

OBSERVATIONS ON THE MENINGOCOCCUS CARRIER-RATE IN RELATION TO DENSITY OF POPULATION IN SLEEPING QUARTERS.

BY CAPTAIN J. A. GLOVER, R.A.M.C.

(With 3 Charts.)

THE carrier-rate of epidemic strains of the meningococcus in any military unit is of great importance from the point of view of prevention of cerebro-spinal fever for three reasons:

(1) A high carrier-rate is a storm warning of an approaching outbreak of cases.

(2) It is an index of the danger of cases occurring amongst the civil population, when men from the unit are billeted upon them, or return home on leave, or on demobilization.

(3) It is an admirable index of the hygienic conditions under which the unit lives. In other words, it appears to vary directly with the degree of overcrowding.

Elsewhere I have tried to deal with the first proposition, the second is sufficiently obvious to stand by itself, it is the third proposition that I hope to prove, and I propose in these short observations to deal only with the carrier-rate in relation to overcrowding, and the extraordinary improvement in the carrier-rate, which follows upon the simple remedy of increasing the distance between beds.

Johnson and Treadgold working on Salisbury Plain in the early days of the War, pointed out that the number of positive contacts found in connexion with a case of the disease was directly proportionate to the degree of overcrowding in the conditions of contact, i.e. of housing.

Marked overcrowding was accompanied by a carrier-rate *amongst contacts of cases* of 20 per cent.

Moderate overcrowding by one of 11 per cent., whilst when there was no overcrowding the carrier-rate was six per cent.

Now these figures, which refer entirely to contacts of cases, practically agree with the results of the examinations of more than 4000 *non-contacts*, soldiers of the London District, who for six months have never been near cases of cerebro-spinal fever.

The determination of the carrier-rate of each unit has been done by the examination of samples of 100 men, and, as a rule, the samples examined are not of men taken haphazard from the battalions, but a certain number of sleeping rooms, or huts are taken, and as far as possible *every* man sleeping in these rooms is examined.

A bed chart, showing the relative positions in which the men sleep, is also used, and proves most useful as an index of the amount of cross infection which obtains. Thus, if one finds a group of three or four carriers of the same type of meningococcus in contiguous beds or in the same corner, and other groups of carriers of either meningococci, or organisms resembling meningococci, in other parts of the room, it is pretty certain that cross infection is rife, and such grouping of carriers is more suggestive of unhygienic conditions than the same number of carriers more uniformly distributed.

It was found, for example, that *amongst non-contacts* severe overcrowding in a unit was usually accompanied by a carrier-rate of about 25 per cent. in that unit; moderate overcrowding by one of 12 per cent.; whilst a unit with no overcrowding averaged 5 per cent.

The limits of severe overcrowding are perhaps a little difficult to define on account of the variation in the class of the accommodation, which included barrack-rooms, rooms adapted from empty houses, breweries, loose-boxes and pavilions, huts of different patterns and sizes, and tents, but by far the most important conditions influencing carrier-rate are:

- (1) the distance between the beds,
- and (2) the ventilation.

We may therefore define severe overcrowding as existing, when the beds in the sleeping quarters are less than one foot apart.

It should be observed that the distance between the beds is a more valuable index than floor space. Thus there are two patterns of the ordinary huts 60 feet long, one type 60' × 20', the other 60' × 15'.

Now, on mobilization standard, 30 men can be accommodated in the first and 22 men in the second type, mobilization standard allowing 40 square feet per man of floor space.

The beds in the large pattern with 30 men will be 1 foot 4 inches away from each other (i.e. after allowing for the stove on one side, as is usual), whereas the beds in the smaller type with 22 men will be more than 2 feet 6 inches apart, the floor space in both cases being identical. There is no doubt that if mobilization standard be adhered to, the smaller type is the safer. Unfortunately, the 60' × 15' type with its

long sides offers an apparently irresistible temptation to overcrowding and is almost invariably crowded above its 22 standard and then it is, of course, more dangerous than its larger brother.

In adapted buildings, such as breweries, race-course pavilions and school-rooms, floor space may be very misleading, as obstructions and fixtures may compel the men to lie close together, as may also deficient heating, or the issue of too few blankets compel them to roll up in the same blankets.

It should be remembered that the standard accommodation was laid down by Royal Commission in 1861, after the horrors and scandals of the Crimean War, and was fixed at 60 square feet of floor space, 600 cubic feet air space, and three feet distance between beds.

In the extreme pressure following the outbreak of this War, permission was granted to use a mobilization standard of 40 square feet floor space and 400 cubic feet air space, but nothing was said as to the distance between the beds. It looks like a simple deduction that if the floor space be reduced from 60 square feet to 40, the distance between the beds will be reduced from 3 feet to 2 feet, but it actually happens that in the ordinary barrack-rooms or huts, where sleeping is not feasible, except along the sides, the reduction is more than 50 per cent.

The distance between beds in an ordinary barrack-room on mobilization standard averages 1 foot 4 inches, after allowing for fireplaces, cupboards and doors; and any beds over this reduce it very rapidly.

Thus, in an actual instance, where the peace strength of a barrack-room was 24, 47 men were actually sleeping in it, and the beds instead of being $\frac{3 \times 24}{47} = 1\frac{1}{2}$ feet apart actually were less than 6 inches apart.

The carrier-rate here was 22 per cent.

The peace standard is practically attained in one or two units in my district, and may be considered to have as its index a carrier-rate of 5 per cent. or under.

A strict observance of the mobilization standard has scarcely ever in my experience been accompanied by a rise above 10 per cent.

If, with spacing on a peace standard, we have more than 5 per cent. or more than 10 per cent. with mobilization standard, it is probable that there is something seriously wrong with the ventilation.

If the carrier-rate rises above 20 per cent., gross overcrowding is practically certain, and if the season be winter, an outbreak of cases of the disease is probable and vigorous measures are urgently indicated.

Isolated cases may, of course, occur with any carrier-rate.

Here are some instances demonstrating these relations (Autumn, 1917):

Accommodation	Distance between beds	Floor space in square feet	Ventilation	Carrier-rate per cent.
Old Barrack-rooms grossly overcrowded	6 inches	39	Spoilt by Lighting Regulations	22
Good Barrack-rooms	10 inches	Just under 40	do. do.	28
" " "	10 inches	40	do. do.	38
Vat-room adapted	under 10 inches	Irregular obstructions	Bad	28
Superior pattern huts grossly overcrowded	Practically touching	25	Good	20
Aylwin Huts	Irregular	26 (Note 170.5 cubic space)	Porous and draughty	15
Loose boxes overcrowded	Very close	—	Poor	19
Grand stand overcrowded	Beds along one wall within 9 inches	Large but owing to obstructions much space unavailable	Poor; but large cubic space	14
Huts 60' x 15' some overcrowding (averages 27 men instead of 22)	2 feet	35	Fair	10
Same type hut average 28 and lower ground	Under 2 feet	34	Fair	13
Barrack-rooms (old)	3 feet	60	Good	5
Huts 60' x 20'	2½ feet	53	Special	3

Partitions in huts are undoubtedly bad owing to their multiplying the number of corners, and small sub-divisions limit infection, but at the same time focus it.

One partition in a hut, for example, in addition to increasing the difficulties of through ventilation, doubles the number of corners, and carriers are often found sleeping in the corners of huts, owing, no doubt, to the dead-end character of corner ventilation.

Two instances of small sub-divisions focussing infection may be quoted:

A detachment of 101 men are sent into camp to ease the pressure on an overcrowded barrack in London.

They undoubtedly left London with a high carrier-rate. After a week under canvas all were swabbed.

The general carrier-rate was 16 per cent.

Of the 101 men 60 slept in tents (bell single flap) each holding 8 men or less.

Of these the carrier-rate was 11 per cent.

Forty-one men slept in four tents holding nine, ten, and eleven (two tents thus) each.

Of these the carrier-rate was 22 per cent.

Now consider the distribution in tents: out of thirteen tents four were quite clear of carriers; four had only one carrier; three had two carriers, and two had three carriers.

In only one tent was there a mixture of carriers of different types; this tent had three carriers amongst nine men; two carrying Type II meningococcus and one carrying Type I meningococcus; all the other four tents which had more than one carrier bred true, that is, had them of the same type.

Thus we see in a unit with a general carrier-rate of 16, but divided into small communities, the difference in risk to a susceptible individual may be immense according as he may happen to sleep in a tent free of carriers or in one in which three out of the nine occupants are carriers.

Another example is furnished by a detachment sleeping in Aylwin huts, 8 to a hut, in December. Fifteen per cent. was the carrier-rate, and it is somewhat surprising that the figure was not higher as the floor space with 8 men in an Aylwin hut is only 26 square feet and the cubic space only 170·5. These so-called huts are probably safer than they would appear, owing to the porous nature of their material and the numerous leaks, etc., through which copious draughts of fresh air continually pour. They really approximate much more to tents than huts.

Now, on analysing this 15 per cent., it was found that out of twelve huts, three were free of carriers, four had only one carrier, whilst one hut had three carriers amongst its eight men and one had four.

The chances of a susceptible individual contracting cerebro-spinal fever when he is introduced into such a community as the last mentioned hut, half of whom are carriers housed with 26 square feet of floor space and 170·5 cubic feet of air space must be considerable in the month of December, and on the results being reported, the conditions were immediately remedied.

Two examples may be quoted of the interesting effect of partitions in huts and rooms.

The first is a hut of the usual dimensions, 60' × 20', but of superior construction, and with larger windows of the French window type. It had a partition dividing it into two. In this hut which, on mobilization standard, should have accommodated thirty men, forty-two men were sleeping, eighteen in one side and twenty-four in the other, instead of fifteen in each compartment.

Four of the eighteen on one side of the partition were carriers, two sleeping side by side.

Of the twenty-four in the other compartment, only twenty-two were examined, and of these nine were carriers with no less than six Type I carriers in adjacent beds on one side of the hut. A clearer case of cross infection could not be imagined.

It will be observed that the carrier-rate of one half is 22 per cent., that of the more severely overcrowded half is 37 per cent.

To show the possible influence of a partition in a room under fair conditions, and to demonstrate what can be found out sometimes by examining closely the results of a sample: 100 men of one battalion were examined, the number being made up of fifty men sleeping in cubicles and well spaced out small rooms; none of these men were carriers. Thirty-four of the remainder came from one barrack-room, which was divided by a partition into inner and outer parts with seventeen men in each. The inner portion was the smaller and in one place the beds were only about 1 foot apart. There was one carrier in the outer part and three in the inner. Therefore, although the whole sample showed the excellent carrier-rate of 4 per cent., yet here was a compartment in the barracks with a carrier-rate of 18 per cent., and obviously a source of potential danger.

THE EFFECT OF INCREASING THE DISTANCE BETWEEN BEDS UPON THE CARRIER-RATE.

That Cerebro-spinal Fever is a disease of which the occurrence is favoured by overcrowding has long been accepted—it is probably impossible to find an infectious disease which is not—and, as the infection is almost certainly conveyed in droplets of mucus in the acts of coughing, sneezing, and loud speaking, it is obvious that by increasing the distance between beds the likelihood of infection passing from man to man will be diminished.

This obvious truth, however, hardly prepares us for the extraordinary improvement in the carrier-rate in a unit, produced by quite a small increase in the distance between beds in a short time, even when that unit has already been heavily infected.

Full mobilization standard means in most barrack-rooms and huts a distance between beds of 1 foot 4 inches, and this, even rigidly carried out, is not sufficient to produce a rapid improvement in an already high carrier-rate.

On the other hand, at the present time, the peace standard of 3 feet between beds, even in a heavily infected unit, seemed almost unattainable, owing to the demands on accommodation.

A purely arbitrary standard midway between, was therefore selected, and the beds being $2\frac{1}{2}$ feet across, $2\frac{1}{2}$ feet was selected as the space between. In a $60' \times 20'$ hut this allows twenty-three men (or twenty-four if the stove be not working), to sleep without the side of any bed being less than $2\frac{1}{2}$ feet from that of its neighbours, and each man has approximately 53 square feet of floor space (with twenty-three men).

In a $60' \times 15'$ hut, mobilization standard, if strictly enforced, only allows twenty-two men, so that with such a hut, there is no difficulty in attaining the desired distance.

A similar provisional standard was attempted with barrack-rooms, and in every case attempts were also made to increase the ventilation, by the fixation of windows, some being converted by wooden sides to fixed hopper ventilators.

The improvement was remarkable and occurred in all classes of accommodation, Aylwin huts, and loose boxes, as well as in the better kinds of housing, although not quite to the same extent.

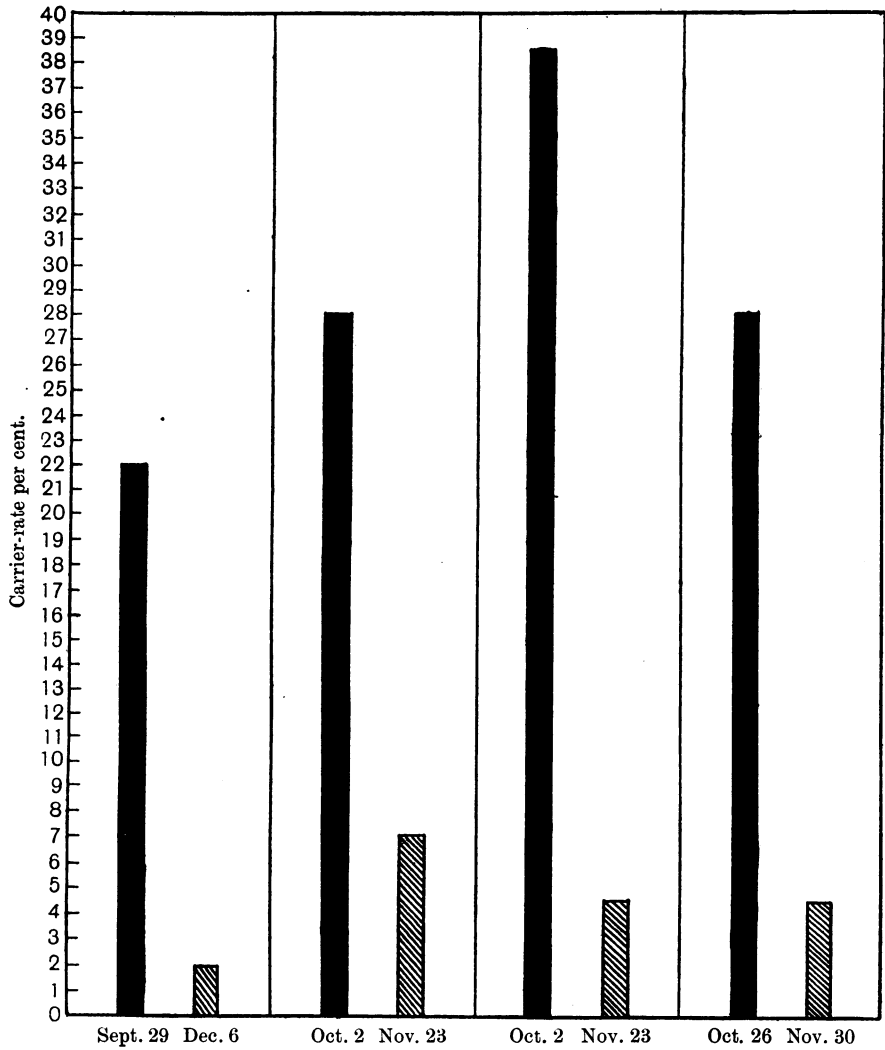
The greatest improvements were shewn in barrack-rooms and in the $60' \times 20'$ huts.

The very remarkable results with barrack-rooms are shewn upon the Chart A.

*Effects of spacing out on the Carrier-rate in severely overcrowded
BARRACK ROOMS.*

Carrier-rate per cent. before spacing out	Weeks spaced out	Carrier-rate per cent. after spacing out
22	8	2
28	6	7
38.5	6	4.5
28	5	4.5
Huts (previously just over mobilization standard)		
17	8	3
Loose Boxes		
19	7	

CHART A. *Effect of "spacing-out" Barrack Rooms.* Shewing carrier-rate per cent. before "spacing-out"—black columns, and after 'spacing-out'—shaded columns.



AYLWIN HUTS.

These are extremely interesting as they belong to the same unit as the second barrack-room shewn above. They remained overcrowded (eight men per hut) all through the same six weeks, during which the barrack-rooms were first spaced out and in which the barrack-room population showed a decrease of carrier-rate from 28 to 7 per cent.

They showed a carrier-rate of 12 per cent. at the beginning of this six weeks (October to mid December), and one of 15 per cent. at the end, and the dangerous distribution of carriers, to which reference has already been made: in other words, whilst the spaced out barrack-rooms improved so much that they had only a quarter of their first percentage of carriers, the Aylwin huts showed a percentage raised from 12 to 15.

The Aylwin huts were then spaced out by removing three men from each, leaving five men, who would, thus, each have 41 square feet floor space and 272 cubic feet air space.

It is impossible to say how far the beds were apart, as each Aylwin hut is a law unto itself.

After this arrangement had been in force five weeks, they were again examined and the carrier-rate found to be 6 per cent. Moreover, no hut had more than one carrier in it.

This plan of spacing out the beds to a distance of two and a half feet between each has been carried out in a very thorough way at one large hutment camp with most excellent results up to the present, but I am anxious to get through the dangerous months of the winter and early spring before speaking with too great confidence. I am told, however, that the general health of the camp has improved immensely. The spacing out, of course, tends to diminish all catarrhal diseases.

For the success of such a scheme everything depends on the interest and co-operation of the Officers of the unit. A barrack-room may be spaced out, and in any case the men will get the benefit of additional air-space, but the full benefit will not be obtained if men are allowed to move their beds close together for warmth or company. In one unit, which had a great success in reducing its carrier-rate, scale plans were prepared and the exact position of each bed drawn.

This enthusiastic unit, unfortunately, and for no fault of its own, furnished an example of the return of the carrier-rate to a higher level when overcrowding became again prevalent. Examining the men in the same rooms, it was found that with a total of 593 men in the barracks

(which just allowed a proper spacing out) these rooms showed a carrier-rate of 4.5 per cent. : after six weeks of gradually increasing overcrowding (the total rising to 803 at the date of the second swabbing), the carrier-rate had risen to 11 per cent.

In these short notes I have not dealt with the question of ventilation, not because it is not equally important with spacing out, but because its importance is much more generally realized, and because many recent War Office Orders have dealt with it.

It must be realized, however, that in many camps and barracks, the "reduced lighting" orders have been dealt with in ways which most seriously interfere with the ventilation of both barrack-rooms and huts, and this accounts for much of the increase in the military carrier-rate, as well as of that in the incidence of pulmonary tubercle.

I should again point out that all carrier-rates given in the preceding figures include only those men carrying meningococci which agglutinate with one or other of the four standard sera issued by the Central Cerebro-spinal Fever Laboratory.

SUMMARY.

1. A high meningococcus carrier-rate in a military unit denotes that dangerous overcrowding exists in this unit.

2. Severe overcrowding (i.e. when beds are less than 1 foot apart) is usually accompanied by a carrier-rate (serological) of at least 20 per cent.

(Twenty per cent. is the danger line indicated in the War Office Memorandum on Cerebro-spinal Fever, March 1917.)

3. A carrier-rate of this height will usually imply that the mobilization standard of 40 square feet has been infringed, and also that beds are less than 1 foot apart.

4. A carrier-rate of 20 per cent. (without awaiting the occurrence of any actual cases of the disease) should be regarded as a signal for prompt and effective action to abolish overcrowding, and to improve ventilation, and to increase the distance between the beds to at least $2\frac{1}{2}$ feet.

5. The distance between beds is of paramount importance.

6. Carrier-rates of between 10 and 20 per cent. are unsatisfactory and imply a certain degree of overcrowding. They must be watched with suspicion, and the mobilization standard strictly enforced.

7. Under the same conditions of overcrowding "non-contact" carrier-rates are the same as "contact" carrier-rates.

8. Quite a moderate degree of "spacing out" of beds, combined with simple methods for improving ventilation are highly efficient agents in reducing high carrier-rates.

9. When, however, a unit shows a high carrier-rate, insistence on the restoration of the mobilization standard is not sufficient.

"Spacing out" must be carried further; and a distance of at least $2\frac{1}{2}$ feet between beds insisted on.

The "peace" standard of 3 feet between beds and 60 square feet of floor space with 600 cubic feet of air space would, of course, be still more effective.

10. The mobilization standard, introduced for a grave emergency, is the lowest possible concession to military necessity, which can be allowed with safety.

The charts B and C shew the occurrence of cross infection from bed to bed, in barrack-room and hut respectively.

In the barrack-room B, which was adapted from a brewery vat-room, although the floor space and cubic space appear ample yet, owing to fixtures and obstructions, the beds were placed within 9 inches of each other.

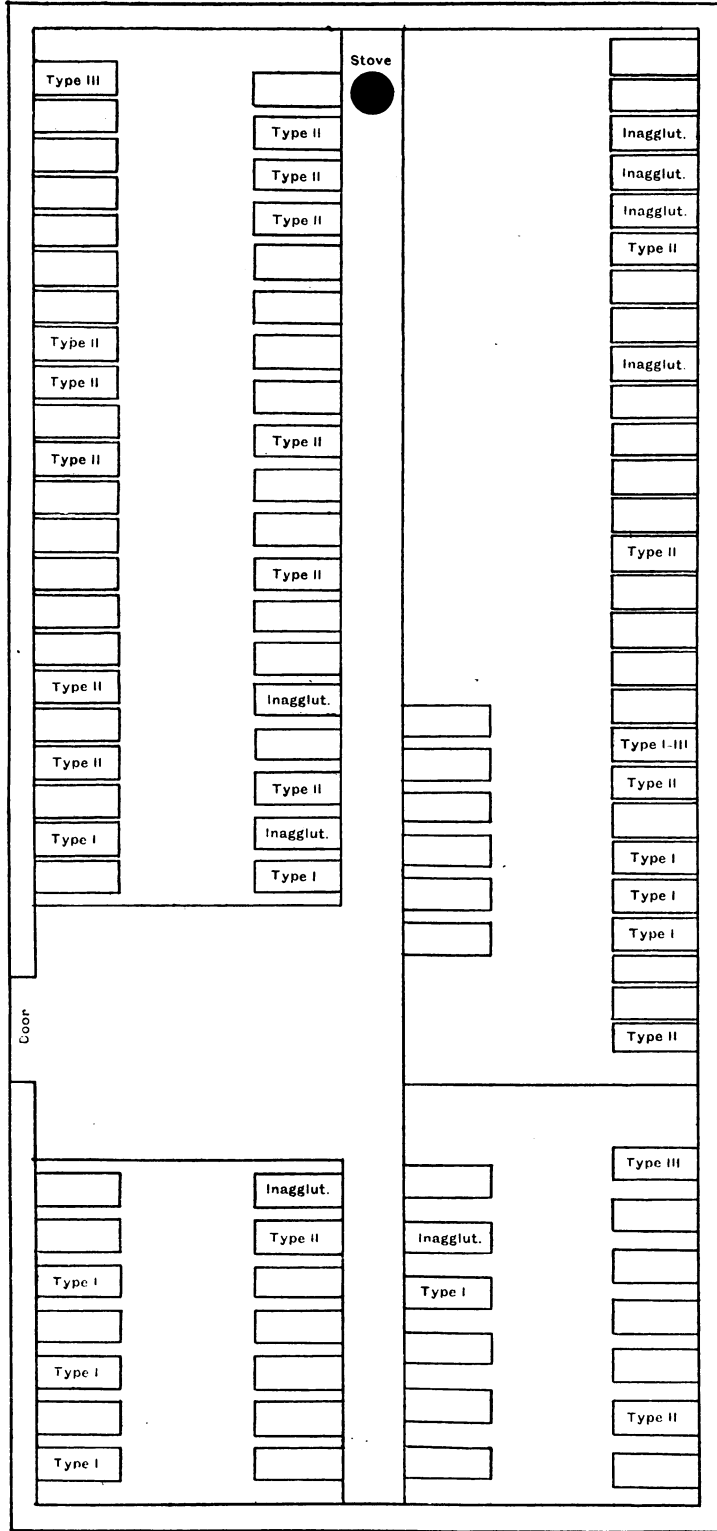
Windows were plentiful but of such a pattern that it was impossible to open them without a fearful down-draught, and they were, doubtless, kept shut by night.

The heating apparatus consists of one poor stove at one end, and the cold resultant would contribute to this shutting of windows.

The groups of carriers of Type I meningococcus, of Type II meningococcus, and of organisms resembling meningococci, which do not agglutinate, in adjacent beds or close to each other in corners, are very striking.

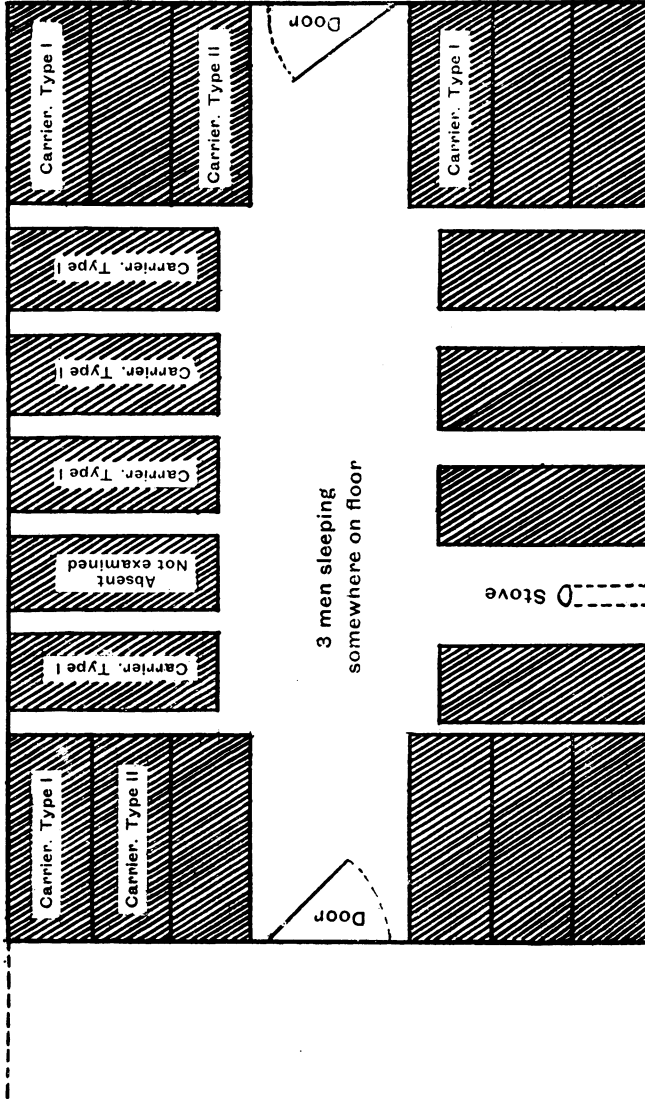
Remarkable improvement followed spacing out, and the fixation of some of the windows, which were converted by a simple method into hopper-side ventilators.

CHART B. *Cross Infection due to proximity of Beds.*



This large Barrack-room was adapted from a Brewery Vat-room. Much of the floor space was not available for sleeping owing to obstructions, etc. Plenty of windows, but owing to their make causing intolerable down-draughts these were not opened at night. Heating by one totally inadequate stove. Note the grouping of carriers of the same type of meningococcus particularly in corners and near the stove.

CHART C. *Cross-infection due to overcrowding.* Plan of half an overcrowded hut which was divided by a complete partition (with a door) into two halves each 30' x 20'—showing the distribution of carriers.



Owing to the doors, the beds on the short sides are actually in contact. The hut was of superior type to the ordinary army pattern and the windows were of a different pattern.

In addition to the bed boards shewn, all of which were occupied, three men slept on the floor.

Each man had, therefore, only 25 sq. ft. of floor space.

Scale: — = 1 1/4 feet.