nifying from 1,150 to 2,300 diameters. In the following table the measurements of Treadwell and Wormley are compared with the measurements made by Gulliver twenty-five years ago, and published by him in the "Proceedings of the Zoölogical Society of London" in 1875.

AVERAGE SIZE OF RED BLOOD CORPUSCLES, IN FRACTIONS OF AN INCH.

Mammals.	By Gulliver.	By Wormley.	By Treadwell.
Man	1–3200	1–3250	1–3200
Monkey	1–3412	1–3382	
Opossum	1–3557	1–3145	
Guinea-pig	1–3538	1–3223	1–3397
Kangaroo	1–3440	1–3410	
Muskrat	1–3550	1–3282	1–3487
Dog	1–3532	1–3561	1–3672
Rabbit	1–3607	1–3653	1–3984
Rat	1–3754	1–3652	1–3908
Mouse	1–3814	1–3743	1–4223
Pig	1–4230	1–4268	1–4163
Ox	1–4267	1–4219	1–4673
Horse	1–4600	1–4243	1–4614
Cat	1–4404	1–4372	1–4648
Elk	1–3938	1–4384	
Buffalo	1–4586	1–4351	
Wolf (prairie)	1–3600	1–3422	
Bear (black)	1–3693	1–3656	
Hyena	1–3735	1–3644	
Squirrel (red)	1–4000	1–4140	1–3847
Squirrel (gray)	......	......	1–3322
Ground squirrel (striped), chipmunk	......	1–4200	1–3762
Raccoon	1–3950	1–4084	
Elephant	1–2745	1–2738	
Leopard	1–4319	1–4390	
Hippopotamus	1–3429	1–3560	
Rhinoceros	1–3765	1–3649	
Tapir	1–4000	1–4175	
Lion	1–4322	1–4143	
Ocelot	1–4220	1–3885	
Mule	......	1–3760	1–4432
Ass	1–4000	1–3620	1–4036
Bat	1–4175	1–3966	
Sheep	1–5300	1–4912	1–5353
Ibex	......	1–6445	
Goat	1–6366	1–6189	1–7982
Sloth	1–2865		
Platypus (duck-billed)	1–3000		
Whale	1–3099		
Capybara	1–3190	1–3164	
Seal	1–3281		
Woodchuck	1–3484	......	1–3489
Musk-deer	1–12325		
Beaver	1–3325		
Porcupine	1–3369		
Llama, Long diam	1–3361	1–3201	
Llama, Short diam	1–6229	1–6408	
Camel, Long diam	1–3123	1–3331	
Camel, Short diam	1–5876	1–5280	
Red fox	......	......	1–3918

	GULLIVER.		WORMLEY.	
	Length.	Breadth.	Length.	Breadth.
Birds—				
Chicken	1–2102	1–3466	1–2080	1–3483
Turkey	1–2045	1–3598	1–1894	1–3444
Duck	1–1937	1–3424	1–1955	1–3504
Pigeon	1–1973	1–3643	1–1892	1–3804
Goose	1–1836	1–3839		
Quail	1–2347	1–3470		
Dove	1–2005	1–3369		
Sparrow	1–2140	1–3500		
Owl	1–1763	1–4076		
Reptiles—				
Tortoise (land)	1–1252	1–2216	1–1250	1–2200
Turtle (green)	1–1231	1–1882		
Boa constrictor	1–1440	1–2400	1–1245	1–2538
Viper	1–1274	1–1800		
Lizard	1–1555	1–2743		
Batrachians—				
Frog	1–1108	1–1821	1–1089	1–1801
Toad	1–1043	1–2000		
Triton	1–848	1–1280		
Proteus	1–400	1–727		
Amphiuma tridactylum	1–363	1–615	1–358	1–622
Fishes—				
Trout	1–1524	1–2460		
Perch	1–2099	1–2824		
Pike	1–2000	1–3555		
Eel	1–1745	1–2842		
Lamprey	Circular.	1–2134		
Nucleus	......	1–6400		

From these tables it is clearly shown that a careful microscopist would not be likely to mistake the blood of a goat, sheep, horse, ox, or pig for the blood of a human being; or that of any animal having blood corpuscles with an average diameter less than $\frac{1}{4000}$ of an inch or 0.0063 mm. (6.3 microns).

Concerning the possibility of distinguishing the blood of a dog from that of man, medical experts are in nowise agreed, a few contending that they can distinguish a recent stain of the blood of a dog from the blood of man, and they have successfully accomplished the task when put to the crucial test of experiment.

The late Col. J. J. Woodward, M.D., when testifying as an expert in the Hayden trial, at New Haven, Conn., in 1879, stated that he had measured twenty corpuscles from a young dog, forty from another, and fifty from a third, in which he found the averages of the corpuscles measured from each one of those dogs larger than the recognized average size of human blood corpuscles. In regard to these measurements Dr. Woodward stated in his cross-examination, by the state: "*I looked to find big corpuscles and I knew that the group around them would be large.*" The same expert has published measurements of the blood of other dogs so large that he inferred that there is no safety in attempting to state positively that a given stain is the blood of man and that it could not be the blood of a dog.

L. Perier has shown that the blood of new-born infants often contains giant corpuscles similar to the large non-nucleated corpuscles of the human embryo, and states that until recently these have not been considered as true red corpuscles.

He also states that these giant corpuscles have a tendency to collect together, and that in estimating average measurements it is important to examine all parts of the slide on which the blood is spread. L. Perier also says that he finds in the blood of infants many globulins nearly spherical, only about half the diameter of ordinary blood discs. If these globulins are not included in the measurement it will be easy to obtain large averages for the blood of infants.

Dr. R. U. Piper, of Chicago, finds that the blood corpuscles of new-born infants retain much of the character of pre-natal blood, and give an average diameter larger than that of the blood of adults. He also finds the blood of young puppies giving a larger average diameter than that of the blood of adult dogs, but these facts do not disparage the value of the microscope as a means of distinguishing the blood of man from that of full-grown dogs, especially if we can obtain for comparison authentic specimens of the blood of the particular man and dog with which a given blood stain is to be compared in a given case.

Dr. Thad. S. Up de Graff (in *The Microscope*, October, 1883) states that the red blood corpuscle of the dog resists the action of water and ruptures less readily than does the red corpuscle of human blood, because, as he thinks, the cell wall or border is thicker in the blood of the dog than it is in human blood.

By a careful study of the micrometric data from which the table of measurements by Dr. Treadwell was calculated I find as a general rule, to which there are some exceptions, that the blood corpuscles of young animals have a greater range (as Perier and Hayem have stated) from the smallest to the largest corpuscle, and a slightly larger average diameter, than have those of adults. This is shown in the case of a male pig, two weeks old, in the first table giving the range of two hundred corpuscles for that and other animals. The same is apparently true of the blood of females as compared with the blood of males. My own measurements of human blood of infants and adults, both male and female, tend to the same conclusions.

In the measurements given in this table the whole of the dark border was measured. The measurements were originally taken and recorded in parts of the American standard inch, which have been reduced to parts of a millimetre by reckoning 1 inch = 25.40098

mm. The measurements in the table are given in microns, 0.001 mm.

To secure a fair average two hundred corpuscles were generally measured, and often this number was measured from several animals of the same class. To show how large a number of corpuscles should be measured to obtain a fair average, the range of averages is given as computed by tens, twenties, fifties, and hundreds; also the range of averages of two hundreds as taken from the separate animals.

J. G. Richardson, M.D., of Philadelphia, during the progress of the Centennial Exhibition at Philadelphia, measured one hundred corpuscles from each of fourteen men of different nationalities, using a one-twenty-fifth inch immersion objective and a cobweb micrometer eyepiece; the microscope thus arranged magnifying eighteen hundred diameters. He found the average diameter of the fourteen hundred corpuscles to be inch $\frac{1}{3224}$ or 7.879 microns. This is smaller than the measurement given in Dr. Treadwell's table, viz., 7.8938 microns.

While the general consensus of opinion among microscopists is that the blood of man can be distinguished with great certainty from the blood of such domestic animals as the pig, ox, horse, sheep, and goat, but few experts would venture any very positive diagnosis in criminal cases between the blood of man and that of the dog; though a *correct* diagnosis has been often given in experimental cases. Over twenty years ago Dr. Woodward published his results in the measurement of the corpuscles of dogs, giving averages which could not be distinguished from the measurements of human blood. Professor Wormley, Dr. Richardson, and Dr. Treadwell opposed his conclusions and sought opportunity (which was never given) to examine Dr. Woodward's specimens of dog's blood. At the famous Hayden trial before the superior court in New Haven, Conn., in 1879, Dr. Woodward explained his method of obtaining a large average of the blood corpuscles of the dog. He stated that he took blood from young dogs, spread on slides, and, looking over a slide till he found a collection of large corpuscles which have a tendency to collect together, he made his measurements from that collection. As a sample of his work, Dr. Woodward stated that on December 14, 1879, he measured 50 corpuscles from a pup four weeks old, a Newfoundland crossed with a setter, and found the average was 326-millionths of an inch, or 8.28 of a micron. December 12, 1879, he measured, selected in the same manner, 40 corpuscles from a Scotch terrier and got an average of 320-millionths of an inch, equal to 8.13 microns. From a Gordon setter full grown he measured 29 corpuscles and obtained an average of 300-millionths of an inch, equal to 7.62 microns. Dr. Woodward, when testifying under oath, said: "I desire to put myself on record as distinctly denying that those measurements of the dog's blood would represent what you would be likely habitually to get if, without picking out young dogs and without selecting a spot to measure appearing to have unusually large corpuscles, you were to measure dog's blood. You would then habitually get smaller figures than I have given here. The average of the corpuscles of dogs would habitually be smaller than I have given here, but I have purposely selected for fixed measurements young dogs, for I knew they had bigger corpuscles, and, in the second place, in taking an old dog, I purposely selected a place on the slide where, to my trained eye, I saw there was a group of big corpuscles. My reason for doing this is to show that if you pick up a half-dozen corpuscles by chance, you may chance on these big things. But I have nowhere stated that the average for the dog is as large as for man; on the contrary, I would like to read my express statement from my printed utterance, that the general average for the dog, for a great number of measurements, will be less than for a great number of men." Dr. Woodward appeared to contend that in examining blood stains you might chance to get a small speck of dried blood, from a dog, having principally these large corpuscles. This argument throws doubt upon any attempt to distinguish between the blood of man and that of the dog unless a large number of corpuscles have been measured. In Figs. 619 and 620 I give examples of the blood of man and the blood of a young female pug dog, both photographed by me on the same negative. They are magnified only 640 diameters in order to include a considerable number of corpuscles in the comparison. In this case no attempt was made to select a place where large corpuscles had collected. I should not attempt to distinguish with any degree of confidence in a criminal case between the blood of man and the blood of a dog.

As a difficulty in distinguishing the blood of different animals by microscopic measurement, Dr. Robert Ryburn (*Medico-Legal Journal*, September, 1892, p. 165) says, the trouble in our investigation of this subject lies in the fact that the blood corpuscles are living organisms that are not possessed of outlines delineated with mathematical accuracy. Replying to this objection we refer to Professor Wormley's statement ("Microchemistry of Poisons," p. 728): "In a series of ten spaces ruled on glass measured by three observers with different instruments the results did not differ more than $\frac{1}{200000}$ of an inch; and that two independent series of measurements, with high

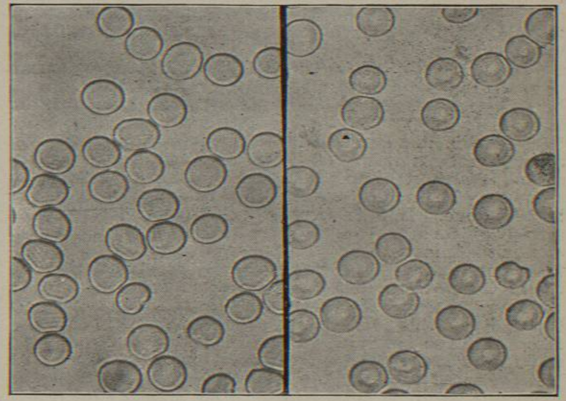

FIG. 619.—Human Blood. × 640. FIG. 620.—Blood of Pug Dog. × 640.

powers, of 20 designated blood corpuscles were absolutely identical for 16 corpuscles, and for the other 4 the greatest difference was only $\frac{1}{200000}$ of an inch." Still further, Professor Wormley reports the measurement of 7 human blood corpuscles, with powers from 1,150 to 3,500 diameters, by different microscopes, and by drawing with the camera lucida. The range of averages of the different measurements was $\frac{1}{3224}$ inch to $\frac{1}{3275}$ of an inch as measured by the camera lucida. The mean of the averages being $\frac{1}{3236}$ of an inch; the same 7 corpuscles measured by Dr. Richardson, using a cobweb micrometer, gave a final average of $\frac{1}{3266}$ of an inch, differing from the former average by something less than $\frac{1}{350000}$ of an inch. To further show the certainty of determining the exact limits of the border of the corpuscle and that different experts are likely to obtain the same results, I would mention that on a slide of human blood, irregularly spread, and dried so that the corpuscles on one half of the slide appeared larger than the other half, Dr. Treadwell measured, with high powers, 75 corpuscles on one side, showing the larger, and 75 on the side showing the smaller corpuscles. The average of the 150 corpuscles thus measured was $\frac{1}{3667}$ of an inch. The writer, using a power of 1,400 diameters and a cobweb micrometer, measured 50 corpuscles on one part of the same slide and 50 on the opposite part of the slide, and found the average of the 100 to be $\frac{1}{3665}$ of an inch, differing by only $\frac{1}{6719777}$ of an inch from the results obtained by Dr.

Treadwell on the same slide. The above reported results remove, as I think, all objections attributed to the personal equation of the observer or the supposed indistinct or woolly appearance of the border of the blood corpuscle.

Prof. Marshall D. Ewell, M.D., LL.D., an excellent microscopist, in the *Medico-Legal Journal*, September, 1892, gives a report of very careful work in micrometry of 4,000 red blood corpuscles. He gives 9.06 microns as the average of 100 corpuscles from a boy thirty-six hours old, and 8.65 microns for another 100, or 8.85 microns as the average for 200 corpuscles; also the mean of 300 corpuscles from two puppies two days old as 8.22 microns, and that of 300 from a puppy eight weeks old as 8.43 microns. This report sustains the views stated above, that young animals have larger corpuscles. Professor Ewell shows by measurements of his own blood, taken on six different days, variations from 9.05 to 8.23 microns (the general average being 8.03 microns). This shows that for the same individual, while in health, the average of 100 or more corpuscles remains substantially constant.

Professor Ewell further says: "(1) There are such large discrepancies between the averages obtained from the measurement of the *fresh* blood corpuscles of animals of the same species, and between the measurements of the same objects by different observers, as to throw doubt upon the published results.

"In the use of the micrometric test no confidence can be placed in the results, unless the errors of the micrometer used, with reference to some authentic standard, are known.

"There is no advantage in using very high powers in such investigations." (By this statement he probably means that there is no advantage in using powers above a one-twelfth inch or a one-eighteenth inch objective as he has done. In this view of magnifying powers most microscopists at the present day are agreed; but when he claims that measuring ruled lines with a one-inch, three-fifth inch, and one-fifth inch objective is as good as with the higher powers, few experts would agree with him.)

"Many diseases alter the size of the red corpuscles; especially is this so in microcythæmia. Fasting diminishes both the size and number of the corpuscles. So also in the case of various drugs."

In view of the foregoing, according to the views of Professor Ewell, *it is impossible in the present state of science to say of a given specimen of blood, fresh or dry, more than that it is, or is not, the blood of a mammal.*

As the paper by Professor Ewell has been extensively quoted, and as Professor Ewell is now the most prominent opponent of medical experts on blood stains, the above conclusions will be further examined.

In regard to the micrometric test Professor Ewell's criticism does not apply to comparative measurements of blood of different animals where the expert, using always the same micrometer, bases his diagnosis on his own measurements alone. At present, however, it is easy for the expert to obtain micrometers made by skilful workmen and carefully rated by comparison with a reliable standard. Yet it is a remarkable fact that the measurements of human blood given by Gulliver, in 1875, $\frac{1}{3200}$; Wormley in 1885, $\frac{1}{3250}$; Schmidt, in 1848, $\frac{1}{3300}$; French Medico-Legal Society, in 1873, $\frac{1}{3257}$; Masson in 1885, $\frac{1}{3257}$; Hans Schmidt, in 1887, $\frac{1}{3412}$; Woodward, in 1875, $\frac{1}{3092}$; Formad, $\frac{1}{3200}$ — made at distant intervals and without comparison by a common standard—differ by only one-half of the difference between the blood of man and that of the pig. If Hans Schmidt did not measure the dark border of the blood corpuscle it would account for the small average which he obtained.

Another source of difference in measurement is in the mode of obtaining and preparing the blood for measurement. If a string is tied around the finger or the circulation is impeded in any other manner, and the blood is obtained by pricking with a needle, and is then spread upon a slide, the corpuscles, deprived of a portion of serum, will measure less than if obtained from a cut with a lancet where the circulation is not obstructed.

So also, if the blood is drawn from the prick of a needle in a warm and dry atmosphere, the corpuscles begin to contract before they can be spread upon a slip of glass.

None of these considerations enables us to reconcile all the discrepancies noticed by Professor Ewell in the writings of different authors; but the great fact is shown, by the unanimous consent of all microscopists, so far as we can ascertain, that less than 3,500 (most writers say less than 3,300) corpuscles of human blood are required to measure an inch, when placed side by side; while more than 4,000 corpuscles of the pig are required to measure an inch, and for the horse, ox, cat, sheep, and goat still more are required. Hence all authors agree that there is a remarkable difference between the average diameter of the human blood corpuscle and that of any domestic animal except the dog.

Taking the pig as the representative of domestic animals, because its corpuscles are larger than those of the ox, horse, cat, sheep, or goat, the following comparison between the blood of the pig and human blood is very significant:

To determine the extent of the possibility of mistaking the blood of the pig, ox, horse, sheep, or goat for human blood, we will examine the table of measurements made by J. B. Treadwell, M.D., using a one-twenty-fifth inch objective made by R. B. Tolles, and Jackson's eyepiece micrometer, made by Tolles, ruled by Professor Rogers, and a stage micrometer ruled, tested, and rated by Professor Rogers.

In this table the measurements of 3,000 corpuscles are given, 200 having been taken from each of fifteen different persons. The measurements are given maximum and minimum by tens, by twenties, by fifties, by one hundreds, and by two hundreds. Six hundred corpuscles from pigs were measured: 200 from a pig three weeks old, 200 from one of two months, and 200 from a pig three months old.

As the corpuscles of the pig have a larger average than those of the ox, horse, sheep, or goat, we make our comparison between the blood of man and the blood of these three young pigs:

		Microns.			Microns.
Man,	smallest ten	7.658	Largest	ten	8.298
Pig,	" "	5.418	"	"	6.520
Man,	" twenty	7.662	"	twenty	8.191
Pig,	" "	7.768	"	"	6.466
Man,	" fifty	7.768	"	fifty	8.079
Pig,	" "	5.880	"	"	6.246
Man,	" hundred	7.852	"	hundred	8.046
Pig,	" "	6.028	"	"	6.169

	Microns.
Smallest ten from man	7.658
Largest ten from the pig	6.520
Difference	1.138
This equals 0.000045 of an inch = $\frac{1}{22222}$ inch.	
Smallest twenty from man	7.662
Largest twenty from the pig	6.466
Difference	1.196
This equals 0.000047 of an inch = $\frac{1}{21276}$ inch.	
Smallest fifty from man	7.768
Largest fifty from the pig	6.246
Difference	1.522
This equals 0.000060 of an inch = $\frac{1}{16666}$ inch.	
Smallest hundred from man	7.852
Largest hundred from the pig	6.169
Difference	1.683
This equals 0.000066 of an inch = $\frac{1}{15151}$ inch.	

We thus see that where only 10 corpuscles are measured in man, taking the smallest average of 10 consecutively measured, this average for an adult man is one-sixth larger than the largest average of 10 consecutive corpuscles measured from a young pig only three weeks old; while the average of the smallest 100 from man, taken consecutively, is about one-fifth, $\frac{16}{78}$, larger than the largest 100 taken from the young pig.

Professor Ewell says: "Drying the blood corpuscles in a clot multiplies the difficulty of identification. It has never been proven that dried corpuscles can be restored to their normal proportions."

I would call attention again to the table on p. 84 of

the present volume, which gives the measurements of 3,000 corpuscles of fresh human blood, including males and females, of all ages, from infants at birth to the man of seventy. The measurements are in microns.

Number of individuals.	Number of corpuscles.	Average.	Max. Min.	By 10s.	By 20s.	By 50s.	By 100s.	By 200s.
15 persons as stated	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	1,000	7.910	5.570 9.687	7.700 8.184	7.723 8.010			
3 young pigs	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

Here we see that the average of 1,000 corpuscles restored and measured from stains of human blood is 7.910 microns, all probably being stains from the blood of adults; while the average from fifteen persons (three being infants) is 7.938 microns. The maximum, where infants are included, in fresh blood is a little more widely separated from the minimum than in the restored stains from adults. So also the range, when taken by tens or by twenties, is a little less for restored blood than for fresh blood, for the same reason. No closer similarity of results could have been expected had all the measurements been taken from fresh blood; one set including infants and the other being taken from adults alone. The fact that there is this difference, as given above, goes to show the great accuracy and perfect restoration of dried blood corpuscles to their normal dimensions.

As a further confirmation of the possibility of restoring dried blood stains to a condition in which their dimensions can be properly compared with fresh blood corpuscles, I copy by permission the following table from Professor Wormley's "Microchemistry of Poisons."

EXAMINATION OF OLD BLOOD STAINS.

Animal.	Age of stain.	Remarks.	Average, inch.	Fresh blood, inch.
(1) Human	2 months old	Stain, unknown	1–3358	1–3250
(2) Human	2½ " "	Stain	1–3236	1–3250
(3) Human	3 " "	Stain	1–3334	1–3250
(4) Human	19 " "	Clot	1–3290	1–3250
(5) Elephant	13 " "	Clot	1–2849	1–2738
(6) Dog	4 " "	Trace of stain, unknown	1–3626	1–3561
(7) Rabbit	18 " "	Clot	1–3683	1–3653
(8) Ox	16 " "	Stain	1–4544	1–4219
(9) Ox	32 " "	Stain, unknown	1–4495	1–4219
(10) Ox	4½ years "	Clot	1–4535	1–4219
(11) Buffalo	18 months "	Clot	1–4312	1–4351
(12) Goat	17 " "	Stain	1–5897	1–6189
(13) Ibex	18 " "	Clot	1–6578	1–6445

"In the case of the human blood No. 1, two months old, the deposit was in the form of a thin stain on muslin, and its nature, other than that it was mammalian blood, was unknown at the time of examination. The corpuscles were readily found, and two series of thirty corpuscles were measured. In the human blood two and a half months old, fifty corpuscles ranging from $\frac{1}{3125}$ to $\frac{1}{3448}$ of an inch were measured.

"The blood stain of the dog, No. 6, was prepared by Dr. Frankenberg, and consisted of a single stain so minute as to be barely visible to the naked eye; its nature at the time of the examination was unknown. In this instance only fifteen corpuscles were measured. In the ox blood four and a half years old, the corpuscles were rather readily obtained, and two closely concordant series of measurements were made."

Another table, quoted by Clark Bell, Esq., in his article on "Blood Stains" in the *Medico-Legal Journal*, September, 1892, p. 157, is worthy of careful study in this connection. It shows results of examinations of blood dried on knives, glass, wood, cloth, paper, and stone, with measurements corresponding very closely with measurements of fresh blood.

I take great pleasure in acknowledging my obligations to Professor Ewell, from whose valuable articles on micrometric study of 4,000 red blood corpuscles, published in the *Medico-Legal Journal* for September, 1892, I have compiled the following table:

Source of blood.	Number of corpuscles.	Mean in microns.	Maximum.	Minimum.	By hundreds, maximum.	By hundreds, minimum.
Robust man	650	8.03	9.98	5.03	8.28	7.95
Boy thirty-six hours old	200	8.86	11.39	5.70	9.06	8.65
Adult man	100	7.85	9.32	6.73	....	....
Purpura hæmorrhagica	200	8.25	10.87	3.45	8.28	8.25
2 cases pseudo-leucocythæmia	400	8.04	11.04	6.56	8.55	8.42
Tuberculosis, anæmic	100	8.35	10.70	5.35	....	....
Plumbism	100	8.65	10.10	5.18	....	....
Gastritis	100	8.32	10.18	6.22	....	....
2 cases syphilis	200	8.11	9.32	3.97	8.11	8.11
Erysipelas	100	7.83	9.15	6.90	....	....
Pernicious anæmia	100	7.69	9.93	6.04	....	....
Menstrual blood	100	7.71	8.80	5.76	....	....
Whole number measured	2,350	8.14	11.39	3.45	9.06	7.95

In regard to the alterations of blood in disease, it is to be noted that no disease causing smaller average sizes of the blood corpuscles of the lower animals can have any tendency to cause such blood to be mistaken for human. If it was sought to ascertain whether a given stain, with corpuscles less than $\frac{1}{3500}$ or $\frac{1}{4000}$ of an inch, could have been obtained from a diseased human being, found by examination to have very small corpuscles, such a case would be judged by the facts discovered and possibly be indeterminable.

If we take $\frac{1}{3200}$ of an inch or 7.937 microns as the generally accepted average diameter of human blood corpuscles, and with it compare the average obtained by Professor Ewell from blood in disease, we find his largest average in plumbism, or lead poisoning, is 8.65 microns, or one-twelfth part larger than the normal average.

Now, if we take the young pig, which, excepting the dog, is the domestic animal having the largest corpuscles, and to the normal average, 6.101 microns, add one-twelfth its diameter, or 0.508 micron, we shall obtain for a possibly diseased pig an average diameter of 6.609 microns; which is smaller by 1.318 microns than that of the average human blood corpuscle. This difference when viewed in the microscope with a magnifying power of 2,500 diameters, the same power used in the photographs reproduced in Figs. 612 and 613, is equal to more than two and a half divisions of the scale in Fig. 613. With only 1,000 diameters the difference would be greater than one division of the same scale. Certainly no microscopist of ordinary skill would be in any danger of confounding blood of such a diseased pig with human blood recovered from a stain.

The only remaining possibility of mistaking stains from the blood of a pig, ox, horse, sheep, or goat for human blood, when fifty or one hundred corpuscles have been measured and found to average 7.9 microns, or even 7 microns, is to suppose it possible that the expert has *wickedly* and *purposely* measured only the largest corpuscles and has not done honest work. With a magnifying power of 1,000 diameters, a Jackson's micrometer measures with great certainty $\frac{1}{50000}$ of an inch. Professor Ewell's filar micrometer, as he states, is graduated to $\frac{1}{1000000}$ of an inch, and is certainly reliable to $\frac{1}{50000}$ of an inch, equal to one of the divisions on the above scale. Hence no expert can have any difficulty in recognizing with absolute certainty differences of 1.3 microns, equal $\frac{1}{20000}$ of an inch.

Professor Ewell says that "by selecting the corpuscles, it would be possible for a dishonest observer to make the average much larger or smaller than the above given [in his table] without the possibility of detection; a fact, the bearing of which upon the value of expert testimony upon this subject is so obvious as to need no comment." I have never claimed, and shall not now claim, that it is any more difficult for a witness to swear falsely in regard to blood stains than in regard to any other subject. But it would be quite possible on cross examination to ask the expert whether, in measuring the corpuscles obtained from a stain, he had measured all the well-defined corpuscles in the field of the microscope, or whether he had selected the large corpuscles and rejected others which were smaller.

In treating blood stains with solvents of fibrin, to liberate the corpuscles for measurement, it has been found in many cases that the corpuscles were smaller than in fresh blood unless maceration was long continued, old stains requiring several weeks before the corpuscles were in a condition to be measured. When a biconcave blood corpuscle is placed in water, the coloring matter (hæmoglobin) is dissolved out, the corpuscle swells up, thickens at the edges, becomes transparent and spherical. In this condition the diameter of the corpuscle becomes less than normal. It thus happens in examining blood stains that all corpuscles which have lost their color or have become spherical are by some experts rejected and not measured. Some corpuscles in fresh blood have much more coloring matter than others, and these corpuscles retain their color and form (as we think) much longer than paler corpuscles. We are not aware that any fluid used or likely to be used for softening blood stains will cause the corpuscles to become larger than normal. In this statement the most noted authors agree.

If the corpuscles obtained from a stain do not recover their normal dimensions it is almost absolutely certain that their average measurement will be less than normal and *never* greater than normal. Thus, in the language of Professor Wormley, we may confidently say: "*Thus, then, while the blood of man might on account of contractions in diameter of the blood corpuscles be confounded with that of some animal having smaller corpuscles, the reverse could never occur.*"

From this discussion I claim that it has been proved beyond any reasonable question:

1. That in favorable cases blood stains can be so treated that reliable measurements and credible diagnosis of their origin can b· given, as shown in the tables given and in others which might be referred to.

2. That if error occurs on account of imperfect restoration of the form and diameter of the corpuscles obtained from a stain, proved (by (*a*) the guaiacum test; by (*b*) the spectroscope; by (*c*) the production of hæmin crystals) to be blood, the error, if any, will be to make human blood appear like that of one of the inferior animals, and never to mistake the blood of the ox, pig, horse, sheep, or goat for human blood.

3. In general, when a stain has been proved to be blood by the above tests, it may be decided certainly whether it is or is not mammalian blood. So, also, a stain from the blood of the ox, pig, horse, sheep, and goat may be distinguished from human blood, thus confirming the claim of an accused person in many cases that his clothes are *not* stained with human blood. This negative testimony is certainly quite as important in many cases as testimony inculpating a prisoner.

Lastly, the expert can say, when the average of a suitable number of corpuscles from a blood stain corresponds with the average of fresh human corpuscles, that the stain is surely not from the blood of the ox, pig, sheep, or goat.

Such testimony by a skilled microscopist is of untold importance in saving the lives of the innocent, and often in overthrowing the plea of those who are guilty. Such testimony is quite as reliable and important to the welfare of society as that of the chemist who testifies to the presence or absence of poison that might have some resemblance to the many recently discovered ptomaïns.

The testimony of the expert might take the following form, as recommended by C. H. Vibbert, "Précis de médecine légale":

"This stain is *not* composed of the blood of such an animal [ox, sheep, horse, pig, or goat] as the accused claims. It is like the blood of man, or some animal having corpuscles very nearly the same size as those of man, as the dog or rabbit."

Or the declaration may take the reverse form, thus: "This stain is *not* composed of human blood; it might be the blood of a horse, ox, pig, sheep, or goat, as claimed by the accused."

Such declarations are justified, then, and then only, when the examination has been conducted with great care and the measurements have been made with reliable instruments.

Moses C. White.

BLOOD-VESSELS, HISTOLOGY OF.—THE ARTERIES.—An artery consists of three coats, which, named from their relative position, are the inner, the middle, and the outer. The structure and relative thickness of these coats vary in vessels of large, medium, and small calibre. A medium-sized artery, such as the radial, shown in the accompanying illustration (Fig. 621), has been taken as the type and first described in detail, the structural peculiarities of the larger and smaller vessels being subsequently noticed.

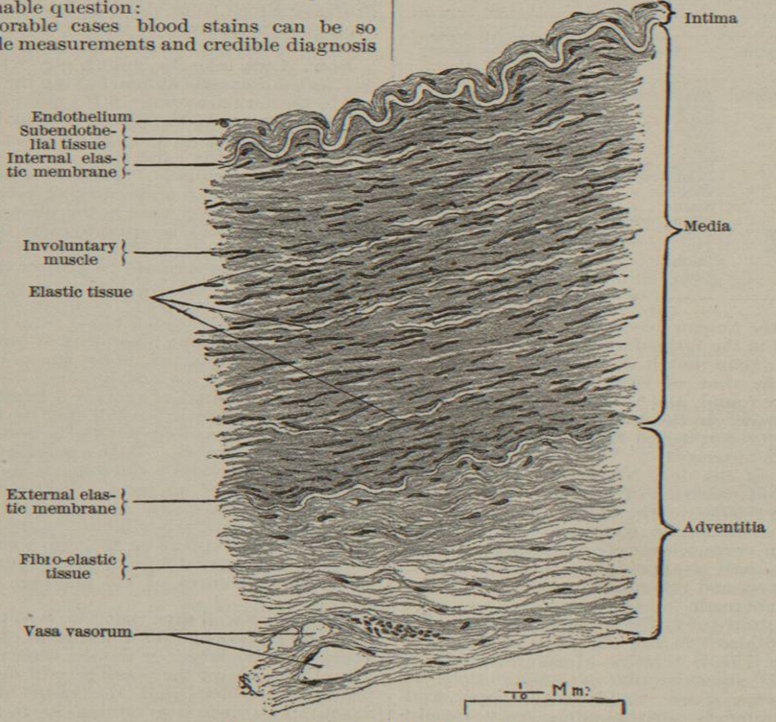

FIG. 621.—Section of Human Radial Artery.

The *inner coat*, or *tunica intima*, is the thinnest coat of the artery and consists of three distinct structures: (*a*) an endothelial lining; (*b*) a layer of subendothelial connective tissue, and (*c*) an internal elastic membrane. The endothelial lining consists of a single layer of flat endothelial

cells, each containing a centrally situated nucleus of round or oval form. When examined in a transverse section of the vessel, in which the cells are seen in profile, the endothelial plates are inconspicuous, the nucleus often being the only part of the cell readily made out. Examined from the surface, after staining with silver nitrate, the boundaries of the individual cells are clearly defined by the darkly tinted cement substance which unites the endothelial plates. In such preparations the lining cells appear spindle-shaped or lanceolate in form, their long axes corresponding with that of the blood-vessel. Careful examination of the outlines of the cell shows these to be serrated or sinuous, contrasting with the more regular lines of apposition in epithelial tissue. The lining cells of blood-vessels were first described by Kölliker and others as epithelium; later, His applied to them the name endothelium as more appropriate for elements derived from mesoderm and closely related to serous surfaces. In principle, endothelial cells are modified connective-tissue elements.

The *subendothelial layer* consists of bundles of white fibrous connective tissue interwoven with a delicate network of elastic fibres, and meagrely distributed branched connective-tissue corpuscles lying within the lymph spaces of the tissue.

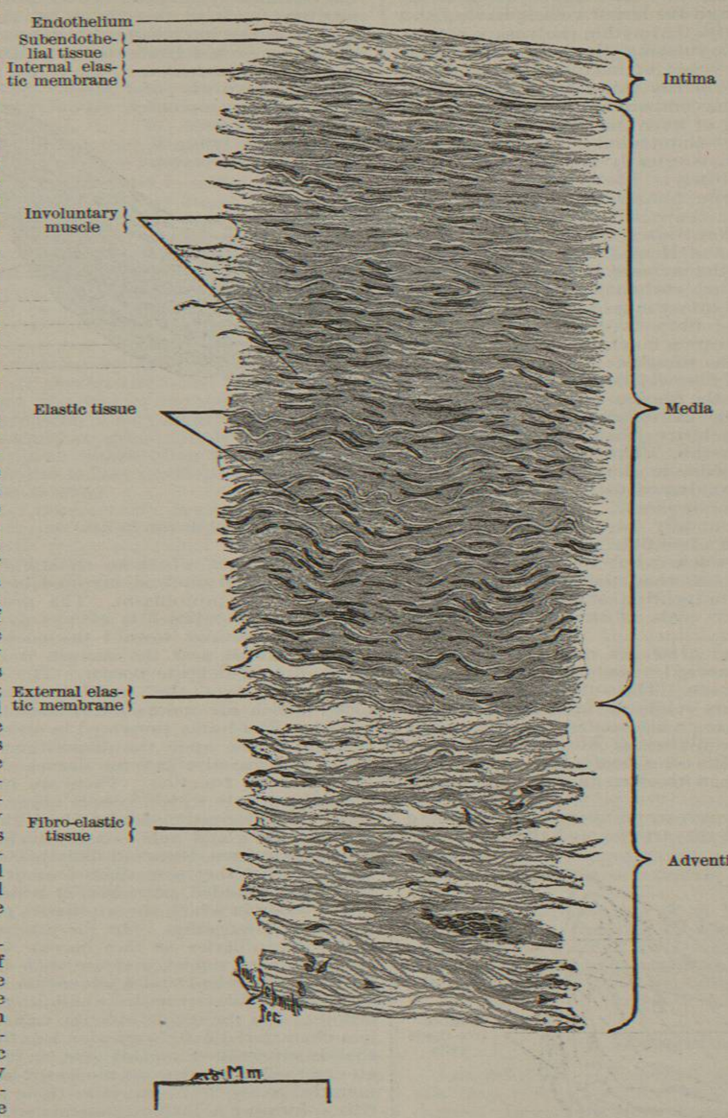

FIG. 622.—Section of Human Aorta.

The *internal elastic* membrane appears in arteries of medium size as a structureless, glistening, corrugated band that stands out as the most conspicuous structure of the intima. It constitutes the most external layer of the latter and forms a sharp line of demarcation between the narrow and faintly stained intima and the broad and more deeply tinted media. While apparently a homogeneous membrane in the smaller arteries, in vessels of large size the internal elastic membrane is represented by a number of delicate lamellæ of elastic tissue, which are pierced by apertures of varying size. The entire structure in these cases has been appropriately named the *fenestrated membrane of Henle*, in recognition of the anatomist who called attention to its peculiar arrangement. The majority of the elastic fibres forming this reticulated network run longitudinally, but are intermingled with some oblique fibres as well as a limited number of branched connective-tissue corpuscles.

The *middle coat*, or *tunica media*, is the thickest coat of the artery. It consists of circularly disposed lamellæ of involuntary muscle intermingled with connective tissue in which elastic fibres are conspicuous. The individual muscle cells are irregularly spindle-shaped, often with ragged outlines, and possess the characteristic rod-shaped nuclei. The muscle cells of the media are shorter and thicker than the slender and more elongated corresponding elements in other localities. The individual cells, held together by interstitial cement substance, are grouped into illy defined bundles, which are closely associated with small spiral bundles of white fibrous and elastic connective tissue, the whole forming the most compact coat of the artery. The elastic fibres are very numerous, and, in ordinary preparations being almost unstained, stand out in marked contrast among the more deeply stained masses of involuntary muscle.

The *external coat*, or *tunica adventitia*, is composed of closely felted bundles of white fibrous and elastic tissue arranged in fine wavy masses. Many of these bundles have a longitudinal direction, while others pursue an oblique course. Connective-tissue cells are present in considerable quantity. While looser in texture and apparently of less strength, the adventitia is nevertheless more resistant than either of the other coats, and is the tunic upon which the integrity of a ligature chiefly depends. The walls of the arteries are nourished by a