

OBSERVATIONS ON THE MATERNAL BLOOD  
AT TERM AND DURING THE  
PUERPERIUM.

By JOHN HENDERSON, M.D.,

Formerly House-Surgeon, Glasgow Maternity Hospital.

THE subject of this paper is one which attracted my attention while holding the appointment of Outdoor House-Surgeon to the Glasgow Maternity Hospital. It is a subject which so far, and more especially of recent years, has had little attention paid to it, and any investigations hitherto made have been confined almost wholly to the blood of pregnancy, the changes during the puerperium being only casually alluded to. Literature on the subject is very scanty, and is chiefly Continental, most of the observations being of rather a remote date. For this reason, apart from the more recent references, as in the work of Cabot on the blood and a paper by Drs. Elder and Hutchison, this paper must almost perforce be presented on its own merits. The examinations upon which it is based were carried out during the period from December 12, 1900, to the end of February, 1901, upon the indoor patients of the hospital. The cases were not selected in any way, but were simply taken as the intervals in work would allow.

A certain amount of consideration must be given to the class of patients dealt with. The institution is a charitable one, and patients are received from all quarters of the town. The majority, however, are drawn from localities where overcrowding is the rule, cleanliness a thing unknown, and good feeding, or even an approach to it, the exception. Generally speaking, the blood of such patients must be in a condition slightly altered and affected by their environment. It necessarily follows, therefore, that such material is not the best upon which to base a series of calculations to arrive at a normal standard. Allowance must be made for this in reviewing the results, although in many cases it is surprising to find the blood well up to the normal standard where one would not expect it.

The usual term of residence in the hospital is ten days, unless the case has been abnormal and the patient is not in a fit condition to leave at the expiry of that period. For this reason practically all the examinations of the series are confined to the first ten days after

delivery. At first an attempt was made to get the patients to return at later periods for observation, but without success.

As regards the time of examination, it was attempted, so far as possible, to examine the blood at the same hour each day, to get the same conditions of nutrition ; but, owing to the irregular nature of the work in the outdoor department of a busy hospital, this was obviously not always possible. In the large majority of the cases the patients were in labour when admitted, so that the initial examination was usually made during the first, or early in the second, stage of labour. Sometimes it was not even possible to get an examination before delivery, but in such cases the first examination was made so soon after—*i.e.*, within a few minutes—that for all practical purposes the result was the same.

With regard to the method of examination, the routine was as follows :

The blood was taken from the lobe of the ear, without pressure, the needle used being that supplied with Gowers' hæmoglobino-meter. A fresh specimen was taken for immediate microscopic examination, and films were prepared for staining purposes.

For the estimation of the corpuscles the Thoma-Leitz hæmacytometer was used, and was found to be very satisfactory. The diluting solution for the red corpuscles was the usual one of Gowers', *viz.*, sodium sulphate and acetic acid, while that for the whites was a solution of glacial acetic acid of a strength of one-third of 1 per cent. coloured with a small quantity of gentian violet. In counting the red cells, usually 120 squares were counted, but often this was done in two separate drops to insure more accuracy. For the white cells, two, and often three, drops were counted for the same reason.

For the estimation of the hæmoglobin, Gowers' instrument was used. This instrument is so far unsatisfactory, in that in a series of examinations like the present, one is alternately using it in day and gas light, and thus differences, though slight, may occur. For this reason, and as the results were very uniform up to that point, I latterly discontinued the estimation of hæmoglobin. Oliver's instrument, which is arranged and graduated for use with artificial light at all times, although much more expensive, would give more satisfactory and accurate results.

The films of blood were dried in air, fixed by heat, and stained with Ehrlich's triple stain. At first a few films were also stained with alcoholic eosin and methylene blue, but this method was not so satisfactory for purposes of differentiation, and was therefore discontinued. In fixing with heat it is a great advantage to have a dry-

heat sterilizer, so that the temperature can be accurately regulated, but in the present series the specimens were made simply by passing the cover-glass rapidly through the flame of a spirit-lamp, the rate of speed and the number of exposures to the flame being learned by experience. With a little practice, useful specimens can be prepared in a short time by this method. As regards the staining process itself, it is comparatively simple. The stain is spread over the cover-glass with a glass rod, and is allowed to remain on for two or three minutes, or longer. Cabot states that it is impossible to overstain with this mixture. In my specimens usually two or three minutes was the time allowed, and this gave good results. The chief, and, in fact, the only, difficulty in the process is the heating, as underheating and overheating alike spoil the specimen. After staining and washing in water, the cover-slip is dried between layers of filter-paper, and mounted in Canada balsam.

The paper is based on about 300 examinations of fresh blood, and a similar number of counts of the red and of the white corpuscles, about 150 estimations of hæmoglobin, and 100 stained films differentiated.

Before considering the condition of the blood at term and during the puerperium, it is necessary for purposes of connection to review shortly what is known regarding the blood in pregnancy. On this point Playfair is very concise, and I have quoted largely from his book.

It has long been known that the puerperal state is associated with well-marked changes in the composition of the blood, although there has always been considerable difference of opinion as to the exact nature of these changes. It used to be believed almost universally that pregnancy was, as a rule, associated with a condition analogous to plethora, and that this explained many characteristic phenomena of common occurrence, such as headache, palpitation, shortness of breath, singing in the ears, etc. It was habitual, therefore, to treat pregnant women on an antiphlogistic system, to place them on low diet, administer lowering remedies, and very often to practise venesection. Indeed, the latter mode of treatment was at times adopted to an alarming extent. About twenty years ago the opinion of the profession on this point underwent a remarkable change. It was then recognised, from various careful analyses of the blood, that the view of plethora was not correct. It was found that the total amount of blood in the system is increased to meet the necessities of the largely increased vascular arrangements of the uterus. This was experimentally proved by Spiegelberg and

Gscheidlin to be correct in the case of bitches. The blood was found to be more watery, its serum deficient in albumin, and the amount of coloured globules to be materially diminished. This was pointed out by Becquerel and Rodier, who analyzed the blood in a series of nine cases. They also found the fibrin and extractive matter to be increased in quantity. This is of peculiar importance, and goes far to explain the frequency of certain thrombotic affections observed in connection with pregnancy and delivery. This latter condition is also considerably increased after delivery by the amount of effete matter thrown into the mother's system to be got rid of.

It was thus established that the blood of the pregnant woman is usually in a condition much more nearly approaching that of anæmia than of plethora, and most of the phenomena formerly attributed to plethora were, of course, as easily, if not more easily, explained on this view. The changes, too, are much more marked towards the end of pregnancy than at its commencement, and it is of interest to note that it is then that the concomitant phenomena alluded to are most frequently met with.

One of the chief advocates of this view was Cazeaux, who described the pregnant state as one essentially analogous to chlorosis, and he contended that it should be treated as such. More recently Quinquad pointed out that a progressive fall in the amount of hæmoglobin takes place throughout pregnancy. He accordingly applied to pregnancy the term 'chlorose puerperale.' Still more recently the accurate observations of Willcocks of London have shown that the blood of pregnancy differs from that of chlorosis in the fact that, while in both the amount of hæmoglobin is diminished, in pregnancy the individual corpuscles are not impoverished as they are in chlorosis, but simply lessened in comparative number, owing to increase in the water of the plasma, due to the progressive enlargement of the vascular area during gestation. His assumption is that, if the number and functional value of the red cells of the unimpregnated condition remain constant throughout pregnancy, a progressive dilution of the blood would necessarily ensue, owing to the considerable and progressive enlargement of the vascular area in the puerperal state. Such an assumption at once explains both the diminution in number of the red cells and the diminution in their functional value. This may also explain the enormous loss of blood from which some women suffer during parturition with comparative impunity, the greater serous dilution of the blood allowing the organism to lose a much larger quantity

without injury than in the normal state. These observations of Willcocks appear to point rather to an excessive increase in the fluid of the liquor sanguinis in pregnancy than to a condition of pure anæmia, which is usually considered to coexist with it. In several cases detailed by him where continuous observations were made in two to three months during the course of pregnancy, a slight progressive fall in the number of red corpuscles took place. In this connection Dr. Maurel states that the increase in number of red globules observed as the menstrual period recedes continues when, under the influence of pregnancy, the hæmorrhage is not reproduced. This increase may go on towards the third month, when, under the influence of causes as yet unknown, the number diminishes again, to increase once more towards the seventh month.

Lusk, in his 'Text-book of Midwifery,' describes the condition as one of serous plethora, the red cells, albumin, iron, and salts of the blood being diminished, while the white corpuscles, the fibrin, and, above all, the water of the blood, are increased. He explains these changes partly, at least, by the demands made on the maternal system by the growing fœtus. With increased waste in the organism, as evidenced by an augmentation in the CO<sub>2</sub> and urea eliminated, there is usually diminished capacity to take and assimilate food. How far these causes are operative in producing the above-mentioned conditions is shown by the slight degree of hydræmia, or the entire absence of blood impoverishment, in women, who possess during pregnancy good appetites and excellent digestions, and who at the same time are able to procure an abundance of nutritious food.

Objection has naturally been made to the theory of Cazeaux, on the ground that a healthy and normal physiological function should not be associated with a morbid condition. This naturally raises the question: How many women in the pregnant state can be considered to be perfectly healthy, especially among those in large towns, and from the lower quarters of these towns, from which class our investigations must almost of necessity be derived? Surroundings, civilization, climate, errors of diet, and, indeed, in many cases starvation, or something approaching to it, occupation, exposure to contagion, uncleanliness, and many other conditions, all tend to render perfect health out of the question.

Playfair sums up the question thus: 'Making every allowance, therefore, for the undoubted fact that pregnancy *ought* to be a perfectly healthy condition, it must be conceded, I think, that in the majority of cases coming under our notice it is not entirely so,

and the deductions drawn by Cazeaux from the numerous analyses of the blood of pregnant women seem to point strongly to the conclusion that the general blood state is tending to poverty and anæmia, and that a depressing and antiphlogistic treatment is distinctly contra-indicated.' Newer text-books of midwifery practically repeat these ideas, but give no further information on the subject, and in books on the blood there are only a few casual references to it. Cabot, whose work on the examination of the blood is the most recent, treats specially of the leucocytosis of pregnancy, though not in great detail. His results will be referred to in the course of this paper.

The foregoing represents the state of our knowledge on the blood of pregnancy, and we are now in a position to take up the thread of our subject at this point, viz., the condition of the blood at term and during the puerperium. The sections will be treated as follows :

- I. The blood as seen in the fresh specimens.
- II. Red corpuscles.
- III. Hæmoglobin.
- IV. White corpuscles.

I. EXAMINATION OF FRESH SPECIMENS.—From these, of course, only a general idea can be obtained, but an opinion can be given in each case as to the :

1. Amount of rouleaux formation of the red cells.
2. Deformity of the red cells, if any.
3. Presence of anæmia, or leucocytosis.
4. Amount of fibrin present.

These points were all carefully noted in detail on the report sheets. As regards the red cells in normal cases, no abnormal feature was recognised in the blood at term, although at times there seemed to be a deficiency in the amount of rouleaux formation. During the first two or three days of the puerperium, however, in many cases slight changes in the shape and size of the red cells were noted, pointing to blood regeneration, which, as will be seen later, is taking place during that time. No nucleated red cell was observed during the puerperium in any normal case, but in several other cases, as in a case of syphilis and several cases of eclampsia, such cells were observed.

In the case of the white cells, a leucocytosis was invariably found, although varying considerably in degree in the different cases.

For actual results, the only point upon which the fresh specimens are relied on to supply information is that of the quantity of fibrin present at term. On this point, in the large majority of cases, it is noted that the formation of fibrin was early or excessive, but a few cases showed no tendency towards this, so far as could be seen. No decided statement on this point can therefore be made, although there is considerable evidence from the statistics to prove that in the blood at term there is usually an increased quantity of fibrin. The researches of Becquerel and Rodier on this subject have been already alluded to. In the same article it is stated that, in thirty-four cases examined, Andral and Gavarret found increase of fibrin.

II. RED CORPUSCLES—I. *At Term.*—In forty-five cases examined just before or immediately after delivery, the counts were found to vary from a minimum of 2,260,000 per cubic millimetre to a maximum of 5,000,000, giving as an average over all 3,906,666 per cubic millimetre. This is, of course, considerably below the number given as the normal for the adult woman—viz., 4,500,000. The minimum count occurred in a case where the patient was, on admission, in a condition resembling in many respects that of pernicious anæmia. Another very low count was in a case where there had been considerable hæmorrhage. These two observations are very much lower than the others, so that to get a more correct normal average they should be excluded. When this is done, the average for the remaining forty-three cases works out at 3,975,348 per cubic millimetre, which is still below the normal standard.

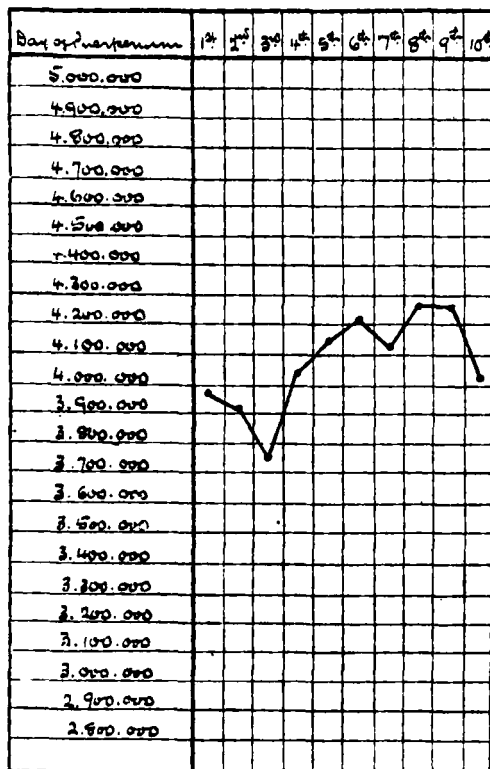
2. *During the Puerperium.*—In almost all the cases, as already stated, the patients were under observation for ten days after delivery. The course of the red corpuscles after delivery is best shown by the following average table, compiled from the examinations made on each day of the puerperium :

1st day, average of 43 counts,	3,975,348 per cubic millimetre.				
2nd	„	„	17	„ 3,912,000	„
3rd	„	„	19	„ 3,757,000	„
4th	„	„	17	„ 4,047,000	„
5th	„	„	19	„ 4,148,000	„
6th	„	„	15	„ 4,208,000	„
7th	„	„	22	„ 4,128,000	„
8th	„	„	14	„ 4,273,000	„
9th	„	„	21	„ 4,270,000	„
10th	„	„	13	„ 4,021,000	„
11th	„	„	4	„ 4,020,000	„

The first day represents the day of delivery. It will be observed that the average for each day does not represent an equal number of examinations, but nearly all have a sufficient number to allow of a reliable average over all. In this table only those examinations which may be considered strictly normal have been included. This average table is represented diagrammatically in Chart I.

CHART I.

SHOWING THE COURSE OF THE RED CORPUSCLES DURING THE FIRST TEN DAYS AFTER DELIVERY.



This chart is constructed from the averages of 204 counts of red corpuscles.  
(See p. 174.)

*At Term.*—With regard to the quantity of red corpuscles at term, we must, of course, make a slight allowance for what may be called normal variations from the normal, as well as for the condition of the patients coming under observation. When this is done, the average of 3,975,348 does not represent any marked degree of diminution, if, indeed, there is any. At this stage it is interesting to compare this average with that obtained by Drs. Elder and Hutchison, in



a paper published in 1894. In sixteen cases in which they examined the blood at term they found the average number of reds to be 3,978,937 per cubic millimetre, which is a strikingly similar result.

*During the Puerperium.*—It will be seen from the chart that there is a slight diminution in number of the red corpuscles during the first two days after delivery. Thereafter the course is a steady upward one until the ninth day, when there is a second downward tendency, which continues as far as the examinations go. The temporary diminution after delivery is naturally explained by the loss of blood at childbirth, the amount depending not only on the amount of blood lost, but also on the capacity of the individual organism for blood regeneration. It should be observed here that during these days also in the specimens of fresh blood, changes in size and shape of the red cells were noted, pointing to new formation of red cells. This process is well seen in the chart, but the second downward tendency is more difficult to explain. It is possible that a certain degree of diminution may be continued during lactation, owing to the drain on the maternal system which this process necessitates. Our examinations would point to such being the case, but how long it is continued, or whether it is present all through the period of lactation, we have no data on which to offer an opinion. All that can be said is that the slight diminution persists so far as the examinations show, as of four examinations made on the eleventh day the average is 4,020,000 per cubic millimetre.

These results, though contrary to the older ideas already referred to, are quite in accordance with the general statements of Cabot on the subject. He holds that normal pregnancy does not affect the count of red cells, but that childbirth and lactation cause a temporary diminution.

III. HÆMOGLOBIN—I. *At Term.*—In thirty-seven cases where the amount of hæmoglobin was recorded, the average is 68·2 per cent.; the lowest observation being 45 per cent., while the highest was 80 per cent. The minimum occurred in a case of hæmorrhage which cannot be considered normal, and, as this is the only record below 60 per cent., it should be excluded to get a more correct average. The average for thirty-six cases is then 68·9 per cent.

2. *During the Puerperium.*—In almost all the cases a slight improvement is noticeable under observation, usually about 5 per cent.; but in two cases the increase recorded was 15 per cent. The following averages compiled from the examinations will give an idea as to the

course of affairs, although the records are not sufficiently numerous to give quite a satisfactory average :

1st day, average of 36 counts	...	...	68·9	per cent.
2nd „ „ 8 „	...	...	73·1	„
3rd „ „ 7 „	...	...	73	„
4th „ „ 6 „	...	...	70	„
5th „ „ 7 „	...	...	73·5	„
6th „ „ 5 „	...	...	72	„
7th „ „ 12 „	...	...	72·9	„
8th „ „ 4 „	...	...	73·75	„
9th „ „ 9 „	...	...	75	„
10th „ „ 8 „	...	...	74·75	„

This represents a steady average increase under observation of 5·85 per cent. This is illustrated by Chart II. Here, also, only normal examinations are included.

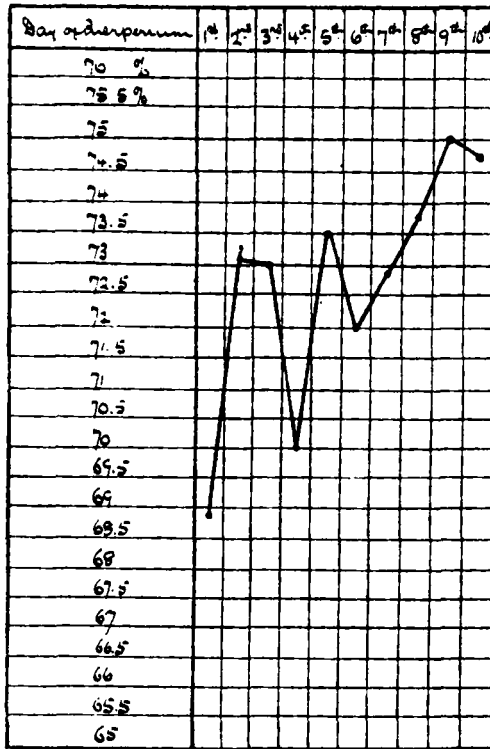
The normal standard of hæmoglobin is one which is very difficult to fix. Of course, with Gowers' instrument 100 is fixed as the normal; but such a standard is rarely, if ever, reached in the adult blood, although in the blood of infants it is usually exceeded. Writers differ as to what may be considered the normal percentage of hæmoglobin. Cabot gives it as his opinion that for a woman a hæmoglobin percentage of 75 per cent. or more means practically normal blood. It is interesting, however, to give the results of A. K. Stone and his assistants on this point. They estimated the hæmoglobin of 189 female patients *who looked anæmic*, and found over 75 per cent. in eighty-nine, or nearly one-half of them. It is obvious, therefore, that, when we use 75 per cent. as the normal, it must be looked upon as the very lowest limit. In any case, however, if we allow 20 per cent., or even 25 per cent., for what may be termed for the present normal deterioration in the richness of the blood in hæmoglobin, there still remains in the present series a deficit to be accounted for, as the average is only 68·9 per cent. Our observations, therefore, point to a distinct, but not marked, reduction in the percentage of hæmoglobin in the blood at term. This is in accordance with the observations of Cazeaux, and the more recent ones of Quinquad and Willcocks, which have already been referred to. In seven cases examined at term, Elder and Hutchison found the hæmoglobin varying from 60 to 83 per cent., giving an average of 72 per cent.

Cabot gives no direct opinion on this point, although he includes pregnancy and lactation as causes of secondary anæmia. He states

that in secondary anæmia it is only comparatively rarely, and in very marked cases, that the diminution in red corpuscles is considerable. The blood characteristic of most cases of secondary anæmia is one in which the number of red cells is approximately normal. The chief changes in such cases are: (1) Lack of colouring matter, and (2) lowering of specific gravity. From this, therefore, we may

CHART II.

SHOWING THE COURSE OF THE HÆMOGLOBIN DURING THE FIRST TEN DAYS AFTER DELIVERY.



This chart is constructed from 102 counts of hæmoglobin. (See p. 177.)

conclude that he recognises a reduction in the amount of hæmoglobin in pregnancy.

*Colour Index.*—At term, therefore, it appears from our observations that the hæmoglobin is diminished more than the red corpuscles, so that the colour index, or 'valeur globulaire,' is less than one which represents the normal. The colour index at term may be arrived at by taking the average first day count of red cells, viz., 3,975,348 (which represents 88.3 per cent. of the normal 4,500,000),

and dividing this into the average first day percentage of hæmoglobin, thus:  $\frac{68.9}{88.3} = .78$ . This shows an average deficiency in the colour index at term in the present series of '22.

IV. WHITE CORPUSCLES—I. *At Term.*—In thirty-eight cases examined at this period, the average is 21,365 per cubic millimetre, the lowest count being 10,600, while the highest was 36,600. From this average those cases are excluded which, for various reasons, such as the administration of chloroform, etc., were obviously abnormal; but a few cases are included which may not have been strictly normal, but in which there could only be at most a slight variation. This series includes both primiparæ and multiparæ, and in all cases a leucocytosis of varying degree was found. So far as possible, all were examined under the same conditions. Of the thirty-eight cases, thirteen were primiparæ, the average count being 21,969 per cubic millimetre, while twenty-five were multiparæ, the average being 21,052. For all practical purposes, therefore, they may be considered as showing an equal degree of leucocytosis, although the average is slightly greater in primiparæ.

2. *During the Puerperium.*—The course of the leucocytes during this period is shown by the following average table, compiled only from observations which may be regarded as normal :

1st day, average of 38 counts, 21,365 per cubic millimetre.			
2nd	„	„	12 „ 17,250 „
3rd	„	„	13 „ 17,015 „
4th	„	„	21 „ 13,752 „
5th	„	„	21 „ 12,276 „
6th	„	„	16 „ 11,975 „
7th	„	„	21 „ 12,190 „
8th	„	„	17 „ 10,147 „
9th	„	„	18 „ 11,061 „
10th	„	„	11 „ 12,327 „

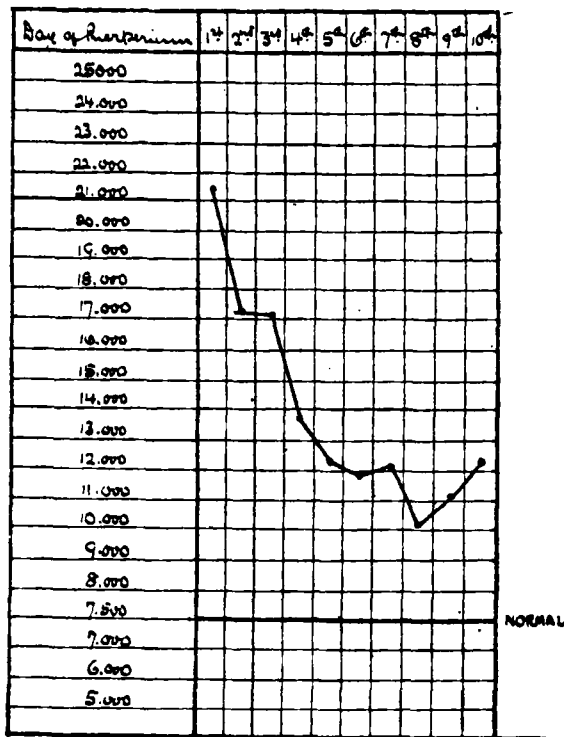
Chart III. illustrates this table.

Here, again, it is necessary to establish a normal standard, and on this point also there is considerable difference of opinion. In persons not usually considered as sick, but simply ill-nourished, the normal count of white cells may be as low as 3,000 per cubic millimetre, and for such persons a count of 10,000 would be decidedly pathological. On the other hand, in vigorous and well-nourished people the white cells may rarely fall below 10,000 per cubic millimetre. Of course, to be strictly accurate, one should know the normal count for each individual in health, but it is obvious that

this is impossible in such a series of examinations as the present. It is necessary, therefore, to have some normal standard.

Löwitt considered that 5,000 to 10,000 might be called the normal limits, and showed how a slight shock is sufficient to materially affect the count of leucocytes. Romberg in fifty-five healthy young women found the average to be 9,058 per cubic millimetre. In the present series the normal is put at 7,500 leucocytes per cubic millimetre, which is the figure usually given for adults, and is the

CHART III.  
SHOWING THE COURSE OF THE LEUCOCYTES DURING THE FIRST TEN DAYS AFTER DELIVERY.



This chart is constructed from 188 counts of white corpuscles. (See p. 179.)

normal used by Cabot. It is, of course, liable to considerable variation, according to the nutrition of the individual, and also at different times of the day, apart from the influence of digestion, although such variation has not yet been explained.

It is evident, from what literature there is on the subject, that this leucocytosis has been recognised for many years. For instance, so far back as 1854 Moleschott stated that 'the number of colourless corpuscles is greatest in boys and smallest in women, except during menstruation and pregnancy, when it is rather above the average.'

The references, however, in most cases are merely casual, and only a very few writers make any definite statement with regard to the matter. These I have picked out, and will give in detail.

In 1881 Willcocks of London gave statistics of twenty-two cases in which he had counted the white corpuscles. He found the average ratio to be 1 white to 595 red corpuscles, the highest being 1 to 184, and the lowest 1 to 1,650 red cells. The counts, however, were not all made at term, some being considerably earlier. The average ratio in the present series on the first day of the puerperium (*i.e.*, at term) works out at about 1 white to 183 red cells, which is almost equivalent to the highest count of Willcocks. In 1893 Elder and Hutchison, in eleven cases examined at term, found the white corpuscles varying from 8,000 to 25,000, giving an average of 14,522 per cubic millimetre. Presumably, as these writers make no statement to the contrary, their examinations were made in primiparæ and multiparæ without selection.

On this subject Cabot remarks that most primiparæ show during the latter months of pregnancy a moderate increase of all varieties of leucocytes, 13,000 being about the average count, although in the last weeks of pregnancy it increases, until at the beginning of labour it is often 16,000 to 18,000 per cubic millimetre. He further states that this increase occurs in about 50 per cent. of multiparæ. On this point my observations are very definite, as all cases showed leucocytosis, although in varying degree. The lowest counts certainly were all in multiparæ, 10,600 being the minimum, but even this is still well above the normal standard of 7,500 per cubic millimetre. As already pointed out also, the average degree of leucocytosis in the present series is rather higher in primiparæ, although the difference is only very slight.

Cabot gives charts of twelve cases (nine primiparæ and three multiparæ) examined on various days during the puerperium. For the sake of comparison I have worked out his averages for the various days as under :

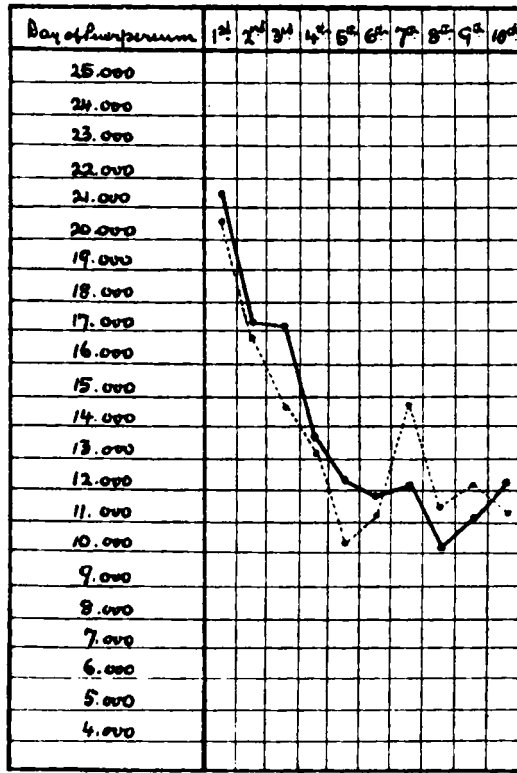
1st day, average of 7 counts, 20,642 per cubic millimetre.						
2nd	„	„	6	„	16,833	„
3rd	„	„	7	„	14,714	„
4th	„	„	9	„	13,111	„
5th	„	„	6	„	10,250	„
6th	„	„	4	„	11,250	„
7th	„	„	3	„	14,833	„
8th	„	„	5	„	11,500	„
9th	„	„	3	„	12,166	„
10th	„	„	4	„	11,250	„

Chart IV. is designed to show the marked resemblance between these averages and those of my series.

Further, in comparing my series with that of Cabot, it is necessary to state that in the former seven of the women had dead children, while in the latter all nursed their children. Of the seven cases referred to, three were only examined twice, and one thrice

CHART IV.

SHOWING THE COMPARISON BETWEEN THE AVERAGE LEUCOCYTE CURVE OF THE PRESENT SERIES AND THAT OF CABOT. (See p. 181.)



Curve of present series —————  
 Curve of Cabot .....  
 .....

during the puerperium, so that their inclusion could only have a trifling effect, if any, on the average curve. It is true that in at least one of these cases the number of leucocytes remained abnormally high, but in the others no such condition was found. On this point Elder and Hutchison remark that in six cases examined after delivery the white cells were found considerably decreased, except in one case where the patient did not suckle her child. In this

case they were increased. No definite opinion, however, can be based on an isolated case.

It is probable that the reduction of leucocytes during the first three or four days after delivery is to a certain extent compensated for, and obscured, by a leucocytosis, due to the regeneration of blood following on the hæmorrhage during delivery. Such a leucocytosis usually persists for a day or two.

The reduction in the quantity of leucocytes after delivery is no doubt aided by a good lochial discharge. This point has been investigated by Bonne, who states that the discharges after labour and leucorrhœal discharges cause diminution of the leucocytes. It therefore follows that in cases of puerperal sepsis, where such discharge is suppressed, or, at least, much diminished, the reduction should not be found. This statement is corroborated by the fact that in the only case of sepsis in the present series the leucocyte curve never fell below 18,000 per cubic millimetre during the fortnight she was under observation, and there was no sign of commencing involution of the uterus until the day of dismissal.

With regard to the duration of the leucocytosis after delivery, it is evident, from the observations on the tenth day in my series, that it is prolonged beyond the puerperium into lactation, but how far it may go on I have no data to found an opinion upon. With a view to getting some information on this point, I endeavoured, as already indicated, to get some of the patients to return for observation during lactation, but without success. So far as I am aware, Cabot is the only writer who makes any reference to this point, and he is of opinion that it may go on for several weeks, although he himself has not investigated the point.

*Effect of Digestion.*—I cannot say much as to the effect of digestion on the leucocytosis of pregnancy, as from the nature of the cases it was rarely possible to have them in hospital long enough before delivery to carry out the required experiment. In only one case was this done satisfactorily, where the patient was brought in for Cæsarean section, and was under observation some days before operation. The blood in this case was examined just before breakfast, and the white corpuscles were found to number 10,200 per cubic millimetre. Two hours after breakfast—*i.e.*, when the digestion leucocytosis, if present, should have been well marked—a second examination was made, and they were found to number 10,400 per cubic millimetre. There was, therefore, no appreciable alteration in this case. The examination was made before breakfast in order to obtain the blood count in that individual when fasting, as during the day the leucocytosis caused



by one meal may not have disappeared before the influence of the next meal begins. In this connection it is necessary to keep in mind that occasionally sound persons are met with who show little or no digestion leucocytosis. Von Limbeck has explained some of these cases by habitual constipation, but in others the reason is more obscure. There is no doubt, however, that after meals of mixed or proteid diet such a leucocytosis is the rule. In herbivorous animals, and presumably in vegetarians, it is not found. Of course, no reliable conclusion can be drawn from an isolated case, but the result detailed above agrees with Cabot's statement that digestion leucocytosis on the top of the constant pregnancy leucocytosis does not occur. This fact is put forward by him as a suggestion as to the causation of the leucocytosis of pregnancy—viz., that the whole thing may be a prolonged digestion leucocytosis, the mother having to eat and digest for two. This will be referred to later in discussing the causation.

With regard to the question of the effect of digestion on the leucocytosis during the puerperium, it would appear from many of my charts that after the fourth to fifth day, when in most cases the leucocytes have reached their minimum or very near it, the influence of digestion is seen. At this point a considerable daily variation in the leucocyte curve appears, apparently depending on the relation of the time of examination to the ingestion of food. It must be remembered, however, in this connection that the number of leucocytes is known to vary at different times of the day in the same individual without obvious cause. In view of this, in one case on the ninth day the leucocytes were counted one and a half hours after dinner, when digestion leucocytosis should normally be present, and were found to be 14,000 per cubic millimetre. Three and a half hours after dinner a second observation revealed the fact that they were reduced to 9,500 per cubic millimetre. In another case, on the ninth day, when the blood was examined at 12.15 a.m., the leucocyte count was found to be abnormally low—namely, 7,400 per cubic millimetre. In this case the patient had tea at 3.30 p.m., and gruel at 7 p.m. the preceding day, but thereafter had no food before examination. The low count is therefore explained by the abstinence from food for at least five hours. The same may be observed in still another case on the seventh day, when under similar conditions the count was found to be 8,800 per cubic millimetre. Other examinations could be cited to illustrate this point, but these will suffice. These illustrations all point pretty clearly in one direction, and it is therefore probable that the influence of digestion on the leucocytes is evident—at least, towards the end of the puerperium.

No reference is made to this point even by Cabot. It may be noted, however, that after the fifth day, on which his lowest average count is made, there are considerable daily variations in the leucocyte curve; but he states that all his cases were examined under the same conditions as regards nutrition, so that the variations in his series cannot be ascribed to any difference in relation to the ingestion of food.

With regard to the varieties of leucocytes taking part in this leucocytosis, the results of my differentiations are pretty uniform. In the process of differentiation I have followed the nomenclature of Cabot, and recognise four varieties :

- (1) Polymorphonuclear neutrophile,
- (2) Large lymphocyte,
- (3) Small lymphocyte,
- (4) Eosinophile ;

but for all practical purposes classes (2) and (3) may be combined (*vide infra*).

It is necessary before proceeding further to state shortly what is understood by these terms, and in so doing I have followed largely the description given by Cabot :

1. *Polymorphonuclear Neutrophile*.—These cells constitute the vast majority of those found in ordinary pus. They have a very irregular nucleus, which stains deep blue or greenish-blue (usually the former in my experience) with Ehrlich's tri-acid stain, and more deeply in some parts than others. The shape of the nucleus is never exactly the same in any two cells, hence the more correct name, 'polymorphonuclear.' They possess granules which stain best with Ehrlich, although faintly also with eosin, so that they are not strictly accurately named neutrophilic, but are faintly oxyphilic in character. For this reason Kanthack and other English observers have named them 'fine granular oxyphiles,' as opposed to the term 'coarse granular oxyphiles,' usually applied to eosinophiles. The granules stain usually violet or purple with Ehrlich, though in some cases they may be pink, and are small and irregular in shape and size, and lie over around the nucleus.

2 and 3. *Large and Small Lymphocytes*.—No definite line of demarcation can be drawn between these, the distinction being pretty much an arbitrary one, so that in my results I do not lay much stress on the percentage of the large as compared with that of the small variety, but rather on the total percentage of lymphocytes present. The small lymphocyte consists of a round blue nucleus about the size of an ordinary red cell, surrounded by a very small

amount of protoplasm, which with Ehrlich's triple stain is almost invisible. In my slides the nucleus is usually very deeply stained, although others have found it pale. The large lymphocyte is larger and paler than the small variety, but its construction is similar.

In many cases the nucleus of the lymphocyte is found to have a deep cut in one side, or, indeed, it may be quite divided, more especially in the small forms. Another transitional variety which I have commonly seen is that where the cell is as big as the larger lymphocytes, and whose nucleus is so indented as to resemble a horseshoe in extreme cases. It is pale all through, even the nucleus being faintly stained. It is evident, therefore, that a few varieties of lymphocyte cannot properly be termed mononuclear. The distinguishing feature is really the absence of granules, and not the presence of a single nucleus.

4. *Eosinophiles*. — These have a polymorphous nucleus and granules. The nucleus is paler than in the neutrophilic cell, and has more of a greenish colour. The nucleus, also, is more loosely connected to the granules which cluster round it, and which are larger than in the polymorphonuclear variety. With Ehrlich's triacid stain the granules are stained a dark-brown or copper colour. These cells are very commonly seen in a broken-up condition in cover-glass preparations, owing probably to their having a looser structure than the other varieties.

The normal percentage of each variety of leucocyte in the blood of the adult is given by Cabot as :

Polymorphonuclear neutrophiles	...	62-70 per cent.
Large lymphocytes	... ..	4-8   ,,
Small lymphocytes	... ..	20-30   ,,
Eosinophiles...	... ..	$\frac{1}{2}$ -4   ,,

It is frankly owned, however, that these figures are only an approximation to the normal standard, which is necessarily vague and elastic. In reviewing and comparing results this must be allowed for, as, to be thorough, the normal for each individual case should be established, but this, in such a series of examinations as the present, is obviously impossible. The above standard, however, is useful in giving data for a reliable comparison.

In the differentiations at term of thirty-two cases which may be considered to be strictly normal I found the average to be :

Polymorphonuclear neutrophiles	...	78·7 per cent.
Large lymphocytes	... ..	8·8   ,,
Small lymphocytes	... ..	10·8   ,,
Eosinophiles	... ..	1·7   ,,

These results, when compared with the normal standard already given, appear to show a relative increase of the polymorphonuclear variety at the expense of the lymphocytes.

So far as I have been able to find, Cabot is the only writer who makes any statement on this point, and his opinion is that there is a moderate increase of all varieties of leucocytes.

*Causation.*— Regarding the causation of the leucocytosis of pregnancy, various suggestions have been made, but so far none of them completely explain the condition of affairs. The suggestion of Cabot that the leucocytosis of pregnancy may be only a prolonged digestion leucocytosis, the mother having to eat and digest for two, has been already alluded to, but this, though feasible, does not appear to be thoroughly satisfactory. Normally, there is a digestion leucocytosis of a periodic nature—*i.e.*, dependent on the ingestion of food. It is true that in many cases, especially in persons whose digestion is slow, or who have their meals at very short intervals from one another, the effect of digestion on the leucocytes after one meal has hardly disappeared before the effect of the next meal is seen. In such cases, however, the ingestion of food increases the already existing leucocytosis. In pregnancy there should be practically the same condition. It must be remembered, however, that during pregnancy the maternal blood must be very much richer in nutritious matter than that of the normal adult, and that the foetus is feeding upon this continuously through the medium of the placenta. The pregnant woman does not, as a rule, eat more than the normal adult woman; indeed, in many cases she eats less food, yet the leucocytosis is still present. Also, even if digestion is constantly going on in the mother, the ingestion of food ought to increase the leucocytosis, although it may be only to a slight extent. It is noteworthy also that, although the pregnant woman during the latter months, and more especially the latter weeks, of pregnancy does not necessarily increase the amount of food ingested, the leucocytosis goes on steadily increasing. It would appear, therefore, that there must be some other cause for this leucocytosis. In favour of this theory of digestion there is the fact brought out in the differentiations at term—*viz.*, that the polymorphonuclear variety of white corpuscles is relatively increased. According to Burian and Schur, in digestion leucocytosis this variety is relatively increased, but so far as can be seen this statement is not corroborated. Cabot merely quotes it, but does not otherwise express an opinion.

The swelling of the breasts with the formation of milk is also mentioned by Cabot as taking part in the causation. This would

naturally cause a gradually increasing, though slight, leucocytosis. In favour of this there is the fact brought out in the examinations—that, after the puerperium, there still remains a modified leucocytosis, which is continued into the period of lactation.

During pregnancy, however, there is increased metabolism in the maternal organism, and this becomes greater with the ever-increasing demands of the growing fœtus. As the fœtus develops, also, there must be from it an increasing amount of waste material thrown off. All this necessitates the presence in the maternal circulation of an ever-increasing amount of effete material, which must be got rid of. This naturally of itself will cause an increase in the number of leucocytes, and it is at least feasible, therefore, that the leucocytosis of pregnancy is chiefly of a toxic nature, increasing with the increased metabolism in mother and fœtus as the pregnancy runs its course, reaching its height at term, then, immediately after delivery, rapidly diminishing when there is no longer any need for it.

It is unfortunate that the leucocytosis of pregnancy has little or no diagnostic value, as in the early months of pregnancy, when diagnosis is difficult, or even impossible, it is not present. In the latter months, also, according to Cabot, such conditions as hydatidiform mole and fibroid tumours may raise the count of white cells as much as pregnancy.

The leucocytosis during the puerperium is of importance from at least one point of view, that it might be confounded with a pathological leucocytosis in a case suspected of being septic.

The maternal blood at term, therefore, shows changes which are characteristic of a mild case of secondary anæmia, there being a considerable reduction in the amount of hæmoglobin present, with but little change in number or appearance of the red corpuscles. This condition is naturally explained by the fact that during pregnancy there is a long-continued drain on the albuminous constituents of the blood for the nourishment of the fœtus. In addition, there is a decided leucocytosis present. Before the end of the puerperal period, however, the blood in normal cases has almost returned to its condition in the unimpregnated state.

I have constructed a composite chart (No. V.), which shows at a glance the course of the red corpuscles, white corpuscles, and hæmoglobin from delivery until the end of the tenth day thereafter.

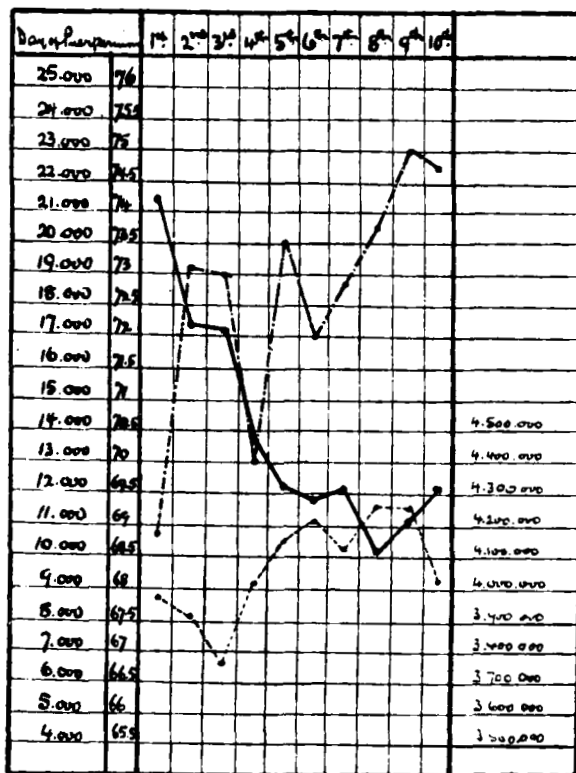
*The Effect of Plural Pregnancy on the Maternal Blood.*—I find no record of the blood examination in a case where there was more than one fœtus, but one case of twins which is included in my series raises

this question. It is natural to suppose that if one foetus *in utero* causes a leucocytosis, two or more will cause a greater increase. In this case, however, it is found that the leucocytosis is considerably below the average at term, being only 13,000 per cubic millimetre. This

CHART V.

*Composite.*

SHOWING THE COURSE TAKEN BY THE LEUCOCYTES, HÆMOGLOBIN, AND RED CORPUSCLES DURING THE FIRST TEN DAYS AFTER DELIVERY, BASED UPON THE AVERAGES GIVEN IN THE TEXT. (See p. 188.)



Leucocytes - represented by \_\_\_\_\_  
Red corpuscles " " .....  
Haemoglobin " " - - - - -

may possibly be explained by the fact that before admission to the hospital she had been drinking heavily for some weeks, and presumably, therefore, she had not had much in the way of ordinary diet during that period. The influence of fasting on the leucocyte count must, therefore, be taken into consideration. Luciani gives par-

ticulars of the blood of Succi, the professional faster, during a thirty days' abstinence. Von Limbeck also records 2,800 white cells in the blood of a patient who had fasted for a week. In both these cases the white corpuscles were found to be much diminished. It has also been established that fasting, by concentrating the blood, temporarily increases the red cells. In my case the red cells at term are recorded as 4,800,000, which is quite above that of the normal adult blood. Unfortunately, I have been unable to get another case of plural birth in which to investigate this point, so that meantime this case must stand by itself.

*The Influence of the Sex of the Child on the Maternal Blood.*—It is only natural to suppose that some such influence should exist, although, probably, only in very slight degree. Hough in 1884 published a long article on the relative influence of the sex of the foetus *in utero* on the mental, physical, pathological, and developmental condition of the mother during gestation, lactation, and subsequently. He states that, according to the sex of the foetus, there is some diversity in the general mutations of the female body. Andral has stated that the blood in pregnancy shows a remarkable tendency to assume the character of the blood of inflammation, but whether that change is greater in proportion or different in nature when a male foetus is carried we do not know. It may, however, be inferred that as the proportion of various substances in the blood differs in adults according to sex, it is, therefore, probable that the greater diversity or less watery condition of the blood in the male foetus determines in the mother the production of more fibrin.

On this point my observations cannot go very far, as in almost all—or, at least, in the great majority—of my cases I observed early formation of fibrin, pointing to excess in the blood. The red corpuscles and hæmoglobin do not show any such variation, but the behaviour of the white corpuscles is worthy of note. In investigating this point I have excluded all cases which were in any way abnormal, and I find that in thirteen cases where there was a female foetus the average count of leucocytes at term was 23,384; while in eighteen cases where the foetus was a male the average was 18,355. The latter average is perhaps even higher than it should be, as in four of the cases a certain amount of the leucocytosis might be caused by excitement, which is specially noted as being excessive. The average for the remaining fourteen cases works out at 16,685 per cubic millimetre. Of the female cases the lowest count was 14,800 (which is not much below the average male) and the highest 47,000; while of the male cases the minimum was 10,600 and the maximum

31,400. It is noteworthy that this count is the only one of the male cases which exceeded 24,600, which is only slightly above the average female count. I do not hold for a moment that this should be used as a means of diagnosing the sex of the child before delivery, because, as seen even in the limited number of cases in the series, there are exceptions on both sides. My attention, however, was drawn early in the series to the fact that with a male child there appeared to be a smaller leucocytosis than with a female, and it certainly was remarkable how often thereafter I was able to give a correct opinion before delivery as to the sex of the child. A very large number of cases would require to be examined before any definite statement could be made on this subject. I have no doubt that it would prove to be as correct a method as that of counting the foetal heart-beats, but, like it, it is a point which is more curious than practical, and is not worthy of further discussion.

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[Some of the above references I have not been able to verify in their original source, but in these cases I have stated the author who has quoted them.]