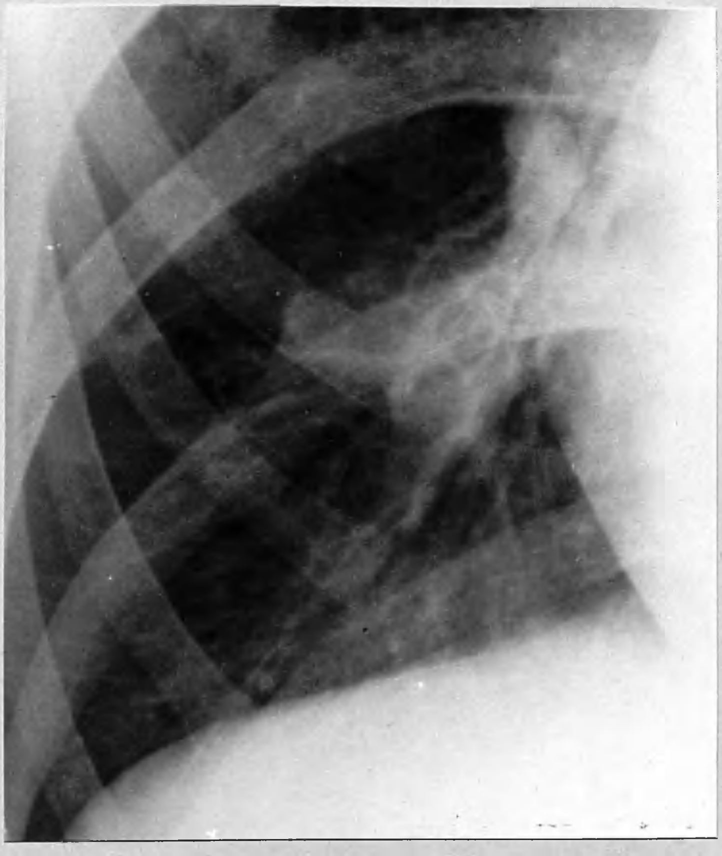

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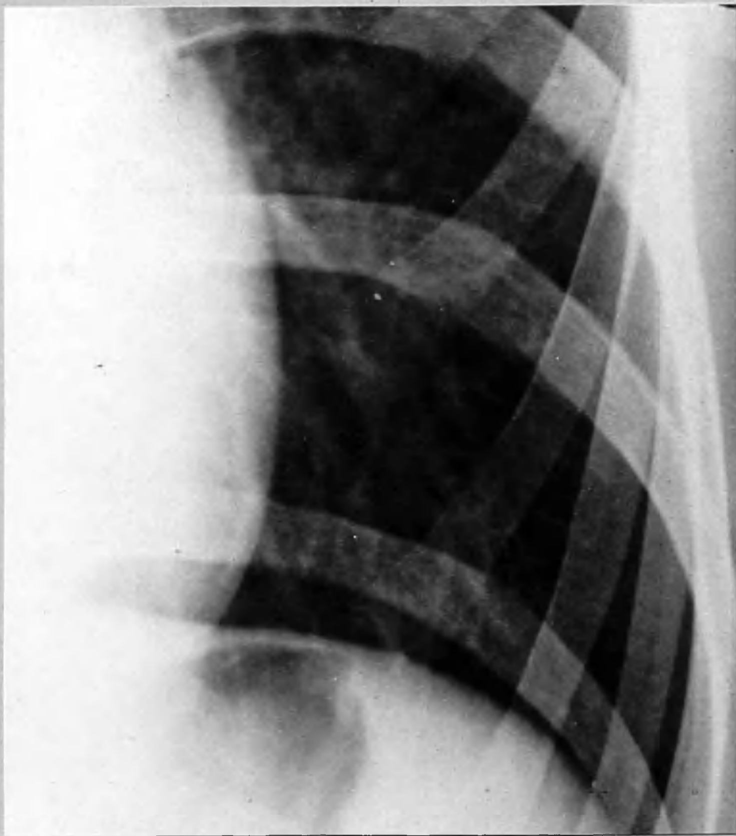

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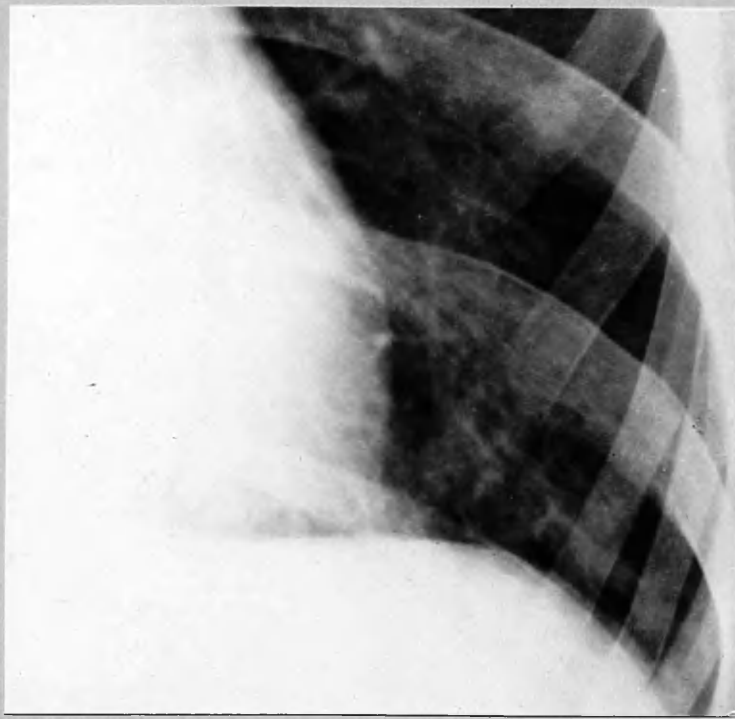

Plate 25.

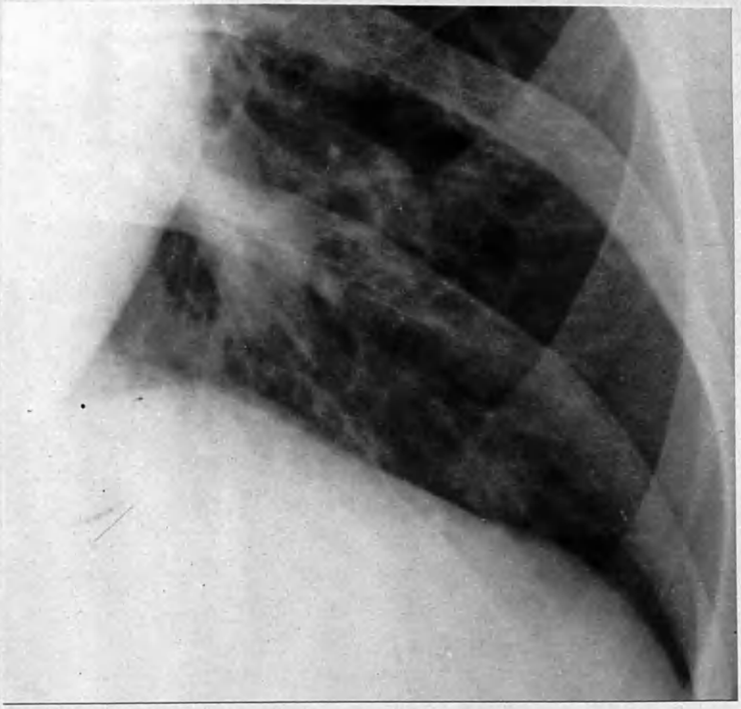

Plate 26.

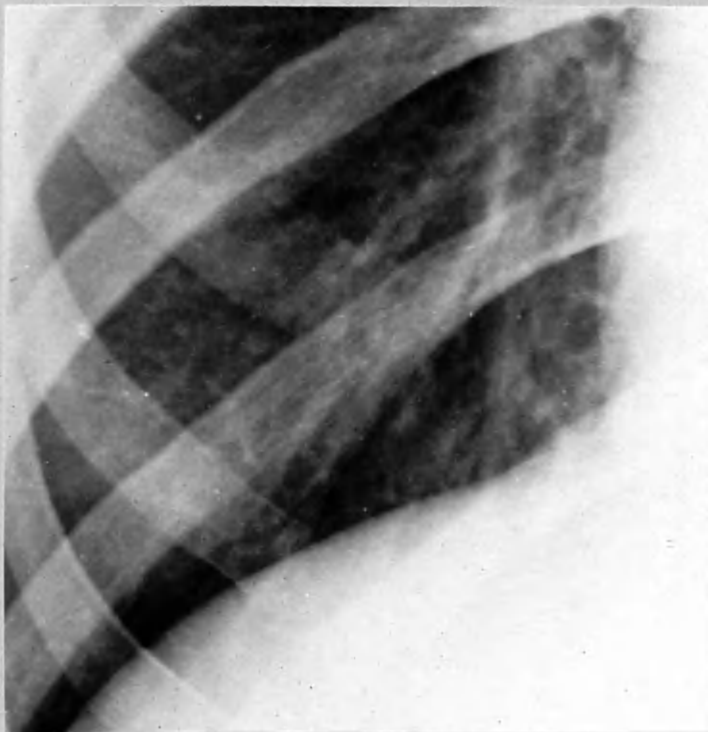

Plate 27.

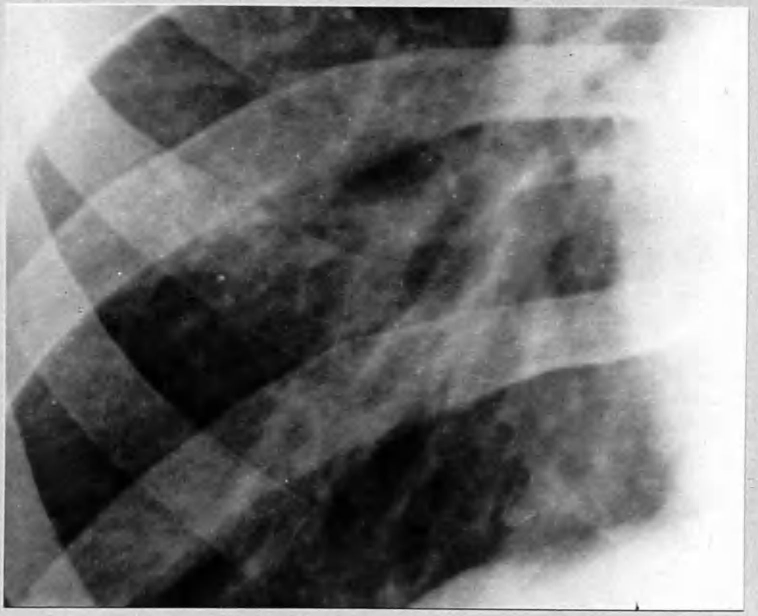

Plate 28.