FURTHER OBSERVATIONS UPON VACCINATION AT WOOLWICH, 1926-27.

BY M. D. MACKENZIE, M.D.,
Medical Officer, Ministry of Health.
AND
CAPTAIN E. H. W. ELKINGTON,
Royal Army Medical Corps,

SECTION I.

These observations are a continuation of the preliminary report published in the September number of the Journal, 1928, and cover the work carried out at Woolwich up to July, 1927. This section deals with the clinical characteristics of primary vaccination in the adult, and how far these are modified by movement of the vaccinated arm.

DESCRIPTION OF AN AVERAGE CASE OF PRIMARY VACCINATION.

Day of Vaccination.—There is little change in the appearance of the insertions during the first twenty-four hours.

First Day.—On the first day there is a faint reddening along the edges and ends of the insertions. There appears to be no change in the blood-count. Average size of areole 21.56 square millimetres. Average maximum temperature 98.8° F.

Second Day.—On the second day the area of redness has increased to about double that of the first day, there being a definite bright red areola round each insertion. The temperature previously normal now falls
Further Observations upon Vaccination at Woolwich

slightly. There is no change in the red or total white blood-count, but with the fall of temperature there is a slight rise in the number of large and small lymphocytes, the increase being chiefly in the small. Areolae 48·2 sq. mm. Temperature 98·3° F.

Third Day.—On the third day the areolae have again increased in area to about twice that of the previous day. There is now usually a small red papule at the site of each insertion. The temperature remains subnormal and is slightly lower than on the previous day. There is a still further proportionate increase in the number of lymphocytes. Areolae 84·3 sq. mm. Temperature 98·2° F.

Fourth Day.—On the fourth day the areolae have still further increased in size. The papules have become vesicles. The temperature reaches its lowest point in its subnormal phase (about 98° F.). There is slight tenderness of the lymphatic glands in the axilla. There is still further increase in the lymphocytic count which now reaches its maximum (usually about 48 per cent of the total white count). The site of the vaccination is frequently “itchy.” Areolae 150·8 sq. mm. Vesicles 55·25 sq. mm. Temperature 98·1° F. Splenic enlargement 0·5 inch.

Fifth Day.—Again the areolae show a regular increase; the vesicles continue to increase in size, but at a slower rate. The temperature begins to rise and is generally slightly above normal. With the rise of temperature there is a decrease in the lymphocytes with a corresponding relative polymorphonuclear increase. There is no marked leucocytosis. The axillary glands are tender and palpable. The patient complains of a feeling of malaise with some headache. Areolae 277·3 sq. mm. Vesicles 89 sq. mm. Temperature 98·6° F. Splenic enlargement 0·75 inch.

Sixth Day.—The areolae continue to increase in size. The vesicles steadily enlarge and are now sharply defined, with slightly raised edges and central umblication. The vesicular contents are limpid fluid. The temperature continues to rise and is generally about 99° F. The blood-picture is practically normal. The constitutional symptoms become more marked and complaints of headache are common. The axillary glands are further enlarged and tender and the spleen is frequently palpable on deep inspiration. Areolae 437·2 sq. mm. Vesicles 136 sq. mm. Temperature 99° F. Splenic enlargement 1 inch.

Seventh Day.—The steady increase in size of the areolae continues with a corresponding increase in that of the vesicles, which are now filled with a slightly turbid fluid. The temperature continues to rise slowly, the blood shows no constant change from normal. The headache is often severe, and there is considerable enlargement and tenderness of the axillary glands. The spleen is often palpable. Areolae 975·9 sq. mm. Vesicles 197 sq. mm. Temperature 99·2° F. Splenic enlargement 1·5 inches.

Eighth Day.—On the eighth day there is a marked increase in the size of the areolae, which now generally coalesce. The vesicles maintain a steady increase in size, the fluid being now almost purulent in appearance.
There is a sharp rise of temperature (frequently to over 100° F.). The red and total white blood-counts remain normal, but with the rise of temperature there is a fall in lymphocytes. The constitutional symptoms are more marked. The arm is generally painful and the skin in the neighbourhood of the vesicles is swollen and indurated. The glands in the axilla are often very painful, and the spleen usually reaches its maximum enlargement on this day. Areole 5,318.5 sq. mm. Vesicles 251 sq. mm. Temperature 100°7 F. Splenic enlargement 1-15 inches.

Ninth Day.—The four areolæ have given place to one, which continues to increase in size. The vesicles, now definitely purulent, are still increasing in size and the centres are markedly depressed. The temperature reaches its maximum of about 101° F. The blood still shows a relative diminution in lymphocytes. There is no marked leucocytosis. Constitutional symptoms are at their height. The arm in appearance is much like that of the previous day, but the local conditions are more pronounced. The glands in the axilla are still painful and enlarged. The spleen is often palpable. Areola (now one) 11,092.2 sq. mm. Vesicles 335.3 sq. mm. Temperature 100°9 F. Splenic enlargement 1.25 inches.

Tenth Day.—The areolæ continue to increase. The vesicles begin to show signs of drying up in the centre. The temperature commences to fall and the patient feels much better. With the fall in temperature there is a relative increase in lymphocytes. The constitutional symptoms disappear, and there is little, if any, pain in the axillary glands, though these are usually enlarged. Areola 11,513.36 sq. mm. Vesicles 416.36 sq. mm. Temperature 100°47 F. Splenic enlargement 1.23 inches.

Eleventh Day.—The areola has now reached its maximum. The vesicles are definitely scabbing, but there is still purulent fluid at their circumference. There is a rapid fall of temperature. The lymphocyte count varies between forty per cent and forty-six per cent of the total white count. Although the local reaction is still marked, there are no constitutional symptoms and the patient feels well. The spleen cannot ordinarily be felt. Areola 18,720.14 sq. mm. Vesicles 480.00 sq. mm. Temperature 99.5° F. Splenic enlargement 1.25 inches.

Twelfth Day.—There is some fading of the areola. The vesicles are now at their maximum size of about 500 square millimetres, an almost constant aggregate area for four insertions, each seven millimetres long. The temperature continues to fall. Areola 13,577.33 sq. mm. Vesicles 511.38 sq. mm. Temperature 99.11° F. Splenic enlargement 1.00 inches.

Thirteenth Day.—The areola has now practically disappeared except in the immediate vicinity of the scabs, which are now complete and dark brown in colour. The temperature is normal.

After twenty to twenty-four days the scabs come off, leaving deep purple pitted scars, which fade in colour in the course of the following four to six months.
Further Observations upon Vaccination at Woolwich

Divergencies from the Average.

Local.—The average daily measurement of the areolae in twenty-six patients shows that the area of the areolae increases rapidly from the seventh day after vaccination, reaching its maximum on the eleventh day and falling rapidly afterwards. The vesicles were first observed late on the fourth day in 65 per cent of cases, and in the remaining 35 per cent on the fifth day. The average maximum size is reached on the twelfth day. Scab formation began as early as the eighth day in one case, and as late as the twelfth day in two cases, but in the majority scabbing began on the eleventh day. It is interesting to note that vesiculation first appeared at a time corresponding with the end of the initial fall of temperature, which for want of a better name may be termed the negative phase. The maximum temperature is reached two days before the area of the areola is at its maximum, and three days before the vesicles attain their greatest size.

General.—Certain general symptoms were complained of. Pain in the left axilla, with definite palpable enlargement of the axillary glands, was common to all; and in practically all cases there was headache and a general feeling of malaise. Two cases complained of sore throat, beginning on the sixth and tenth days respectively; there was slight injection of the pharynx and tonsils which lasted for two days. Of the general symptoms headache was the most severe; it was usually frontal, but occasionally occipital.

Temperature.—The four-hourly temperature charts of twenty-eight cases particularly examined give very similar pictures. The average maximum daily temperature shows that there is a definite fall from the second day, reaching its lowest point, 98·1° F., on the fourth day. Thence the temperature gradually rises to a maximum of 100·9° F. on the ninth day, the temperatures for the eighth and tenth days showing a drop of 0·2° F. and 0·4° F. respectively. The normal is reached on the thirteenth day. The highest temperature shown by any of the twenty-eight cases was 104·2° F. on the ninth day. There were only three whose temperatures never went as high as 100° F. In eighteen of the remaining twenty-five the maximum temperature was 102° F., or higher.

Spleenic Enlargement.—During the examination, on the eighth day after vaccination, of a patient who complained of headache and abdominal discomfort, it was found that he had an enlarged and tender spleen. After this observation, made by Captain Elkington, R.A.M.C., who was in clinical charge of the cases, a daily examination of the abdomen throughout the course of vaccinia in thirty-one consecutive cases was made; in twenty-one of these cases there was definite temporary palpable enlargement of the spleen. In all cases in which the spleen was enlarged to the extent of one inch or more below the costal margin, there was tenderness on palpation. In one case, where the lower edge extended to two and a half inches below the costal margin, there was severe pain of a pleuritic character.

In two cases the enlargement was palpable as early as the fourth, in
two on the fifth, in three on the sixth, in three on the seventh, in six on the
eighth, in three on the ninth, and in two on the tenth day after vaccination.
In the two patients who showed enlargement on the fourth day, the spleen
reached its maximum enlargement (about two and a half inches below the
costal margin) on the eighth day and was still palpable on the thirteenth
day. The longest time for which the spleen was palpable was ten days,
and the shortest one day; the average number of days on which the spleen
could be felt in the twenty-one cases was 2·25 days, and the average
maximum enlargement occurred on the eighth day after vaccination.
Table XII summarises the relationship between the size of the areolæ and
vesicles, the average daily maximum temperature, and the average splenic
enlargement.

<table>
<thead>
<tr>
<th>Day of observation</th>
<th>Average size of areola in 26 cases in sq. mm. (approx.)</th>
<th>Average size of vesicle in 26 cases in sq. mm.</th>
<th>Average maximum daily temperature Fahrenheit in 28 cases</th>
<th>Average splenic enlargement in 21 cases in inches (only approximate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st...</td>
<td>21·65</td>
<td>--</td>
<td>98·82</td>
<td>--</td>
</tr>
<tr>
<td>2nd...</td>
<td>48·23</td>
<td>--</td>
<td>98·25</td>
<td>--</td>
</tr>
<tr>
<td>3rd...</td>
<td>84·80</td>
<td>--</td>
<td>98·21</td>
<td>--</td>
</tr>
<tr>
<td>4th...</td>
<td>150·64</td>
<td>55·25</td>
<td>98·10</td>
<td>0·5</td>
</tr>
<tr>
<td>5th...</td>
<td>277·38</td>
<td>89·00</td>
<td>98·67</td>
<td>0·75</td>
</tr>
<tr>
<td>6th...</td>
<td>437·23</td>
<td>136·00</td>
<td>99·00</td>
<td>1·0</td>
</tr>
<tr>
<td>7th...</td>
<td>975·62</td>
<td>197·4</td>
<td>99·27</td>
<td>1·5</td>
</tr>
<tr>
<td>8th...</td>
<td>5,318·50</td>
<td>251·15</td>
<td>100·72</td>
<td>1·75</td>
</tr>
<tr>
<td>9th...</td>
<td>11,092·28</td>
<td>335·98</td>
<td>100·99</td>
<td>1·25</td>
</tr>
<tr>
<td>10th...</td>
<td>11,513·36</td>
<td>416·36</td>
<td>100·47</td>
<td>1·23</td>
</tr>
<tr>
<td>11th...</td>
<td>18720·14</td>
<td>450·00</td>
<td>99·5</td>
<td>1·25</td>
</tr>
<tr>
<td>12th...</td>
<td>13,577·33</td>
<td>511·38</td>
<td>99·11</td>
<td>1·0</td>
</tr>
<tr>
<td>13th...</td>
<td>11,870·42</td>
<td>506·34</td>
<td>98·57</td>
<td>0·9</td>
</tr>
<tr>
<td>14th...</td>
<td>9,491·20</td>
<td>472·84</td>
<td>98·17</td>
<td>0·8</td>
</tr>
</tbody>
</table>

**TABLE XII.**—The average daily red and white blood-count in seven men on
successive days after vaccination made by Capt. Preston, R.A.M.C.

<table>
<thead>
<tr>
<th>Day after vaccination</th>
<th>Red blood-count</th>
<th>White blood-count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>5,078,571</td>
<td>5,731</td>
</tr>
<tr>
<td>2nd</td>
<td>5,171,428</td>
<td>5,298</td>
</tr>
<tr>
<td>3rd</td>
<td>5,228,570</td>
<td>6,600</td>
</tr>
<tr>
<td>4th</td>
<td>5,471,428</td>
<td>6,428</td>
</tr>
<tr>
<td>5th</td>
<td>5,443,858</td>
<td>5,371</td>
</tr>
<tr>
<td>6th</td>
<td>5,314,285</td>
<td>6,371</td>
</tr>
<tr>
<td>7th</td>
<td>5,414,285</td>
<td>6,242</td>
</tr>
<tr>
<td>8th</td>
<td>5,029,571</td>
<td>5,785</td>
</tr>
<tr>
<td>9th</td>
<td>5,785,714</td>
<td>7,142</td>
</tr>
<tr>
<td>10th</td>
<td>6,057,142</td>
<td>7,257</td>
</tr>
<tr>
<td>11th</td>
<td>5,514,285</td>
<td>6,285</td>
</tr>
<tr>
<td>12th</td>
<td>6,260,000</td>
<td>5,400</td>
</tr>
<tr>
<td>13th</td>
<td>5,290,000</td>
<td>6,120</td>
</tr>
</tbody>
</table>

**Blood Changes.**—Observations on the red and white blood-cells of seven
cases have been made. On the day following vaccination a total red and
white blood-count was done in each case and repeated each day for twelve days. The observations on the differential count were made on a series of twelve cases. In both series the blood was taken at the same hour each day. A summary of the results of the red and white blood-counts is shown in Table XIII. There appears to be no marked change in the red count during the progress of vaccinia. No leucocytosis was observed. In the differential count the ratio of the polymorphonuclear leucocytes to the lymphocytes appears to vary inversely with the temperature. With the fall of temperature which immediately follows vaccination, there is a rise in the lymphocyte count to about forty-eight per cent. The number of lymphocytes increased as the temperature fell, and conversely.

Rashes.—A local scarlatiniform rash caused by the strapping used to keep the dressings in position was a common feature seen early in the present year. When this cause had been recognized and the strapping was no longer used, this rash ceased to occur.

There are, however, other rashes associated with vaccinia. These appear generally about the ninth or tenth day after vaccination, whereas those due to the strapping appeared at an earlier date (fourth or fifth day).

The later rashes, which appear independently of the type of dressing employed, fall into one of three groups, viz., papulo-vesicular rashes (generalized vaccinia), true serum rashes, and erythematous rashes which may be localized or general and which may or may not be partially hemorrhagic.

The pustular type of rash is the commonest and often closely resembles the acne pustules commonly found in young adults. The lesions may be distributed largely on the vaccinated arm or may be found only on the back, arms or face. The individual lesions ordinarily commence as papules, become vesicular and finally pustular, but a large number abort in the papular stage. This eruption is not associated necessarily with an unduly severe reaction on the arm or an abnormally high temperature.

A second group of rashes (serum) closely resemble those seen after the administration of antitoxin. The distribution is most intense on the vaccinated arm but may extend to a variable degree over the trunk. The lesions are generally bright red macules or are urticarial in appearance. The eruption is commonly accompanied by pruritus. Almost all the lesions seen in ordinary serum rashes may be observed in these cases.

The third and most interesting group of rashes appears about the tenth day. The distribution is generally most marked locally on the vaccinated area and in the corresponding axilla, but in two cases the distribution and appearance of the rash were indistinguishable from that of the prodromal rashes met with in cases of severe small-pox. In these cases the rash was limited to both axillae, both arms as far as the wrists, the thighs as far as the knees, the buttocks, perineum, groins and lower part of the abdomen.

1 This statement and Table XIII is based solely on the work of Captain Preston, R.A.M.C., who carried out the blood-counts.
The back, chest, face, legs and hands were free from rash. The lesions vary from a punctate erythema to a macular haemorrhagic rash. Of the cases showing the typical distribution of prodromal rashes in small-pox, one was finely punctate and haemorrhagic when first observed, and the other was morbilliform in type but bright scarlet in colour and later became haemorrhagic. The occurrence of these rashes is not constantly associated with an undue severity of the local reaction on the arm, and the constitutional disturbance as shown by the temperature is variable.

Apart from the existence of a rash, subcuticular haemorrhage may be frequently observed in the skin closely surrounding the vesicles in severe cases of vaccinia. This haemorrhage appears either as a punctate lesion or as small purple areas. The condition appears to be associated only with severe reactions and is invariably strictly local in distribution.

**Effect of Exercise on Recently Vaccinated Men.**

A series of investigations was carried out in order to determine the effect of a moderate amount of exercise on men recently vaccinated for the first time.

The details of the method of vaccination are given in the Preliminary Report.

In each case one linear insertion about nine millimetres long was made for each insertion; four insertions were made. G.L.E. lymph was used. For the purposes of observation the men were divided into three groups:

- **Group A.**—Men vaccinated and at once admitted to hospital, where they were kept throughout the course of the vaccinia. The vaccinated arm was completely rested in a sling.

- **Group B.**—Men treated in every respect similarly to Group A except that each man did two hours’ arm exercise daily. The exercise consisted in work on a mariner’s wheel and free arm and ladder exercises in the gymnasium.

- **Group C.**—Men vaccinated and submitted to what was ostensibly whole-time work, including ground levelling, coal heaving, etc. The circumstances in which this was done were such as permitted of considerable remissions from time to time, and were therefore not strictly comparable with those which obtain in men who are normally pursuing those occupations.

In the case of Groups A and B the temperature was recorded every four hours for fourteen days after vaccination. The men in Group C were inspected on the tenth and fourteenth day after vaccination only.

In contrasting Group A and Group C, it is only possible to give the results of visual impressions with regard to the severity of the reaction. Arrangements were made, however, for the cases to be seen by a number of different observers, including some members of the Vaccination Committee. They were unanimously of opinion that vesicular develop-
ment was more rapid in men of Group C than in those of Group A. On the fourteenth day after vaccination the men in Group C showed complete scab formation, whereas in those in Group A the lesions were still partially vesicular in character. Also the arms of the men in Group C did not show more severe reactions than those in Group A, but rather the reverse.

These two conclusions are confirmed when Groups A and B are contrasted. Both groups were under close observation in hospital and daily measurements of the lesions were made.

In the men in Group B both the lowest and the highest temperatures were reached approximately one day earlier than in Group A.

The development of the vesicle was more rapid in Group B than in Group A.

With reference to the relative severity of reaction in the two groups, the reaction as indicated by the temperature is not more severe in cases doing exercises but rather the reverse. This is borne out by the fact that the average size of the vesicle is slightly larger in men resting than in men exercising.

SECTION II.

This section summarizes a number of observations made with regard to the relative severity of six-mark and two-mark vaccination and the effect of varying methods of inoculating the lymph.

As in the previous cases reported upon, the vaccinations were performed on men aged 18 to 20 years who had not been previously vaccinated. The technique followed was that described in detail in the Preliminary Report. The length of the insertions in each case was carefully marked with dividers on the arm before the incision was made, and in every case the total length of the incisions was the same in both six-mark and two-mark cases, viz., six marks each six millimetres long, or two marks each 18 millimetres long. After the operation the arms were kept at rest, the men being admitted to hospital for a period of fourteen days. Daily measurements of both areola and vesicles were taken, as described in the Preliminary Report, and the temperatures of the cases were recorded every four hours. All the insertions in all the cases were successful. The results described must be broadly interpreted.

RELATIVE SEVERITY OF SIX-MARK AND TWO-MARK VACCINATION.

As noted above, the total lengths of the incisions in both six-mark and two-mark cases were the same. The average areola in both groups is strikingly similar in size until the seventh day. On and after the seventh day, until the twelfth day, the areola area for six-mark cases is definitely larger than that of the two-mark cases. On the twelfth and thirteenth days the total areola area in both groups is approximately the same.

In the case of the vesicular area in both groups, the date of first
appearance of the vesicle (with a single exception) in both groups is the same, viz., the fourth day after vaccination. Furthermore, at the time of their first appearance, and for some three or four days afterwards, the average total vesicular areas in both groups are closely similar in size. After the seventh day following vaccination, however, the six-mark cases show a definitely larger vesicular area than do the two-mark cases, a difference which remains patent until the thirteenth day. The average maximum areola and the average maximum vesicular area occur at approximately the same time in both groups, viz., six-mark cases average maximum areola after 9.5 days, two-mark cases 10 days, six-mark cases average maximum vesicular area after 11 days, two-mark cases 11 days.

With regard to the relative temperatures in the two groups, the average maximum daily four-hourly temperature reaches its highest point in both groups on the eighth day. For three days after vaccination the average temperature in both groups is the same. From the fourth day until the ninth day the two temperature curves closely follow one another, the temperature of the six-mark cases being, however, distinctly higher than that of the two-mark cases. After the ninth day following vaccination the average temperature curves of the two groups are closely similar. The highest temperature recorded was in a six-mark case, viz., 104.6°F.

The observations detailed above suggest that the number of insertions does not affect the date of appearance of the vesicle, the date of the average maximum areola, the date of the average maximum vesicular area, or the date of the average maximum temperature. In other words, vaccinia does not appear to be accelerated or retarded by the number of insertions made.

On the other hand, the same original length of incision with approximately the same dose of lymph gives rise to varying areola and vesicular area, and temperature according to whether it is divided into six or two lengths. In the case of the six insertions the areola and vesicles were larger and the temperature was higher than was the case in the two-mark cases. It follows as a corollary, that in order to get the same vesicular area in the two cases if two insertions only are made, these must be of a greater total length than is the case if six insertions be made.

**The Relative Severity in Reaction of Two Methods of Inoculation of Lymph.**

A number of men not previously vaccinated were divided into two groups. Both groups were kept at rest in hospital and were treated precisely similarly, except in regard to the method by which the lymph was introduced. The technique followed was that described in the Preliminary Report. All the cases were vaccinated with four insertions with the same total length of incision. All the insertions in all the cases were successful. In one group (Type I cases) the whole tube of lymph was energetically rubbed into the insertions, whilst in the second group (Type II cases) the
incisions were only touched lightly with a lancet bearing a very small quantity of lymph, as small a quantity as possible of lymph being introduced, but care being taken to infect the whole length of each insertion.

Contrasting in the first instance the areoles of the two groups on the day after vaccination, the average areola area in both groups is the same. Broadly speaking, the two curves are similar until the ninth day. From the ninth day to the eleventh day, however, the Type I cases show a distinctly larger average areola than do the Type II cases. On and after the eleventh day, allowing for the unavoidable inaccuracies in measurement of an area of inflammation, the areola areas in the two groups are similar.

In the case of the vesicular area in both groups, in three out of the eleven Type II cases vesiculation did not occur until the fifth day and, moreover, in the remaining cases the average vesicular area on the fourth day was only twenty-six square millimetres in the Type II cases, as compared with eighty square millimetres in the Type I cases, whereas the average areola area on the day following vaccination, and on the subsequent days until the ninth, is closely similar in both groups.

Once vesiculation is established the rate of development is approximately the same in both groups, the average maximum size being reached on the eleventh, twelfth, and thirteenth days in both groups. The average maximum areola and the average maximum vesicular area occur at almost the same time in the two groups, viz., Type I cases, average maximum areola area 9.7 days; Type II cases, 10.2 days; Type I cases average maximum vesicular area 12.1 days; Type II cases 11.9 days.

With regard to the relative temperatures in the two groups, the average maximum daily four-hourly temperature reaches its highest point in both groups on the eighth day. During a period of four days after vaccination the average temperature in both groups is similar. The temperature curve of the Type I cases appears to rise more rapidly than that of the Type II cases, but both reach the same maximum on the same day. The temperature curve of the Type I cases falls rather more rapidly than that of the Type II cases. Broadly speaking, however, and allowing for the small numbers of cases available for observation, the two temperature curves are very similar.

The observations detailed above suggest that apart from the earlier appearance of the vesicles, the dates of average maximum areola area, of average maximum vesicular area, and of average maximum temperature, are closely similar in both groups. It would appear, therefore, that vaccinia is not accelerated or retarded in either group.

On the other hand, as far as deductions can be made from the small numbers available, the effect of energetically rubbing the lymph into the incision appears to affect the local reaction rather than the general reaction. The temperature, which constitutes our only practical method of comparing
the severity of the general reactions, reaches a similar average maximum in both groups on the same day and, as has been noted above, the temperature curve in both groups is closely similar throughout the course of the illness. It is, however, when the areola and vesicular areas are compared that a marked difference is noticeable in the two groups. The early development of vaccinia is similar in both groups, but eventually the Type I cases evince a markedly more severe reaction than the Type II cases, as shown by the definitely greater average areola and vesicular area. It follows that, given the same length of original incision, larger vesicles will be formed if the lymph is well rubbed into the incision at the time of vaccination than will be the case if the lymph is only lightly applied. The larger vesicles, however, in the cases under observation, do not seem to be accompanied by any greater general reaction, as evidenced by the four-hourly temperature.

SECTION III.

This section outlines the practical applications of the investigations carried out at Woolwich.

(1) Single-Line Scarifications and Severity of Reaction.—The effect of using single-line scarifications, as contrasted with cross-hatched scarifications, is greatly to reduce the severity of the local reaction to vaccination.

(2) Single-Line Scarifications and the Interpretation of the Result of Vaccination.—Single-line scarifications facilitate the interpretation of the result of re-vaccinations. If multiple scarifications be used, the exuded serum and necrotic, damaged tissue may be recorded as a “take” in a case which is in point of fact a failure.

(3) Single-Line Scarifications and the Immunity Reaction.—Single-line scarifications only can be used for accurately determining the end-point of the immunity reaction.

(4) Exercise and Vaccination.—Three independent series of experiments appear to show that there are no fewer severe arms if men are excused duty after vaccination, but rather that the reverse is the case. It is to be noted, however, that there was no opportunity of testing the effect of very hard and continued manual labour (e.g., miners or stokers in civil life), and the only definite conclusion that can be drawn is that a certain amount of exercise after vaccination is definitely beneficial, and that this amount is not exceeded in the ordinary training of a recruit in the Royal Artillery.

(5) Scar Area and Immunity.—It is shown that the amount of immunity remaining at 18 years of age after infant vaccination varies with the size of the scar area, but not with the number of insertions, except in so far as these increase the total scar area. The Ministry of Health require that a total area of at least half a square inch should be obtained by public vaccinators, and it will be seen from the figures published in the
Further Observations upon Vaccination at Woolwich

Annual Report of the Chief Medical Officer of the Ministry of Health, for 1926 (p. 39), that this area appears to give complete immunity to smallpox to an infant for a period of at least ten years. In order, therefore, to protect a soldier during his time service, it is probably necessary to obtain at least half a square inch of total scar area in a case of primary vaccination. This area of scar tissue results if four single-line insertions be made, each incision being about three-eighths of an inch (six to seven millimetres) in length, or two single-line insertions, each being about three-quarters of an inch (sixteen to eighteen millimetres) in length.

(6) Number of Insertions.—It is shown that the number of insertions made in infancy does not, per se, apart from the area of scar produced, affect the amount of residual immunity in men of 18 years of age. Moreover, it is observed that with two-mark vaccination a less severe reaction is produced for the same total length of incision than is the case if six insertions are made. The most satisfactory results would therefore appear to be obtained by two single-line insertions of sufficient length to give half a square inch of total scar area.

(7) Value of the Immune Reaction.—The value of the immune reaction is confirmed. Under the ordinary conditions of routine vaccination in the Army, when inspection is carried out on the seventh day after vaccination, it is impossible to observe the immune reaction. Instances arise, however, both in civilian and military populations, in which the saving of time resulting from the early interpretation of the result provided by the immune reaction may be of great value, e.g., in the protection of staff drafted into a small-pox hospital in emergency, or in connection with emigration, or the landing of individuals abroad in countries where a certificate of recent successful vaccination or immunity to small-pox is a condition of landing, etc.

(8) Inoculation of the Lymph.—Care must be taken to inoculate the whole length of each insertion with lymph, but there is no advantage to be gained by energetically rubbing the lymph into the insertion. The latter method results in an unnecessarily severe local reaction.

(9) Date of Inspection of Primary Vaccinations.—It will be seen that in cases of primary vaccination the temperature reaches its maximum on the ninth day, the areola on the eleventh day, and the vesicles on the twelfth day after vaccination. Inspection of the arm on the seventh day after vaccination gives, therefore, no idea of the severity of the reaction, which does not reach its maximum until two days afterwards in the case of the constitutional disturbance, or four days afterwards in the case of the local reaction. Primary vaccinations should therefore be inspected on or about the tenth day after vaccination.

(10) Relation of Constitutional Disturbance to Local Reaction.—The observations show that vaccination is accompanied by severe constitutional disturbance, manifested by high temperature (average maximum 101° F., individual maximum 104.2° F.), enlargement of the spleen and lymphatic
glands, changes in the blood-count, headache, malaise, and sometimes the development of a generalized rash. It is further shown that the constitutional symptoms and signs reach their maximum some two or three days before the local reaction does so. Observations of the individual cases demonstrate that the amount of the local reaction is no criterion of the severity of the constitutional disturbance. From a practical point of view it is, therefore, very important not to judge the amount of constitutional disturbance by the appearance of the arm. A patient may have a temperature of $103^\circ$ F., and a spleen enlarged two fingers’ breadth below the costal margin, with no abnormal local reaction. In such a case, unless care in examination be taken, a patient who is really ill may be regarded as a malingerer.

(11) Rashes.—These may be produced by strapping, and it is therefore important only to use strapping which is known to be free from the resin causing the rash, or failing this to employ bandages or tapes. In connexion with the occurrence of rashes, it is important to remember that post-vaccinal rashes may be mistaken for the prodromal rashes of small-pox or for the rash of scarlet fever.