The presence of mordants on various materials may necessitate occasional alterations in our proceedings. More particularly will this be the case if the stained fabric has been afterward wetted and the blood by this means to a great extent removed.

What blood remains on the cloth is then very likely to be incorporated with the mordant. In such cases a process such as the following should be adopted: Digest a portion of the stained cloth in dilute ammonia, and afterward squeeze out the liquid. Deoxidize the *thick, turbid, unfiltered solution* in the ordinary manner and examine it for the deoxidized hæmatin bands, using concentrated sunlight, or the lime-light if necessary.

It is to be remembered that in the case we are supposing the hæmatin is probably chemically combined with the mordant; hence filtration, or allowing the deposit to subside, is equivalent to removing most of the blood-coloring matter. The turbidity of the liquid must be overcome in such cases, not by removing the deposit, but by increasing the intensity of the transmitted light.

Examination of Stained Fabrics that have been Washed after Staining, and the Treatment to be Adopted in the Examination of the Water that was used for Washing Them.—Hæmatin is a very insoluble body. Probably, therefore, after an article stained with blood has been washed in water, provided a sufficient time has elapsed for the change of the blood-coloring matter into hæmatin to be effected, enough will be left on the stained cloth to produce the spectra necessary for its identification. But it must be remembered that if the stain be perfectly recent, that is, before any of the hæmoglobin is converted into hæmatin, the whole of the blood may then be washed out by rinsing in cold water, and no trace be afterward found on the stained material. Hot water will not effect this removal of the blood like cold water, owing to its further action. Hence, if in a criminal case there is proof that an article has been washed in *cold water*, evidence as to the absence of blood stains is of little value; while if, after staining, the article was washed in *hot water*, the probability is there will be no difficulty in satisfactorily proving the real character of the stain. In many cases, after a stained fabric has been washed, the blood stain will be found spread over a considerable surface. Under such circumstances a large piece must be cut out, and digested with a proportionately large quantity of ammonia, or of citric acid solution, the liquid being concentrated afterward by evaporation at a gentle heat.

The water used for washing such materials may have to be examined. This can be done by concentrating the liquid, if necessary, and examining it in the usual manner If, however, it is found that there is any deposit in the water, it should be carefully collected, acted on with ammonia, and heat applied if the blood be insoluble in the cold solution.

If the recently stained fabric, however, be washed with *soap and water*, hæmoglobin will be rapidly converted by the action of the alkali into hæmatin. Soap and water, therefore, really sets the stain, and the probability is that, after washing, there will be little difficulty in detecting it on the fabric itself by the ordinary means. It may be necessary sometimes to examine the soap and water to see if it contains blood. This may be done as follows · Agitate the soap and water with ether and allow the mixture to stand until the ether has completely separated. Remove the ether with a pipette, and again and again shake the liquid up with ether until the aqueous solution is perfectly clear and free from soap This liquid must then be concentrated, and examined as usual for blood

Examination of Stains on Leather.—Blood stains on leather, or upon any body containing tannic acid, require special management on account of the precipitation of the coloring matter which is more or less certain to result. Proceed as follows.

(*a*) Cut off a fine shaving from the stained portion of the leather, so that there may be as much blood and as little leather as possible on the shaving. Bend this shaving so that the side that is stained may be brought into contact with a little water placed in one of the experimental cells, while the leather side of the shaving is not wetted. In this manner solution of the blood will probably be effected, and enough coloring matter obtained for experiment.

Mr. Sorby points out, however, that when a drop of blood falls on leather, the serum soaks into the leather, and leaves the blood corpuscles on the surface. If the leather be then washed, it would probably be impossible to obtain the blood spectra by the method just described. The following process, recommended by Mr. Sorby, has been found to work satisfactorily:

(*b*) Digest, for a considerable time, a portion of the stained leather in a mixture of one part (by measure) of hydrochloric acid and fifty of water. This will effect a solution of the mixed compound of the blood-coloring matter and tannic acid. Pour off the acid liquid, but do not filter it. The solution may appear almost colorless, or of a slightly yellow tint. Add to this an excess of ammonia, when the color will become either a pale purple or a neutral tint, the tint shade being considerably intensified on the addition of the ferrous salt and double tartrate, which are now to be added. The solution is then to be examined in an experimental cell, using a sufficiently intense light, such as the lime-light, or direct sunlight, to penetrate the turbid solution. Under these circumstances the spectrum of deoxidized hæmatin will be seen. If the liquid be too turbid to allow even a direct ray from the sun to be passed through it, allow the cell to remain for a few minutes in a horizontal position so that a little of the deposit may subside, although if this can possibly be avoided it is desirable to do so, because it will be found that the removal of the deposit at the same time destroys the intensity of the spectrum, proving that the greater part of the hæmatin under these circumstances exists as a compound insoluble in dilute acid.

Before commencing the experiment with the stained portion of the leather, it is advisable to make out clearly how large a piece of the unstained leather may be treated with a given quantity of the acid without producing too dark a solution, and to take care afterward not to employ a larger piece of the stained portion of the leather than is justified by these trial experiments.

Blood Stains on Earth and on Clothes soiled with Earthy Matters.—The stained earth is to be carefully collected and digested in a considerable quantity of ammonia. This is to be poured off, concentrated by evaporation, and the spectroscopic experiments conducted as usual on the turbid solution, an intense light, such as the lime-light or direct sunlight, being used for the purpose, in the manner already described. A similar process should be adopted in examining stained fabrics soiled with earthy matters. This is important to note, inasmuch as the coloring matter in a solution of blood will be found to be completely carried down by earthy matter when shaken up with it.

General Precautions to be Observed in Conducting Microspectroscopic Observations.—We now add a few words of general advice and a few precautions necessary to be observed in examining blood stains by the spectroscope.

(1) If the fabric on which the blood stain occurs be colored, always examine the spectrum produced by the coloring matter alone, taken from unstained portions of the fabric. Further, it is well to put a little blood on an unstained portion, and to examine its spectra when dry, and thus fully determine, before commencing experiments on the stained portion, any possible interference in the blood spectra resulting from the presence of such coloring matter.

(2) On no account decide that an observed spectrum from a suspected stain is due to blood unless it *exactly* coincides with bands produced by a known solution of blood of equal strength treated in a similar manner and examined side by side. It is advisable to have several tubes of the deoxidized hæmatin of different strengths for purposes of comparison These solution are best

kept in hermetically sealed tubes, so as to have them at hand whenever they are needed.

(3) In all cases examine the spectra both by daylight and by artificial light. We prefer artificial light for general work, but in every case it is advisable to try both means of illumination. Direct concentrated sunlight, or the lime-light, should be tried whenever the solution is thick and turbid.

(4) Never be content with observing a single spectrum of blood. Remember, further, it is often impossible to obtain the unaltered blood spectrum. Hence never satisfy yourself that a stain is not blood until you have failed to obtain all the spectra produced by the appropriate reagents.

(5) If the liquid under examination be *too strong*, too much light will be cut off by the solution, and the absorption bands will be in this way obscured. If the solution be *too weak*, the bands will be too faint, and so likely to be overlooked. Practise in this matter to obtain the happy medium. Never (if possible) be satisfied with a single examination.

(6) Use extremely minute quantities of the several reagents. Hæmatin produced by an acid is not very soluble in a strong solution of citrate of ammonia. If you add too much protosulphate of iron the precipitate produced so obscures the field as to mask the absorption bands.

(7) Adjust the width of the slit during the spectroscopic examination. All absorption bands are best defined when the slit is very narrow, while, if the bands are very faint, they will often be best seen at the very moment when the slit is being completely closed.

(8) Remember that, with our present knowledge, the spectrum microscope affords no information whatsoever as to whether the blood is from man or beast, nor from what class of animals it is derived; nor, if it be human blood, does it enable us even to hazard a conjecture as to the locality of its origin. 9. Lastly, unless the stain is bright red—an appearance which can be noted only on white or nearly colorless fabrics—never venture an opinion as to the probable age of the stain.

Of the certainty of this method of research, Mr. Sorby says (*Medical Press and Circular*, May 31, 1871): "I unhesitatingly say we can distinguish blood (by the microspectroscope) from all other animal and vegetable coloring matters."

5. Microscopical Examination of Blood Stains.—Besides the fluid portion of blood, certain organized bodies are found, called corpuscles, consisting of two varieties, the white and the red. In the higher animals the red corpuscles are the smaller but the more numerous, while the white corpuscles are rather larger and somewhat granular in structure and of a spherical form. The red corpuscles are circular, biconcave discs, of soft viscid matter, mostly soluble in water, but only very slowly dissolved by serum and the fluid part of the blood. The outer part of the red corpuscles is of firmer consistence than the interior, especially in the older corpuscles, but there is no special envelope or cell wall. By the action of water the coloring matter may be dissolved out, leaving the form of the corpuscle but little changed, except that it becomes nearly spherical.

When blood is spread upon glass, or any hard non-porous substance, the corpuscles adhere and retain their diameters unchanged, but when blood dries in a clotted mass, the red corpuscles shrink and often assume a crenated or stellate form.

If the stain to be examined is a mere film on a steel instrument or other smooth, hard substance, as glass or varnished wood, it may be laid on the stage of the microscope, and with a quarter or one-eighth inch objective, with Beck's patent illuminator above, the light of a lamp may be reflected down through the objective. In this manner the stain may be examined as an opaque object.

By this method the writer has succeeded in recognizing and measuring blood discs, magnified fourteen hundred diameters, on the blade of a knife which had lain in the forest, covered with leaves, through two winters. Generally blood stains form a mass too thick to be examined by this method, yet even then the corpuscles contracted to dimensions much below normal may be recognized as blood by this method of examination.

If the stain is in the form of shining scales, or if it is on cloth, leather, or any porous substance, it may be picked off with a needle or pointed instrument, and the dust or particles of clot received upon a glass slide and moistened with a suitable fluid to separate the corpuscles and restore them to their normal dimensions.

Fluids used in the microscopic examination of blood corpuscles should be such as will not destroy them, and such as will not increase or decrease their dimensions beyond their normal size. For this purpose a fluid should generally be used having the same specific gravity as blood serum, 1.028 or 1.029.

Robin's fluid consists of distilled water, to which is added chloride of sodium, one per cent., and bichloride of mercury, one-half of one per cent.

Roussin's Fluid.—Glycerin, three parts; sulphuric acid, one part; with water sufficient to reduce the specific gravity to 1.028.

Hayem's fluid consists of distilled water, with the addition of sulphate of sodium, two and one-half per cent.; pure chloride of sodium, one-half per cent., and bichloride of mercury, one-fourth per cent.

Professor J. G. Richardson employed water with the addition of common salt, three-fourths of one per cent.

Dr. Thad. S. Up de Graff, who was very successful in distinguishing the blood of man from that of the lower animals, employed water with bichloride of mercury, one-half of one per cent.

Many other microscopists use glycerin and water, mixed in such proportions as to give a specific gravity of 1.028.

Each of the fluids described has some advantage over the others. The fluids containing bichloride of mercury are not likely to be infested with fungi when specimens are kept for a length of time. Glycerin water interferes less with other tests which may be applied after the microscopie examination is completed; but in this respect it has no advantage over Richardson's salt solution.

Filtered serum from the blood of a frog may be employed in examining stains supposed to be from mammalian blood. Albumen of egg is also sometimes used.

In moistening blood stains with any fluid whatever it is to be remembered that the substance of the stain absorbing the fluid renders it more dense than it was when prepared; therefore, if the fluid employed has no greater density than blood serum there is no opportunity for the blood corpuscles of the stain to enlarge beyond their ordinary dimensions in normal blood. As yet no fluid has been described which will cause dried blood corpuscles to swell up to a greater diameter than the original fresh blood. When by the action of water the red corpuscle becomes spherical, its diameter is diminished.

When a blood stain is situated upon paper more of it remains on the surface than when the stain is upon cloth, and, after the paper is moistened, the film of blood can sometimes be detached from the surface in small scales or lumps. Mingled somewhat with filaments of the paper, and with molecular material, we find blood globules more abundant than in stains upon cloth. The form of the globules is also better preserved, and they are often seen in nummular masses, as in fresh blood, and we recognize the central depression and dentate borders characteristic of corpuscles of mammalian blood. These masses also preserve the color which distinguishes blood from all colored objects of vegetable or mineral origin.

Stains upon wood have characteristics similar to those of stains upon paper.

Stains upon woollen goods are somewhat more difficult to determine than those on cotton, linen, paper, or wood.

If we use the sulphate of soda solution for the examination of fresh stains (not more than six days old)

upon iron or steel, the fibrin separates and leaves the corpuscles floating free in the liquid, and the clot shows the characteristic fibrillar arrangement. We find also the white corpuscles either isolated or entangled in the clot. The white corpuscles are no less characteristic than the red by their size, form, finely granular appearance, and nuclei, which appear near the centre, brought into view by the sulphate of soda solution. This solution acts upon the white corpuscles almost as quickly as pure water, but causes them to swell less. The characteristics which distinguish white blood globules from pus should be noted whenever there is a possibility of finding the two together, which is not common in legal cases.

If blood stains have been deposited on rusty iron or steel, or have remained long on such instruments even if not rusty, the glycerin solution is much to be preferred in their examination, as it does not act upon the metal; while sulphate of soda or any of the acid solutions cause the deposit in the preparation of dark granules formed of a salt of iron.

The fine dust obtained by scratching a stain with a needle point or by crushing a large particle picked off from a shining clot, should be covered with a circle of thin glass, and a drop of one of the solutions described above should be allowed to run under the cover. If the stain is recent, it will be in a condition for examination in a few days, or in some cases in a few hours. If the stain is old, over six months, a much longer time is required to soften it. If the object is only to recognize blood corpuscles when the dust-like particles have been softened, the fluid may be drawn away by touching one side of the cover glass with blotting paper, at the same time placing a drop of a staining fluid—as a watery solution of eosin or iodine—on the opposite edge of the cover. After two or three minutes the colored fluid may be withdrawn in the same manner, and salt solution or glycerin water allowed to take its place, when the blood corpuscles, if any exist, will be easily distinguished, and may be measured by the use of the micrometer. Where a stain on paper, leather, or blades of grass is so thin that no particles of clot can be removed, Prof. F. B. Wyman, M.D., hardens the stain in formalin or in equal parts of alcohol and ether for five or ten minutes, then stains in a watery solution of eosin, dehydrates with alcohol, clears in oil of bergamot, and mounts the paper, leather, or grass in Canada balsam as ordinary sections of tissue are mounted. The blood corpuscles of the stain are then clearly seen and can be measured.

If the stains are not very recent, provision must be made to prevent evaporation of the fluid used to soften them. Take a glass slide with a circular excavation in the middle, called a "concave centre," and moisten it around the edges of the cavity with glycerin. Thoroughly clean a glass cover an eighth of an inch or more larger than the excavation, lay it on white paper, moisten the centre with the glycerin solution (sp. gr., 1.028), dropping into the solution so placed the dust obtained from the stain, then invert the slide upon the thin glass cover in such a manner that the glycerined edges of the cavity on the slide may adhere to the margins of the cover; turn the slide face upward, and examine with the microscope. In the fine dust thus moistened, isolated red and white blood corpuscles will often be seen immediately. If not, lay the slide face downward on a suitable support, and examine from day to day until the corpuscles become visible and cease to enlarge. They cannot exceed their normal size when treated by this method.

Prof. Joseph G. Richardson, M.D., made a minute dot of glycerin, about the size of this period (·), on a thin glass cover, and pushed into it a particle of suspected blood clot, the smallest that can be seen by the naked eye, one-thousandth or one-five-hundredth of an inch in diameter, receiving the cover on the concave slide as described above. By this method he obtained a strong solution of the coloring matter of blood, in which the absorption bands peculiar to blood could be seen, if blood was present in the stain; and by a little practice the bands may be modified by the addition of sulphuret of sodium, as advised by Preyer and Sorby.

By a similar method, using a little more material on a cover glass moistened with a very small drop of three-fourths-per-cent. salt solution, he was able to see, first, the absorption bands of blood with the microspectroscope, then, turning the slide so as to drain off superfluous fluid, and using the microscope with a magnifying power of about two thousand diameters, he was able to see and measure both white and red blood corpuscles, so as to distinguish human blood from the blood of the ox, pig, horse, or sheep.

In examining a slide prepared by either method above mentioned, if the material is blood, we first observe that the edges of the solid particles gradually become translucent and the fluid around assumes a reddish-yellow color, showing that the coloring matter is soluble. In this condition of the preparation by use of the microspectroscope the characteristic absorption bands of blood will be seen.

After a little time, if the amount of fluid applied be sufficient, the solid particles are softened, and, as they swell up, yellowish-white corpuscles with a slightly granular structure are seen; these are the well-known white blood corpuscles, which, with a magnifying power of one thousand diameters or upward, may be distinguished from other organized structures of either animal or vegetable origin. After longer maceration the characteristic red corpuscles of blood, with smooth and sharply defined edges, begin to appear, and after a time are found floating free in the fluid under the cover glass. If the stain is mammalian blood, some of the corpuscles will be clearly seen as biconcave discs with a light centre and a dark edge or border. If any doubt remains in regard to the nature of these corpuscles, it may generally be resolved by the use of a higher magnifying power. Grains of pollen may be generally distinguished by a roughened edge, or by small points on the surface. Spores of fungi are often found mixed with blood stains, but in general the texture is different from that of blood. Occasionally the biconcave structure of red blood corpuscles can be distinguished, as a slight motion causes some of them to roll over as they move across the field. Unicellular algæ, often seen in wet preparations, may be distinguished by the granules which they contain, having a greenish-brown or reddish color. These are grains of chlorophyll. Spores of fungi growing in fluids have generally, if undisturbed, some systematic arrangement not found in the positions assumed by blood corpuscles.

Erdmann records a case (*Zeitschrift für analyt. Chemie*, ii., 1862, and *Gazette Hebdomadaire*, quoted in *Edinburgh Medical Journal*, October, 1862, p. 370) which shows the importance of employing more than one kind of test in examining stains supposed to be blood. "The only trace of an assassination at Leipsic was a brownish stain found at the spot where the crime had been committed. Under the influence of rain, the stain had assumed the appearance of coagulated blood. An aqueous solution of this stain furnished a reddish fluid, which gave with tannin, with ferrocyanide of potassium, and with Millon's solution,* the same chemical reaction as the aqueous extract of dried blood. Examined under the microscope, the brown matter was found to contain some corpuscles very similar to those of blood. But Erdmann having failed to discover crystals of hæmin, conceived doubts as to the value of the other characters, and repeated with great care the microscopical examination. He then discovered that the bodies supposed to be blood globules were the spores of algæ called *porphyridium cruentum*, on account of the resemblance of its spores to blood corpuscles."

This blood-colored gelatinous alga, *porphyridium cruentum*, growing upon moist ground, is of doubtful

* Millon's solution is a strongly acid (nitric and nitrous) solution of proto- and pernitrate of mercury, made by dissolving metallic mercury in its weight of strong nitric acid with the aid of heat.—Micrographic Dictionary.

occurrence in the United States (*Am. Quar. Mic. Journ.*, April, 1879). Thudichum, in "Tenth Report of Med. Officer to Privy Council," 1867, p. 216, mentions a red, gelatinous mass, growing upon a human thigh-bone, which was macerating at St. Thomas' Hospital. The glass vessel in which it was macerating was similarly covered. The microscope showed the red material to consist of minute cells in a gelatinous mass, with which larger green cells were interspersed. The water filtrated from them contained a number of minute bodies in suspension. It was red, and gave a spectrum very similar to that of blood. The plant in question is called by Thudichum red saprophytes.

To avoid mistaking algæ or other organized bodies for blood corpuscles, the guaiacum test, the hæmin-crystal test, and the spectroscope should be used.

The mammalian corpuscle, in its normal condition, is a delicate endosmometer, taking in or giving out fluid according to the relative density of the liquor sanguinis and contents of the corpuscle, allowing rapid variations within certain limits. Accordingly, the corpuscles may be either swollen, puckered, or shrunk into a variety of figures, flat, tumid, like a shallow circular or oval cup, stellate, notched, granulated, mulberry-shaped, crescentic, angular, lanceolate, fusiform, or comma-shaped, or they may possess other figures defying description. In certain of the *cervidæ* the angular, crescentic, and lanceolate corpuscles are abundant. In connection with disease, deformed corpuscles are also found.

The recognition of blood stains, and the probable determination of the animal from which they came, depend on the use of solvents of the same endosmotic power as the serum of normal blood, and on the microscopic examination and measurement of the corpuscles having the normal form. In the blood of birds, fish, and reptiles having red blood discs of an oval or ellipsoidal form, it is sometimes possible, when they are standing on end or are distorted by drying, to see them as circular bodies. Time must therefore be allowed for the stains to be fully softened and the corpuscles to be isolated by the solvent before their origin can be decided. There are also some round corpuscles mingled with the elliptical, but they are too few in number to mislead a careful observer.

Stains formed by menstrual blood contain uterine and vaginal mucus mingled with cells of epithelium.

At the commencement of menstruation the linen is stained of a brown color, changing gradually to red. About the third day blood corpuscles are abundant, mingled with leucocytes and epithelium. The cessation of the courses is marked by the diminution of the red blood globules and the increase of leucocytes, rendering the flow more nearly purulent. Menstrual blood does not differ from any other blood, except that it is mingled with mucus and epithelium and an abnormal proportion of leucocytes, and that fibrin is almost entirely absent. The absence of fibrin is the most characteristic distinction of menstrual blood.

Blood Stains compared with Stains formed by Lochial Discharges.—Medical experts are often called, especially in cases of infanticide, to distinguish between stains of blood and those formed by the lochiæ. These stains are to be examined by the same methods as are available for stains of normal blood. In the lochial discharge, about six hours after delivery, we find about five leucocytes to one hundred red blood corpuscles. At the end of the first day only about one-third of the organized structures are red blood corpuscles. The leucocytes are nearly equal in number to the red corpuscles; pavement epithelium from the vagina is also abundant.

Among the cells are some spheroidal or somewhat polyhedral by reciprocal pressure, united in groups similar to the deeper layers of epithelium of the vagina or neck of the uterus. The liquid, more or less viscous or odorous, which holds these elements in suspension, is studded with grayish granules. On the second day the leucocytes increase in number and the red globules diminish, and little by little the lochiæ assume a russet tint, which on the third or fourth day passes into a grayish white or yellow.

From the fifth to the seventh day, varying in different subjects, the red corpuscles almost entirely disappear, and the leucocytes become decidedly granular. Pavement epithelium is still found, but less abundantly than during the preceding days. The epithelial scales are generally imbricated, coming off in patches. The gray molecules become more adhesive and abundant, and the fat granules diminish in number. Fibro-plastic, fusiform bodies without a nucleus, pale and transparent, are also found. This composition of the lochiæ continues without much change until the close of the flow. By these characteristics stains of lochial discharges can generally be distinguished from normal blood.

The blood of all animals contains certain organized structures called corpuscles. In all mammals except a few of the camel tribe the red corpuscles, which are the most numerous form, are circular biconcave discs of which there are in man from four to five million in each cubic millimetre of blood. Another form nearly spherical, called white corpuscles, of which there are about ten thousand to the cubic millimetre, have a nucleus and vary greatly in numbers in different stages of the digestive process and in different conditions of health.

It is with the red corpuscles that we are principally concerned in the study of blood stains.

In birds, fishes, and reptiles generally the red corpuscles are ellipsoidal and have a nucleus. By these differences

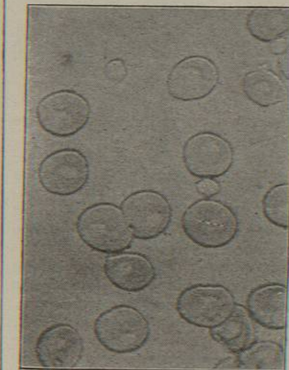

FIG. 610.—Blood of Lamprey Eel.

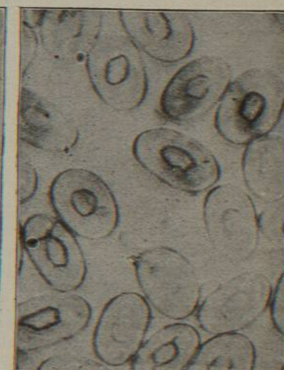

FIG. 611.—Blood of a Snake.

of form it is easy, when using the microscope, to distinguish between the blood of a mammal and that of all other animals with two or three rare exceptions.

In the blood of some of the camelidæ we find ellipsoidal corpuscles, but those can rarely if ever come into consideration in medico-legal cases. In the lamprey eel we find circular corpuscles with a nucleus; and these, again, are not likely to be mistaken for the blood of man or other mammal. On page 85 we give exact reproductions of photographs of the blood corpuscles of man and of the principal domestic animals, magnified 2,560 diameters, with a scale in which each division represents *half a micron* or about one-fifty-thousandth ($\frac{1}{50000}$) of an inch.

We thus see that when viewed by the high powers of the modern microscope wide differences are found between the blood of man and that of such animals as the pig, horse, ox, sheep, and goat.

In the blood of any single animal there are small and large corpuscles giving a considerable range between the smallest and largest in the same blood, while the general average of the corpuscles in man is greater than it is in any of the other animals whose blood is shown in the engravings. The accompanying table shows the range

and general average, measured in *microns*, for man, dog, pig, horse, sheep, and goat:

TABLE SHOWING VARIOUS SIZES OF RED BLOOD CORPUSCLES (MEASURED IN MICRONS) IN MAN AND DOMESTIC ANIMALS.

Microns.	Man.	Dog.	Pig.	Ox.	Sheep.	Goat.
9.50						
9.25	1					
9.00	5					
8.75	3					
8.50	15					
8.25	32	..	2			
8.00	28	..	1			
7.75	51	5	5			
7.50	48	14	4			
7.25	10	21	6			
7.00	2	45	10			
6.75	4	56	15	1	1	
6.50	0	26	13	1	0	
6.25	1	11	19	0	0	
6.00	..	16	44	29	0	
5.75	..	5	19	16	0	
5.50	..	1	13	20	3	
5.25	..	1	17	71	9	
5.00	..	..	10	34	30	
4.75	..	..	6	19	38	
4.50	..	..	4	8	71	
4.25	..	..	4	1	26	2
4.00	..	..	3	..	12	11
3.75	..	..	5	..	3	94
3.50	..	..	..	..	7	63
3.25	..	..	..	..	..	24
3.00	..	..	..	..	..	6
Number of corpuscles*	200	200	200	200	200	200
Maximum	9.31	7.85	8.39	6.77	6.77	4.31
Minimum	6.39	5.46	3.85	4.46	3.85	3.16
Mean	8.01	6.87	6.07	5.44	4.75	3.69

* These numbers (two hundred in each column) include all between the number in the left hand column opposite to which they are placed, and the number next above.

In any specimen of blood we find corpuscles of varying size, but a remarkable uniformity in the average measurements of blood from animals of the same kind.

Some discrepancies appear in the tables of measurements of blood as given by different authors. The tables found in most works on physiology or on medical jurisprudence were made when the instruments employed and micrometers used were by no means as perfect as the microscopes and micrometers now available. The following table has been prepared with great care. The measurements, with two or three exceptions, were made by J. B. Treadwell, M.D., with a $\frac{1}{16}$-inch objective, magnifying about twenty-five hundred diameters linear, and a glass micrometer placed in the eyepiece. The blood was spread upon glass and quickly dried. The reduction and arrangement of the results as given in the table were performed by the writer of this article. The standard of measurement was a micrometer ruled by Prof. W. A. Rogers, of Cambridge, Mass., and carefully compared with the standards procured at great expense by the United States Government.

MEASUREMENTS OF MAMMALIAN BLOOD.

Source of blood.	Number of corpuscles measured.	Mean diameter.	Minimum and maximum.	Range of averages by tens.	Range by twenties.	Range by fifties.	Range by hundreds.	Range by two hundreds.
5 men, ages 23 to 49 years	1,000	7.941	5.773 9.394	7.697 8.152	7.782 8.110	7.845 8.061	7.884 8.046	7.902 7.983
5 women, 18 to 55 years	1,000	7.927	6.350 9.287	7.825 8.152	7.787 8.026	7.873 7.993	7.901 7.963	7.913 7.950
3 infants, at birth, 1 male, 2 females	600	7.950	4.233 10.160	7.667 8.298	7.716 8.100	7.833 8.031	7.918 7.983	7.938 7.970
Boy, 8 years old	200	7.983	6.929 9.160	7.747 8.282	7.828 8.191	7.891 8.079	7.965 8.000	7.983
Man, 70 years old	200	7.916	7.005 9.236	7.658 8.121	7.662 8.105	7.768 8.028	7.852 7.980	7.916
15 persons, as above	3,000	7.938	4.233 10.160	7.658 8.298	7.662 8.191	7.768 8.079	7.852 8.046	7.913 7.983
Blood stains (human) restored	1,000	7.910	5.570 9.687	7.700 8.189	7.723 8.010			

MEASUREMENTS OF MAMMALIAN BLOOD.—*Continued.*

Source of blood.	Number of corpuscles measured.	Mean diameter.	Minimum and maximum.	Range of averages by tens.	Range by twenties.	Range by fifties.	Range by hundreds.	Range by two hundreds.
25 dogs	2,500	6.918	4.618 8.931	6.138 7.352	6.445 7.305	6.523 7.258	6.673 7.198	
Guinea-pig, male, 3 months	200	7.476	5.849 8.390	7.231 8.698	7.309 7.659	7.249 7.634	7.393 7.559	
Woodchuck, female	200	7.280	5.387 8.467	7.043 7.528	7.112 7.374	7.215 7.351	7.279 7.282	
Muskrat, male	200	7.283	6.158 9.391	6.920 7.535	7.120 7.555	7.195 7.428	7.245 7.320	
2 rabbits, 1 white, 1 mixed	400	6.365	4.618 8.082	6.196 6.596	6.227 6.485	6.294 6.409	6.349 6.383	6.354 6.377
2 hares, 1 male, 1 female	400	5.764	4.618 7.120	5.367 6.080	5.377 6.049	5.604 5.863	5.733 5.779	5.756 5.772
Gray squirrel, 1 female, 1 male, 5 months	400	6.876	5.926 7.851	6.366 7.436	6.627 7.079	6.774 7.080	6.823 7.004	6.827 6.926
Red squirrel, female, 5 months	200	6.607	4.926 8.313	6.227 6.851	6.381 6.897	6.496 6.709	6.592 6.622	
Striped squirrel, female	200	6.753	5.387 7.697	6.573 6.981	6.647 6.901	6.701 6.815	6.747 6.758	
Red fox, male, 5 months	200	6.482	5.541 7.312	6.250 6.674	6.408 6.562	6.474 6.544	6.470 6.494	
Pig, 2 of 3 months, 1 of 2 weeks	600	6.101	3.849 8.391	5.418 6.520	5.757 6.466	5.880 6.246	6.028 6.169	6.069 6.144
Ox, 3 male, 2 female (one 1 day, one 3 months)	1,000	5.436	3.916 6.774	5.150 5.703	5.296 5.622	5.345 5.543	5.347 5.482	5.406 5.461
Horse, 10 years	200	5.503	4.618 6.774	5.203 5.818	5.257 5.633	5.473 5.553	5.493 5.513	
Ass, 1 male, 1 female	400	6.293	5.003 7.697	6.018 6.566	6.138 6.539	6.201 6.377	6.219 6.376	6.259 6.326
Mule, 6 years	200	5.421	3.464 6.312	5.280 5.680	5.327 5.545	5.877 5.472	5.419 5.424	
Cat, 1 adult, 1 kitten, 3 weeks	400	5.463	2.617 6.774	4.311 5.780	4.361 5.676	5.268 5.573	5.419 5.522	5.431 5.495
Sheep, male, 15 days, female, 1 year	400	4.745	3.079 6.774	4.503 4.972	4.588 4.869	4.665 4.785	4.725 4.764	4.744 4.746
Goat, 1 male, 1 female	400	3.567	2.617 4.080	3.394 4.764	3.401 3.710	3.467 3.693	3.535 3.638	3.546 3.587
Mouse, house, common	200	6.038	2.309 7.004	5.772 6.281	5.891 6.200	5.990 6.094	6.037 6.039	
Mouse, house, long-tailed	200	6.099	4.618 6.696	5.857 6.258	5.968 6.208	6.063 6.143	6.089 6.109	
Mouse, field	200	5.095	4.080 6.928	5.733 6.041	5.803 6.995	5.814 5.967	5.891 5.919	
Rat, male	200	6.500	3.079 8.005	6.289 6.820	6.346 6.695	6.441 6.694	6.490 6.510	
Mole, male	200	6.216	4.618 7.697	6.095 6.435	6.080 6.339	6.131 6.293	6.175 6.258	
*Elephant	100	9.259	7.164 11.504	....	....	....	9.259	
Woman, 19 years, anæmia	100	7.346	3.464 9.237	6.674 7.605	7.012 7.628	7.177 7.515	7.346	
Child, 6 weeks old, starved to death	100	7.573	4.465 8.636	7.328 7.712	7.493 7.639	7.572 7.574	7.573	
*Human embryo, 143 grains, non-nucleated corpuscles	20	11.346	9.736 13.486	11.032 11.661	11.346			
*Human embryo, nuclei of nucleated discs	10	8.089	5.394 11.611	8.089				
A male cat, stupefied 5 hours by alcohol	100	5.489	4.772 7.235	5.327 5.680	5.426 5.846	5.479 5.498	5.489	

* Measured by M. C. White.

I was informed by Dr. Richardson that he measured from the outside of the dark border of the corpuscle on one side to the inner side of the dark border on the opposite side of the corpuscle. If we add one-fiftieth of the diameter for the remainder of the dark border we should obtain 8.036 microns, which is a trifle larger than the average given in the table. This difference may possibly be attributed to minute differences in the micrometers used, or it may be owing to what is known as the personal equation of the observer.

Professor Wormley, of the University of Pennsylvania, whose extensive and valuable measurements of blood corpuscles are published in the second edition of his work on "Microchemistry of Poisons," measured the whole of the dark border of the corpuscle. Professor Wormley used a one-tenth inch objective made by Beck, and a one-thirty-second inch objective made by Gundlach, mag-

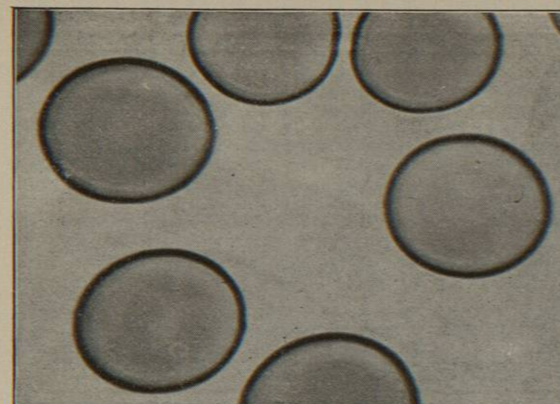

FIG. 612.—Human Blood (Red Corpuscles). × 2,560.

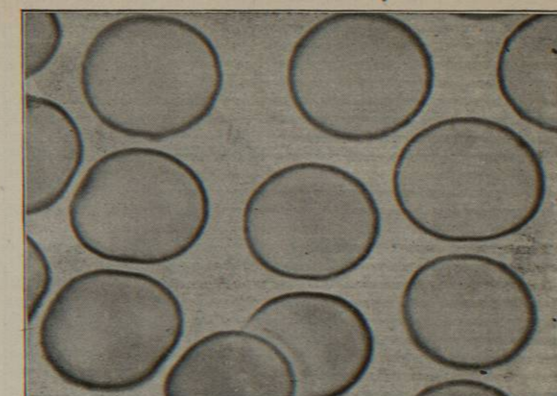

FIG. 616.—Red Discs of Dog. × 2,560.

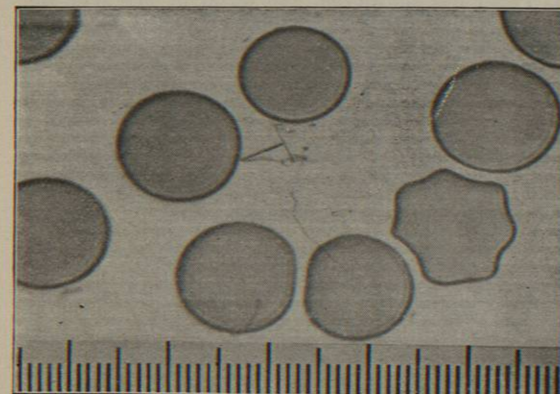

FIG. 613.—Blood of Pig. × 2,560. Division of scale, $\frac{1}{50000}$ inch.

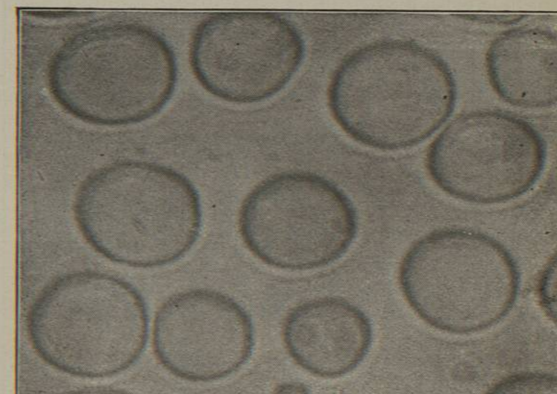

FIG. 617.—Blood of the Ox. × 2,560.

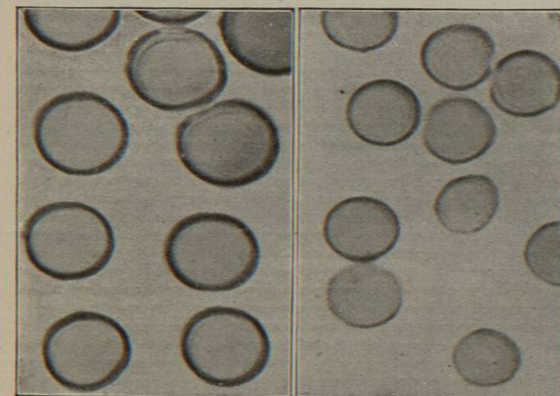

FIG. 614.—Blood of Sheep. × 2,560. FIG. 615.—Blood of Goat. × 2,560.

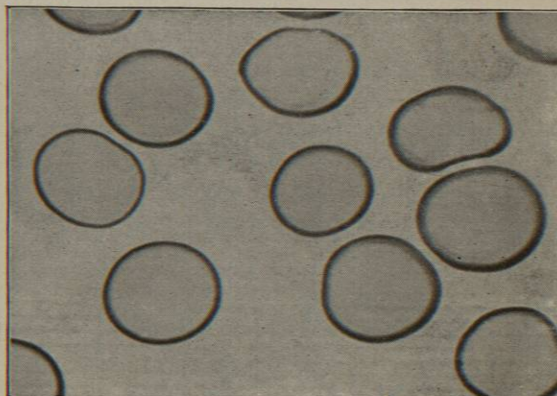

FIG. 618.—Blood of Horse. × 2,560.