

ON THE SURFACE - TENSION
OF URINES .

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C N T H E S U R F A C E - T E N S I O N A N D
V I S C O S I T Y O F U R I N E S .

The subject of the following experiments was suggested to me by Dr. James, to whom I am much indebted for the loan of apparatus, and through whose favour I had the inestimable advantage of working in the laboratory of the Royal College of Physicians.

Though submitted under the title of "Surface Tension and Viscosity" these experiments deal chiefly with the former and only incidentally with the latter.

It has for some time been known that the surface-tension undergoes marked change in some pathological conditions and this fact has been made use of in Hay's test for the detection of bile.

This test consists in sprinkling on the surface of two samples of urine, the one known to be normal and the other suspected of containing bile, some sublimed Sulphur, which, if bile is present, will, owing to the diminished surface-tension, become wetted more quickly in the latter.

Hence the idea suggested itself that perhaps a more careful comparison of the surface-tensions of urines might give indications of pathological changes either overlooked or unrevealed by the ordinary methods of examination.

The question then presented itself "How is this comparison to be made?"

There are many ways of measuring surface-tension, most of them depending on the measurement of the "angle of contact" between the fluid and a glass plate dipped into it. The "angle of contact" is well shewn in the surface-curvature of fluids in capillary tubes. For example, in water the angle of contact is less than 90° and the surface is concave upwards, while in the case of Mercury the angle of contact is greater than 90° , and the surface is convex upwards. In this case the angle of contact is determined by the relative strengths of the tensions along the three surfaces: fluid and glass, glass and air, and fluid and air.

Further, the relation of these three factors determines whether the fluid will rise or fall in the capillary tube.

By keeping two of these factors constant we can get a rough approximation of the third, that is

is to say by using the same capillary tube, in air we can, by noting the height to which different fluids will rise, get a rough comparison of their relative surface-tension. Perhaps the simplest way of measuring the angle of contact, when it is finite, is that suggested by Gay-Lussac.

"If the liquid be introduced gradually into a small glass sphere (from below) there will be one position in which its surface throughout is plane. By determining this position the angle can at once be calculated." (Tait's "Properties of Matter", p.262) But for all these methods one thing is absolutely essential; viz., the glass must be perfectly clean, and the fluid surface must be perfectly clean.

Anyone who has experimented with small pieces of camphor on water will know how essential it is that the water surface should be clean, and how the mere insertion of an apparently clean finger is sufficient to arrest the extraordinary movements of the particles of camphor.

It is obvious that this degree of cleanliness would be well-nigh impossible to obtain in a fluid so liable to contamination as urine.

Another method of measuring surface-tension is that due to Lord Kelvin viz., by the produc-

tion of ripples. It has been employed with fairly accurate results (See C.M.Smith, Proc. R.S.E., 1890) but it is not applicable for clinical purposes.

It should be understood at the outset that our object is not the determination of absolute physical quantities, but merely a sufficiently accurate measurement for clinical comparisons. It has been observed that bilious urine if poured slowly out of a beaker or urine-glass, breaks up into a greater number of smaller drops than normal urine or water treated in the same way and this has suggested the method of comparison employed here, viz., by counting the number of drops which are given by the same quantity of different fluids.

In the formation of drops we have two factors to consider, viz., surface-tension and viscosity (or internal fluid friction).

In most of the fluids dealt with in these experiments it is probable that viscosity plays a very small part, but in some fluids, such as glycerine and treacle, especially if the surface-tension is low, viscosity may altogether prevent the formation of drops and the fluid may be drawn out into long strings. The effect of viscosity is chiefly seen in the alteration in the rate of flow, through a fine tube, of different fluids.

In the apparatus used in these experiments viscosity can affect the formation of drops only in one or other of two ways.

In the first place if the viscosity is greatly increased it will retard the flow of the fluid sufficiently to allow the drops to hang on longer than they otherwise would, and, on the other hand, if the viscosity is greatly diminished, the rate of flow will be increased and the fluid escaping at the free end of the tube with more momentum may cause the drops to fall sooner than they otherwise would.

This may readily be shewn by experimenting with an ordinary water tap, for by turning the water off and on one can get small or large drops respectively. But I believe that the variation in viscosity of the different fluids employed in these experiments is too small to be appreciable and further by the construction of the apparatus, to be afterwards described, that effect is probably reduced by one half.

One great advantage of this method of measuring surface-tension by means of drops, particularly in clinical work, is that the error due to surface contamination is reduced to a minimum. Suppose for instance a quantity of urine giving 500 drops be taken and suppose that a small amount of grease has fallen on the surface. Then, if the fluid

be allowed to drop from the bottom of the vessel, for each of the 500 drops you will have a new surface and only those drops which are formed in part from the surface layer, and which, by the way, escape last, will have their surface-tension altered. And the larger the total number of drops, the smaller will the error become.

Thus the object of these experiments is twofold:-

- (a) To enquire into the clinical value of Surface Tension.
- (b) To enquire into the value of this method (suggested by Dr. James) of measuring it.

The fluids experimented with fall into two main groups:-

- (a) Pure solutions.
- (b) Mixed solutions or clinical samples.

Group (a) includes the following:-

- (1) Distilled Water.
- (2) Saline Solutions.
- (3) Urea.
- (4) Glucose.
- (5) Alcoholic Extract of human bile.
- (6) Sodium Salts of the bile acids of the Cx.
- (7) Albuminous bodies.

Group (b) includes:-

- (1) Tap Water.
- (2) Urines.
 - Albuminous.
 - " and Bloody.
 - Diabetic.
 - Bilious.
 - Febrile.
 - Normal.

In order to carry out this method with accuracy, everything must be kept as nearly constant as possible, excepting, of course, the fluid we are experimenting upon.

Thus we must have:-

1. Some means of accurately measuring the quantity of fluid.
2. Some contrivance for producing drops which must be the same for all fluids and which must, as nearly as possible, present the same detachment surface.
3. Some means of accurately counting the number of drops formed.
4. It is desirable to use a considerable quantity of fluid to eliminate or minimise error.

As regards the last of these points, I found that 100 c.c., which gives rather more than 500 drops of distilled water, a very convenient quantity to work with. This quantity takes rather more than twenty minutes to pass through the apparatus, and therefore ~~more~~ more would be inconvenient.

As regards counting it is desirable to have some mechanical contrivance. Simple counting by the eye is out of the question. It is excessively tedious and therefore very liable to confusion and error.

The mechanical contrivance devised by Dr. James consisted of two parts:-

- (a) A small escapement wheel, with the teeth numbered, which was worked by a small electro-magnet.
- (b) A delicate lever with a pan on one end, on which the drops fell, and a spring at the opposite end.

Towards the end with the pan was a small bridge, consisting of two copper points dipping into mercury. These two points were joined up in the circuit of a bichromate cell.

When a drop fell on the pan of the lever the circuit was closed across the bridge and the electro-magnet of the escapement wheel was set in action. The escapement wheel was found to be not delicate enough for the work and it was abandoned for a chronograph and revolving recording-surface. The lever was retained throughout the experiments and worked very satisfactorily.

As regards the measurement of the quantity of fluid used and the formation of the drops, I may say that I had considerable trouble and spent considerable time before I arrived at the apparatus as I finally used it.

At first I used as a reservoir a 100 c.c. pipette supported in a vertical position. Starting and finishing points were marked on the stem and the

reading was fairly accurate. For a dropping point I had attached to the lower end of the pipette by a piece of rubber tubing, the capillary tube of a haemocytometer. It was found necessary to have another piece of rubber tubing with a clip at the top of the pipette to hold back the fluid till all was ready. This apparatus was very unsatisfactory.

- 1st. It was very unsteady and the drops often fell wide of the pan.
- 2nd. There was a considerable alteration in the head of fluid from beginning to end, and at the end the drops escaped very slowly.
- 3rd. Its great height was inconvenient. It was found necessary to give the drops a fall of about 18 inches so that the clip at the upper end of the pipette was about 4 ft. above the table.
- 4th. The drops were very small, barely sufficient to work the lever.

It then occurred to me to use a small wide jar with a siphon through the bottom of it. By this means one did away largely with the alteration in the head of fluid, also the whole apparatus was more within reach and could be more easily filled and started. Further, the siphon would stop automatically always at the same point, i.e., whenever the mouth of the short limb emerged from the fluid. In order to get a better flow and to increase the size of the drops I made a new dropping point with a piece of $\frac{1}{4}$ in. glass tubing.

It had a very fine constriction above, another not so fine below and a bell-mouth.



This gave very good drops and the fluid passed through in about ten minutes, but there was always a bubble of air between the two constrictions which made the termination of the flow uncertain. This apparatus had still the rubber tube which I considered would be a disadvantage owing to the difficulty of cleaning it. I therefore had a new apparatus made entirely of glass, which may be described as follows:-

It consists of four parts.

- (a) Reservoir.
- (b) Siphon-Tube.
- (c) Scale-Tube.
- (d) Dropping-Tube.

The diagram at the end, which is drawn to scale, will shew these parts.

For the reservoir I procured a brewer's test-glass of about 5 oz. capacity. It is about 6 cm. in diameter and 6.5 cm. deep and has a narrow opening through the bottom. This I had ground to fit the collar of the siphon tube. (See diagram). I provided the reservoir with a lid to prevent evaporation during the passage of the fluid.

The siphon-tube is made of a piece of $\frac{1}{4}$ in. glass tubing, the length of the short limb being 4.0 cm., and that of the long limb 8.5 cm.

The scale-tube is a piece of 1/10 in. glass tubing fused into the siphon tube close to its inlet. It is bent upwards into a vertical position and has near the top a series of marks 1 m.m. apart. These are for accurately reading off the level of the ~~level of the fluid~~ at the starting-point.

The dropping tube consisted of a piece of thermometer-tubing 4 cm. long. This piece of tubing is fused on to the lower end of the long limb of the siphon-tube, and has at its free end a bell mouth 1 cm. in diameter and 1 cm. in depth. The bore of this tube is about 0.5 m.m. The dimensions of this tube were arrived at entirely by experiment.

The recording surface which I used in the R.C.P. Laboratory was an endless roll of paper driven by a small electric dynamo. As this roll travelled at a definite rate I had to arrange my tube so as to give a distinct interval between the drops of the fastest dropping fluid I was likely to use. Having fixed the rate at which the drops were to be formed with water, I had further to experiment till I got the largest drops possible at that rate. The rate

at which the fluid passes through the capillary tube is affected by the length of the tube, the bore of the tube and by the shape of the bell mouth. In connection with the latter point it is well known that by properly adjusting the funnel at the delivery end of a small pipe the internal fluid friction in that pipe may be diminished by one half and consequently the delivery doubled (See Dr. Buchan on "Plumbing," p.197). As I had obtained the largest drops possible, that is the largest delivery, at the given rate, it is probable (as stated above) that I had diminished the effect of viscosity by one half.

I also found that the size of the drop was slightly affected by the thickness of the lip of the bell-mouth. Possibly when the tip is broad the fluid tends to spread itself on it, and more spheres of molecular action come within reach of the glass and so the adhesive powers of the drop will be increased. It is well known that the adhesion of water to glass is stronger than that of water to itself, for if a clean glass plate be laid upon water and then lifted up, it will be found not to have separated from the water but to have torn some of the water away with it.

Now let us consider the four desiderata above enumerated in connection with this apparatus:-

1. Accurate Measurement of the Quantity of Fluid.

It is very easy by means of the scale-tube to read off the level of the fluid in the reservoir. No doubt the level of the fluid in the scale tube will vary slightly with the surface-tension of fluid but as the tube is $1/10$ in. in diameter, this variation will not be great; with the fluids used probably not more than 1 m.m. I have found by experiment with water that a fall of 1 m.m. in the scale tube is equal to 17 drops.

Therefore if the surface-tension of any fluid be diminished by an amount equivalent to 1 m.m. in the scale tube there will be more fluid in the reservoir by 17-20 drops. This, of course, magnifies the difference between the two fluids.

As regards the termination of the flow of the fluid, it will be observed that the fluid continues to pass into the mouth of the siphon after the general level of the fluid in the reservoir has fallen below the level of the inlet of the siphon. This it does through a little funnel formed by a skin of fluid which results entirely from the surface-tension of the fluid.

Therefore the greater the surface-tension

the longer will this funnel persist and the more fluid will pass. This will produce an effect the opposite of that noted in connection with the scale-tube and may perhaps neutralise it. As the last drop of fluid travels over the arch of the siphon and down the long limb it will be noted that it always stops automatically as soon as the surface-film on its free side reaches the beginning of the narrow dropping tube.

The tension across this constriction is sufficient to support the fluid in the capillary tube and a whole drop about to fall from the bell-mouth.

2. Production of Drops.

The conditions under which the drops are formed in this apparatus are, as far as it ^{is} possible to control them, the same.

The alteration in the head of fluid from beginning to end is not nearly so considerable as in the case of the pipette. Further, the effect of the alteration in the head of fluid is diminished by virtue of the siphon arrangement. The pressure in the two limbs of the siphon is the same at the level of the inlet, but below this level in the long limb the pressure is increased by the weight of the column of

fluid between any point and the level of the inlet of the short tube. Therefore the column of fluid in the long limb which is in excess of that in the short limb may be regarded as exerting a suction action upon the rest of the fluid in the siphon. Now this action will be exerted as long as the siphon is full and will be greater in proportion as the long limb is longer than the short. Again, it may be noted that in this apparatus the bell-mouth at the end of the dropping tube has a greater diameter than the siphon tube in the ratio of 10 : 6.25. By increasing the diameter of a pipe we diminish the rate of flow and thereby increase the pressure with which the fluid escapes.

So that the fluid enters the siphon with a pressure equal to the atmospheric pressure plus the weight of a column of fluid equal to the depth of the inlet and leaves the siphon with the same two pressures plus the weight of the excess column of fluid in the long limb plus the increase due to the larger outlet. Thus altogether the effects of pressure variations will be considerably diminished.

As regards ^{the} surface-of-detachment of the drops it will be seen that it is as nearly as possible the same for every case. I may observe, in

passing, that I have never noticed any of the fluids showing a tendency to creep round the lip of the bell-mouth, as was suggested might occur.

3. Accurate Counting of the Drops.

The means of counting the drops has already been described and the diagram at the end will suffice to explain the arrangement .

In counting up the drops, as marked on the recording surface, I found it an advantage, in order to avoid confusion and error, to count by tens and number each lot as I went along. In this way one could see at a glance if any mistake had been made and if the eye got confused it was easy to make a fresh start.

4. The quantity of fluid to be used has already been discussed.

In addition to counting the number of drops I considered that it might be of interest and advantage to take the following concomitant observations:-

- I. Wet and Dry Bulb Thermometer.
- II. The time taken by the fluid to pass through the apparatus.
- III. Rate of Flow.
- IV. The temperature of the fluid.

The wet and dry bulb I took in order to calculate from them the "Defect of Saturation" (which may be taken as an index of the evaporating power of the atmosphere) which I thought might affect the surface-tension.

The time and rate of flow were just taken roughly to give an idea of the viscosity of the different fluids.

The temperature of the fluid I took, because it is known to have a direct effect on both the surface tension and viscosity, and I thought the variations in temperature during the experiments might produce appreciable effects.

In such coarse experiments as these I did not consider that changes in barometric pressure would be appreciable and therefore I did not keep a record of them.

I obtained, however, a record that was taken close by which shows the general curve of changes during the time the experiments were going on.

My routine in carrying out the observations was as follows:-

1st. Washed the "Dropper".

This I did by filling the jar with tap-water, adding a small quantity of strong Sulphuric or Hydrochloric acid and allowing it to drop through. I then held the jar under running water for a minute or two, filled it again and allowed the tap water to drop through.

This operation was performed whenever there was any visible deposit on the glass jar or siphon-tube, and, latterly, after using any fluid with markedly low surface-tension. In addition to this, before and after each experiment the apparatus was thoroughly washed with tap water.

2nd. Filled the Reservoir.

In doing this I took care that the instrument was in a strictly vertical position, and that there were no bubbles of air in the scale-tube. Inattention to these points would have led to error as regards the quantity of fluid used.

3rd. Took the Temperature of the Fluid.

4th. Started the Dropper and set the motor and battery working.

I found that owing to the constant presence of a film of fluid in the capillary tube the siphon did not start whenever the jar was filled up.

This was an advantage for it enabled me to fill up the jar above the level of the zero mark on the scale tube, and so to make sure, before beginning to count, that everything was in working order. I started the siphon by applying suction to the bell-mouth.

5th. I took the time when the fluid fell to the zero mark in the scale tube and made a mark opposite the corresponding drop on the recording surface.

6th. Counted the number of drops per minute.

7th. About the middle of the experiment I took the reading of the Dry and Wet Bulb.

8th. At a certain point near the end of the experiment I again took the temperature of the fluid and the number of drops per minute.

9th. At the end of the experiment I again took the time.

In describing the experiments I think it will be an advantage, in the first place, to run over them in order in which I took them as that will bring out certain points and will enable me to refer to others in connection with the solutions.

I will then arrange them in tabular form according to the nature of the fluids.

	<u>Distilled Water.</u>		
<u>1.</u> Feb. 1st.	T.° of room. D.B. 67°F. W.B. 57°F.	<u>Drops.</u> 511	
<u>2.</u> Feb. 1st.	T.° of Room. D.B. 67°F. W.B. 57°F.	510.	
<u>3.</u> Feb. 2nd.	<u>Bilious Urine.</u>		
	T° of Room. D.B. 63. W.B. 55.	707	

These three experiments will not be included in the tables because owing to an accident the dropper suffered a slight alteration. I give them because the first two show that fair accuracy had been attained in counting the drops and the 3rd. because it gives an idea of the range one may expect.

Feb. 3rd.	I. <u>Distilled Water.</u>	<u>Drops.</u>
	T.° of Room. D.B. 64. W.B. 57 Time 5.11 - 5.33½	506

Feb. 4th.	<u>II. Saline Solution.</u> C. 75%	<u>Drops.</u>
	T° of room. D.B. 63.5, W.B. 57 Time. 5.0 - 5.21.	492
" 5th.	<u>III. Saline Solution.</u> 5.0%	
	T° of room. D.B. 57.5. W.B. 51.5 Time, 10.32 - 10.56.	488
" "	<u>IV. Saline Solution.</u> 10%	
	T° of room. D.B. 58.5. W.B. 52.5 Time. 11.5 $\frac{1}{2}$ - 11.28 $\frac{1}{2}$	516
" "	<u>V. Distilled Water.</u>	
	T° of room. D.B. 59. W.B. 52.5	517
" 7th.	<u>VI. Distilled Water.</u>	
	T° of room. D.B. 63.5. W.B. 56.5 Time. 4.50 - 5.10 $\frac{1}{2}$	505
" 9th.	<u>VII. Urea.</u> 3% sol.	
	T° of room. D.B. 61. W.B. 56.5 T° of fluid (a) 14°C. (57.2°F.) (b) 15°C. (59.0°F.) Time. 5.9 - 5.30.	499
" 10th.	<u>VIII. Urea.</u> 5%	
	T° of room. D.B. 68. W.B. 62. T° of fluid (a) 19.5°C. (67.1°F.) (b) 19.5°C. (67.1°F.) Time. 4.58 - 5.18	517

From the above facts it will be seen that neither saline solutions nor solutions of Urea produce much alteration in the surface-tension.

The solutions of NaCl are of similar strengths to those used later in preparing solutions of serum-globulin. The solutions of Urea are of the strengths most likely to be met with clinically.

The normal percentage of Urea is about 2 (Halliburton's Physiolog. Chemistry) but it is not uncommon for it to go up to 4 or 5..

Feb. 10th.	<u>IX.</u> <u>Alcoholic Extr. of Human Bile.</u> (C.5% sol.)	<u>Drops.</u>
	T° of room. D.B. 69. W.B. 61. T° of fluid. 19.5°C. (67.1°F.) Time. 5.32 - 5.55.	643

This substance was kindly supplied to me by Dr. Noel Paton. It was in the dry state and consisted chiefly of the bile salts with a small amount of pigment.

Feb. 14th.	<u>X.</u> <u>Glucose (pure) 5%</u>	<u>Drops.</u>
	T° of room. D.B. 68. W.B. 59. T° of fluid. (a) 13°C. (55.4) (b) 17°C. (62.6) Time. 4.55½ - 5.21.	555
" 15th.	<u>XI.</u> <u>Glucose (pure) 10%</u>	
	T° of room. D.B. 63.5 W.B. 57. T° of fluid (a) 20.5°C (68.9°F.) (b) 18.5°C (65.3°F.)	521

23.

Feb. 15th.	<u>XII. Alc. Extr. of Human Bile.</u>	2.0% Drops.
	T. of room. D.B. 63. W.B. 56.	
	T° of fluid. (a) 18.5°C (65.3°F.)	822.
	(b) 18.5°C (65.3°F.)	
	Time. 5.8 - 5.30.	
	<u>Remarks.</u> Drops very fast; 140-50 per minute.	

From the above it will be seen that the solutions of Glucose (which, together with all the other solutions of pure substances ~~but~~ the proteids and alcoholic extract of human bile, were prepared for me by Alex. Fraser, Teviot Place) do not produce much effect on the surface-tension. The range which I obtained with distilled water during the course of the experiments being 497-551. The extract of human bile on the other hand shows a marked diminution even with the weaker solution.

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In order to test the effect of increase of temperature on the number of drops and the rate of flow I took some distilled water and raised its T° to 100°C. then put it into the dropper and took its T° at the beginning and end.

Feb. 16th.	<u>XIII. Distilled Water.</u>	<u>Drops.</u>
	T° of room. D.B. 63.5. W.B. 56.	
	T° of fluid. (a) 43°C (109.4°F.)	611.
	(b) 32°C (89.6°F.)	
	Time. 4.52 - 5.10	
	Rate. (a) 42 per minute.	

Feb. 16th.	<u>XIV. Distilled Water.</u>	<u>Drops.</u>
	T° of room. D.B. 64.5. W.B. 57.5	
	T° of fluid. (a) 15.5°C (59.9°F.)	536.
	(b) 16.5°C (61.7°F.)	
	Time. 5.26 - 5.48½	
	Rate. 25 per minute.	

The rate here given is not the calculated average rate, but the rate as counted during the experiment. I afterwards counted the rate both at the beginning and at the end to show the alteration during the progress of the experiment.

Feb. 17th.	<u>XV. Glucose. (pure) 2.0%</u>	<u>Drops.</u>
	T° of room. D.B. 64.5. W.B. 58.	
	T° of fluid. (a) 19.5°C (67.1°F.)	532.
	(b) 19.5°C (67.1°F.)	
	Time. 4.42 - 5.3.	
	Rate (a) 27. (b) 24.	

Feb. 17th.	<u>XVI. Glucose. (pure) 7.5%</u>	
	T° of room. D.B. 65. W.B. 60.	
	T° of fluid. (a) 18.5°C (65.3°F.)	542.
	(b) 19.5°C (67.1°F.)	
	Time. 5.16½ - 5.40½.	
	Rate (a) 25. (b) 22.	

" 22nd.	<u>XVII. Tap Water.</u>	
	T° of room. D.B. 62. W.B. 56.	
	(a) 14°C (57.2°F.)	498.
	T° of fluid. (b) 16°C (60.8°F.)	
	Time. 4.54 - 5.17.	

This I tested to make sure that no error was introduced by the process of washing. The number of drops falls within the range of distilled water and like the solution of NaCl tends to the low side.

Up to this point the only solutions which had given a marked increase in the number of drops were those of the alcoholic extract of human bile.

I therefore determined to try solutions of purified salts of the bile acids to see how small a quantity of bile salts could be detected. For this purpose I obtained from London some purified salts of the bile acids of the Ox. The sample consisted of glycocholate and taurocholate of Sodium.

In the bile of the ox, as in the bile of man, the glycocholate is present in greater quantity than the taurocholate. The ratio in human bile is roughly 3-1 (See Halliburton's Chemical Physiology and Pathology, pp.677-680)

For brevity I will include these salts under the heading "Glycocholate Solution."

Feb. 22nd.	<u>XVIII. Glycocholate Sol. C.5%</u>	
	T° of room. D.B. 62. W.B. 55.	<u>Drops.</u>
	T° of fluid. (a) 15°C (59.0°F.) (b) 16°C (60.8°F.)	926.
	Time. 5.25 - 5.49.	
	Rate. (a) 43. (b) 39.	

Feb. 23rd.	<u>XIX. Distilled Water.</u> T° of room. D.B. 61.5. W.B. 55. (a) 15°C (59.0°F.) T° of fluid. (b) 16°C (60.8°F.) Time. 5.17 - 5.40. Rate. (a) 26. (b) 23.	<u>Drops.</u> 503.
Feb. 23rd.	<u>XX. Glucose (pure) 5.0%</u> T° of room. D.B. 60.5. W.B. 53. (a) 16°C (60.8°F.) T° of fluid. (b) 17°C (62.6°F.) Time. 5.1½ - 5.25. Rate. (a) 25. (b) —	518.

I repeated the experiment with this solution because the results obtained on the former occasion appeared anomalous both as regards time and number of drops.

Feb. 24th.	<u>XXI. Glycocholate Solution. C. 25%</u> T° of room. D.B. 60. W.B. 53. (a) 13°C (55.4°F.) T° of fluid. (b) 14.0°C (57.2°F.) Time. 5.38 - 6.1 Rate. (a) 38. (b) 34.	<u>Drops.</u> 895.
" 25th.	<u>XXII. Glycocholate Solution. C. 1%</u> T° of room. D.B. 66. W.B. 58.5. (a) 13°C. (55.4°F.) T° of fluid. (b) 16.5°C (61.7°F.) Time. 4.56 - 5.20. Rate. (a) 39 - (b) 34.	832.

Feb. 25th.	<u>XXIII. Distilled Water.</u>	Drops.
	T° of room. D.B. 64. W.B. 57.	
	T° of fluid. (a) 12°C. (53.6°F.)	551.
	(b) 15°C. (59.0°F.)	
	Time. 5.34 - 5.58.	
	Rate. (a) 25. (b) 23.	
Mär. 1st.	<u>XXIV. Glycocholate Sol. 0.025%</u>	
	T° of room. D.B. 65. W.B. 56.	
	T° of fluid. (a) 13.5°C (56.3°F.)	694.
	(b) 16.0°C (60.8°F.)	
	Time. 4.57 - 5.20	
	Rate. (a) 34. (b) 29.	
" "	<u>XXV. Glycocholate Sol. 0.05%</u>	
	T° of room. D.B. 66. W.B. 57.5	
	(a) 16°C. (60.8°F.)	745.
	T° of fluid. (b) 17.5°C. (63.5°F.)	
	Time. 5.32 - 5.55.	
	Rate. (a) 36. (b) 33.	

From the above observations it will be seen that the pure bile salts produced a very marked effect on the number of drops.

Even the weakest solution, which is equivalent to 2.5 parts in 10,000 shows an increase which is far above the range of distilled water.

It was my intention at this point to test the following solutions of proteid substances:-

- (a) Serum-Albumin, 0.1%, 1.0%, 2.0%
- (b) Serum-Globulin, 1.0% in 0.75% NaCl.
- (c) Deutero-Albumose, 1.0%
- (d) Peptone. 1.0%

The strengths of the solutions of serum albumin are such as are likely to be met with clinically, those of the other proteids, are such as may be compared with the albumin, I selected Deutero-Albumose because it is the proteid in the urine most liable to be mistaken for peptone (see Halliburton's Chemical Physiology and Pathology, p.786) and is more common than proto-albumose.

Peptone is believed to be very rare in the urine (See Hutchison & Rainy's Manual of Clinical Methods)).

The solutions of proteids, however, (for which I am greatly indebted to Dr. Lockhart Gillespie) are very difficult to prepare and must be allowed to take their time in dissolving.

Therefore I was obliged to go on to the examination of urines.

Mar. 2nd.	<p><u>XXVI. Urine (Diabetic)</u></p> <p>T° of room. D.B. 64. W.B. 56.5</p> <p>T° of fluid. (a) 17.5°C (63.5°F.)</p> <p>(b) 18.5°C (65.3°F.)</p> <p>Time. 5.11 - 5.37½</p> <p>Rate. (a) 24. (b) 22.</p> <p><u>Analysis of Urine.</u> Clear Straw:</p> <p>Acid: sp.gr. 1034: No deposit:</p> <p>No blood; Alb., or Bile: <u>Sugar 6.1%</u></p>	Drops. 562.
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Mar. 2nd.	<u>XXVII. Urine</u> (? Bile)	<u>Drops.</u>
	T° of room. D.B. 63.5. W.B. 56.	
	T° of fluid. (a) 17°C. (62.6°F.)	63C.
	(b) 17.5°C. (63.5°F.)	
	Time. 5.47 - 6.10	
	Rate (a) 30. (b) 27.	
	<u>Analysis.</u> Dark amber: Acid: Sp. gr.	
	Sp. gr. 1020; Deposit of urates:	
	No blood, Albumin: or Sugar.	

This urine had the appearance of a biliary urine but did not give the reactions with Gmelin's and Pettenkoffer's tests. It will be seen that the number of drops is high. On a subsequent occasion I got Pettenkoffer's reaction distinctly with this same urine.

Mar. 3rd.	<u>XXVIII. Urine.</u> (Albuminous)	<u>Drops.</u>
	T° of room. D.B. 61.5. W.B. 57.5	
	T° of fluid. (a) 15.5°C (59.9°F.)	603.
	(b) 16.5°C (61.7°F.)	
	Time. 5.23½ - 5.47½	
	Rate. (a) 28. (b) 25.	
	<u>Analysis.</u> Pale Straw: Acid:	
	1015: Mucus: No blood, pus,	
	sugar or bile. <u>Albumen</u> present	
	in small quantity.	
" 4th.	<u>XXIX. Urine.</u> (Albuminous)	
	T° of room. D.B. 61.5. W.B. 5.3	
	T° of fluid. (a) 17°C. (62.6°F.)	665.
	(b) 17°C. (62.6°F.)	
	Time. 4.35½ - 5.0	
	Rate. (a) 30. (b) 27.	
	<u>Analysis.</u> Amber: 1020: Acid:	
	Mucus: No blood, pus, bile or	
	sugar. <u>Albumen</u> 0.25% as estimated	
	with Esbach's "Albuminometer."	

Mar. 4th.	<p><u>XXX. Distilled Water.</u></p> <p>T° of room. D.B. 61. W.B. 53. T° of fluid. (a) 14°C. (57.2°F.) (b) 15°C. (59.0°F.)</p> <p>Time. 5.11 - 5.34. Rate. (a) 25. (b) 23.</p> <hr/>	<p><u>Drops.</u></p> <p>531.</p>
" "	<p><u>XXXI. Distilled Water.</u></p> <p>T° of room. D.B. 61. W.B. 54. T° of fluid. (a) 15.5°C. (59.9°F.) (b) 16.5°C. (61.7°F.)</p> <p>Time. 5.39 - 6.2. Rate. (a) 26. (b) 24.</p> <hr/>	<p>534.</p>
" 7th.	<p><u>XXXII. Urine. (Normal).</u></p> <p>T° of room. D.B. 63. W.B. 56. T° of fluid. (a) 17°C. (62.6°F.) (b) 17°C. (62.6°F.)</p> <p>Time. 5.27 - 5.51. Rate. (a) 29. (b) 26.</p> <p><u>Analysis.</u> Dark amber: acid: 1C25: No abnormal con- stituents.</p>	<p>631.</p>

This urine though to ordinary tests normal, gives a high number of drops. The case was one of lead poisoning, but I believe that the lead was not detected in the urine.

Mar. 8th.	<p><u>XXXIII. Urine.</u></p> <p>T° of room: D.B. 61.5. W.B. 53. T° of fluid. (a) 16.5°C. (61.7°F.) (b) 16.5°C. (61.7°F.)</p> <p>Time. 4.49 - 5.12½. Rate. (a) 31. (b) 28.</p>	<p><u>Drops.</u></p> <p>681.</p>
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same case

This urine is from the [^]case as sample XXIX (a case of cardiac disease). On this occasion I boiled the urine for 5 minutes to precipitate the albumin; I then filtered and restored the fluid to its original bulk with distilled water. The removal of the albumin did not diminish the number of drops to any great extent, if at all.

Mar. 8th.	<p><u>XXXIV. Distilled Water.</u></p> <p>T° of room: D.B. 60. W.B. 52. T° of fluid. (a) 14°C. (57.2°F.) (b) 15°C. (59.0°F.)</p> <p>Time. 5.27½ - 5.51½ Rate. (a) 24. (b) 22.</p> <hr style="width: 20%; margin: auto;"/>	<p><u>Drops.</u></p> <p>543.</p>
" 9th.	<p><u>XXXV. Urine. (Normal).</u></p> <p>T° of room: D.B. 63.5. W.B. 56. T° of fluid. (a) 16.5°C. (61.7°F.) (b) 17.5°C. (63.5°F.)</p> <p>Time. 5.3 - 5.26½. Rate. (a) 32. (b) 29.</p> <p><u>Analysis.</u> Amber: 1023: acid: mucus: no abnormal constituents.</p>	<p>694.</p>

This urine, which gives larger number of drops, though apparently normal, is from a case of malignant peritonitis.

Mar. 9th.	<u>XXXVI. Urine</u> (Normal).	<u>Drops.</u>
	T° of room: D.B. 63. W.B. 56.	
	T° of fluid. (a) 17.5°C. (63.5°F.)	585.
	(b) 18°C. (64.4°F.)	
	Time. 5.36 - 5.58.	
	Rate. (a) 28. (b)	

This urine was rather dark, otherwise normal. The number of drops is not far removed from the maximum for water.

Mar. 10th.	<u>XXXVII. Urine.</u>	<u>Drops.</u>
	T° of room: D.B. 63. W.B. 57.	
	T° of fluid. (a) 17.5°C. (63.5°F.)	727.
	(b) 18.5°C. (65.3°F.)	
	Time. 5.40 - 6.3	
	Rate. (a) 34. (b) 30.	
	<u>Analysis.</u> Dark reddish brown: acid: 1021: Very heavy deposit of urates. A trace of Albumin present, otherwise no abnormal constituents.	

This urine was still very cloudy after filtration.

I may here remark that all the fluids were carefully filtered before use whether there was a deposit or not. In order to test more carefully the effect of removing the albumin from a urine I took two samples of the same albuminous urine, from a case of acute Bright's and precipitated the albumen in one of them. They gave practically the same results.

Mar. 14th.	<u>XXXVIII. Urine (Albuminous).</u>	<u>Drops.</u>
	T° of room: D.B. 61. W.B. 53.5	
	T° of fluid. (a) 16°C. (60.8°F.)	613.
	(b) 16°C. (60.8°F.)	
	Time. 5.32 - 5.57.	
	Rate. (a) 26. (b) 24.	
" "	<u>XXXIX. Do. (Albumin removed.)</u>	
	T° of room: D.B. 61.5. W.B. 53.	
	T° of fluid. (a) 14°C. (57.2°F.)	622.
	(b) 15.5°C. (59.9°F.)	
	Time. 4.57 - 5.21½.	
	Rate. (a) 26. (b) 25.	
	<u>Analysis.</u> Dark: smoky: 1021:	
	acid: Albumin 3% (Esbach)	
	blood. No pus, bile or	
	sugar.	
" 15th.	<u>XL. Urine (Diabetic).</u>	
	T° of room: D.B. 67. W.B. 58.	
	T° of fluid. (a) 19.5°C. (67.1°F.)	583.
	(b) 19.5°C. (67.1°F.)	
	Time. 4.58 - 5.24.	
	Rate. (a) 24. (b) 22.	
	<u>Analysis.</u> Pale straw: 1027:	
	acid: Glucose 4.36%,	
	Urea C. 72%. A deposit of	
	yeast and mucus, otherwise	
	normal.	
" "	<u>XLI. Urine (?Bile)</u>	
	T° of room: D.B. 63. W.B. 57.5.	
	T° of fluid. (a) 17.5°C. (63.5°F.)	624.
	(b) 18.5°C. (65.3°F.)	
	Time. 5.34 - 5.57½.	
	Rate. (a) 29. (b) 26.	
	<u>Analysis.</u> V. dark: 1020: acid:	
	mucus: bile: otherwise	
	normal.	

This urine is from the same case as No. XXVII in which there was a suspicion of bile. On this occasion it gave Pettenkoffer's reaction slightly but distinctly.

Mar. 16th.	<u>XLII. Distilled Water.</u> T° of room: D.B. 61. W.B. 59. T° of fluid. (a) 16°C. (60.8°F.) (b) 17.5°C (63.5°F.) Time. 5.1 - 5.23. Rate. (a) 26. (b) 24.	<u>Drops.</u> 535.
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It will be observed here, as well as in some other experiments, that there is a discrepancy between the readings of the Dry Bulb and the final temperature of the fluid. I found that this was due to the faulty arrangement of the Wet and Dry Bulb Thermometer; the cistern of the Wet Bulb being fixed between the two bulbs lowers the temperature of the dry bulb by 1.5° - 2°.

To make sure that the error was not due to a difference in the dry bulb thermometer and the chemical thermometer which I used in the fluid, I completely dried the Wet and Dry Bulb Thermometer and then found that its readings coincided with those of the chemical thermometer. Therefore, in the tables, wherever the temperature of the Dry Bulb was lower than the final temperature of the fluid, I have substituted the latter.

Mar. 17th.	<u>XLIII. Deutero-Albumose. 1%</u>	<u>Drops.</u>
	T° of room: D.B. 63.5. W.B. 59.5	
	T° of fluid. (a) 18.5°C. (65.3°F.)	758.
	(b) 18.5°C. (65.3°F.)	
	Time. 5.33 - 5.55½	
	Rate. (a) 37. (b) 34.	
" 18th.	<u>XLIV. Peptone. C.25%</u>	
	T° of room.	
	T° of fluid. (a) 21°C. (69.8°F.)	555.
	(b) 20.5°C. (68.9°F.)	
	Time. 5.21 - 5.41.	
	Rate. (a) 29. (b) 27.	

I was, unfortunately, only able to obtain 28 c.c. of a 1% solution of peptone and therefore was obliged to dilute it to $\frac{1}{4}$ its strength to get the requisite quantity to fill the dropper. In this strength it gives practically no difference from water, but this is more than is likely to be found in the urine.

It will be observed that the Deutero-Albumose gives a marked increase in the number of drops, but it does not occur to this extent in the urine, C.2 - C.25% being the maximum. I believe a case was recorded by Drs. Noel Paton and Bramwell in which C.3% occurred.

Mar. 19th.	<u>XLV. Glycocholate Solution, 0.5%</u> T° of room: D.B. 66.5. W.B. 58. T° of fluid. (a) 20.5°C. (68.9°F.) (b) 20.5°C. (68.9°F.) Time. 3.30 - 3.51. Rate. (a) 45. (b) 40.	Drops. 940.
" 21st.	<u>XLVI. Glycocholate Solution, 0.1%</u> T° of room: D.B. 68. W.B. 58. T° of fluid. (a) 19°C. (66.2°F.) (b) 20.5°C. (68.9°F.) Time. 2.52 - 3.14. Rate. (a) 42. (b) 37.	830.

These experiments were repeated for comparison with the results obtained in some control experiments which will be afterwards explained.

Mar. 21st.	<u>XLVIII. Urine (albuminous)</u> T° of room. D.B. 67. W.B. 58. T° of fluid. (a) 19°C. (66.2°F.) (b) 19.5°C. (67.1°F.) Time. 4.16½ - 4.39. Rate (a) 30. (b) 29. <u>Analysis.</u> Pale straw: acid: 1CC9: mucus: albumin, C.36%. No sugar, blood or bile.	<u>Drops.</u> 664.
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This patient was suffering from Chronic Bright's and Malaria and was in a febrile attack when the sample was taken. I took it again, on another occasion when his T° was normal and the results were very much the same.

Mar. 22nd.	<u>XLIX. Distilled Water.</u>	
	T° of room: D.B. 64. W.B. 55.	<u>Drops.</u>
	T° of fluid. (a) 18.5°C (63.3°F.)	524.
	(b) 18.5°C (65.3°F.)	
	Time. 4.31. - 4.52.	
	Rate. (a) 26. (b) 24.	
" "	<u>L. Urine (Normal)</u>	
	T° of room: D.B. 64. W.B. 55.	
	T° of fluid. (a) 18.5°C (65.3°F.)	556.
	(b) 18.5°C (65.3°F.)	
	Time. 5.5 - 5.26.	
	Rate. (a) 29. (b) 26.	

This urine was from the same case as No. XXXVII which gave 727 drops. Seeing that it had quite cleared up, I thought it would be interesting to try it again.

Mar. 23rd.	<u>LI. Urine (Febrile).</u>	
	T° of room. D.B. 61. W.B. 53.	<u>Drops.</u>
	T° of fluid. (a) 17°C. (62.6°F.)	779.
	(b) 17°C. (62.6°F.)	
	Time. 3.54 - 4.17½	
	Rate. (a) 34. (b) 30.	
	<u>Analysis.</u> Very dark: 1014: acid: Mucus: Albumin (a trace) No albumose or peptone; no blood: no sugar, bile(?) the urine looked bilious, but did not give the reactions.	

This was from a very severe case of pneumonia with a very high T°. The man died the same

night so it was impossible for me to examine further into the cause of the change in surface tension.

Mar. 23rd.	<u>LII. Urine.</u> (Bilious) T° of room: D.B. 61. W.B. 53. T° of fluid. (a) 17°C. (62.6°F.) (b) 17°C. (62.6°F.) Time. 4.53½ - 5.17. Rate. (a) 32. (b) 28.	<u>Drops.</u> 688.
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This urine was from a very marked case of jaundice and gave Gmelin's and Pettenkoffer's reactions very distinctly. As the number of drops was not quite so high as I expected I thought the effect of the bile salts might be counteracted by the viscosity of the mucin present. I therefore resolved to precipitate the mucin with dilute acetic acid.

The result was rather surprising. The number of drops was distinctly increased, but the rate of flow was almost identical in the two cases.

Analysis of this Urine. Very dark brownish green: Acid: 1Cl4: Mucus: No albumin, Blood or Sugar.

Mar. 25th.	<u>LIII. Urine.</u> (Bilious). T° of room. D.B. 61.5. W.B. 56. (a) 17°C. (62.6°F.) T° of fluid. (b) 17°C. (62.6°F.) Time. 4.19 - 4.42. Rate. (a) 33. (b) 29.	<u>Drops.</u> 711.
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Mar. 25th.	<u>LIV. Do. Mucin removed).</u> T° of room: D.B. 61. W.B. 56. T° of fluid. (a) 15.5°C. (59.9°F.) (b) 16.0°C. (61.7°F.) Time. 4.56 - 5.22. Rate. (a) 33. (b) 29.	<u>Drops.</u> 783.
" 28th.	<u>LVaneUrine (Albumin & Blood).</u> T° of room: D.B. 63.5. W.B. 53.5. T° of fluid. (a) 17.5°C. (63.5°F.) (b) 17.5°C. (63.5°F.) Time. 4.31 - 4.54. Rate. (a) 30. (b) 26. <u>Analysis.</u> Dark: smoky: acid: 1Cl5: Mucus: Albumin 0.49% Blood. No sugar, pus or bile.	615.
" "	<u>LVI. Serum Globulin. 0.24% in</u> <u> 2.0% Na Cl.</u> T° of room: D.B. 63. W.B. 53. T° of fluid. (a) 15°C. (59.0°F.) (b) 16°C. (60.8°F.) Time. 5.11 - 5.34½. Rate. (a) 27. (b) 25.	594.

This solution of globulin, though quite as strong as is likely to be met with clinically, was weaker than I had intended to use it and though it gave an increased number of drops the increase was not great. I therefore took 2 samples of the fluid, one 300 c.c. and the other 200 c.c. and evaporated both down to 100 c.c. at 37°C.

To prevent the growth of bacteria during

the evaporation, which would have decomposed a globulin into albumose, I placed a small lump of thymol in each sample. The thymol being insoluble in water would not be expected to affect the surface-tension, and I found on testing distilled water in which Thymol had been suspended for 5 hours that there was no alteration.

Mar. 29th.	<p><u>LVII. Urine</u> (albuminous)</p> <p>T° of room. D.B. 62.5. W.B. 54. T° of fluid. (a) 16.5°C. (61.7°F.) (b) 17 °C. (62.6°F.)</p> <p>Time. 3.9 - 3.36. Rate. (a) 33. (b) 27.</p> <p><u>Analysis:</u> Pale; acid; 1CC9: Mucus: Albumin C. 36%. No sugar, blood or bile.</p>	<p><u>Drops.</u></p> <p>658.</p>
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This urine is from the same case as No. XLVII, his temperature now being normal.

Mar. 30th.	<p><u>LVIII. Distilled Water.</u></p> <p>T° of room: D.B. 64. W.B. 55.5 T° of fluid. (a) 19°C. (66.2°F.) (b) 19°C. (66.2°F.)</p> <p>Time. 4.10 - 4.30. Rate. (a) 28. (b) 24.</p>	<p><u>Drops.</u></p> <p>497.</p>
" 31st.	<p><u>LIX. Urine</u> (albumin & blood).</p> <p>T° of room: D.B. 64. W.B. 55. T° of fluid. (a) 19°C. (66.2°F.) (b) 19°C. (66.2°F.)</p> <p>Time. 4.11 - 4.33. Rate. (a) 34. (b) 30.</p>	<p>685.</p>

Analysis of above urine. Very
 dark and smoky: neutral:
 mucus: Albumin: Blood:
 No bile or sugar.

This urine was from a case of acute, super-
 imposed on chronic, Bright's and therefore, probably,
 though the urine was loaded with blood, the amount of
 albumin excreted as such would not be so great as in a
 case of ordinary acute Bright's. The number of drops
 is high.

Mar. 31st.	<p><u>LX. Urine.</u> (Bile?)</p> <p>T° of room: D.B. 64. W.B. 55. T° of fluid. (a) 18.5°C. (65.3°F) (b) 19.0°C. (66.2°F)</p> <p>Time. 5.1½ - 5.25. Rate. (a) 37. (b) 31.</p> <p><u>Analysis.</u> Very dark amber: clear: acid: 1C25: No albumin blood or sugar. Bile?</p>	<p><u>Drops.</u></p> <p>744.</p>
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This urine was suspected of containing bile
 but did not give the reactions.

Its froth was not distinctly green: with
 Gmelin's test, performed with the addition of Chloro-
 form to carry down the pigments, it gave a brownish
 colour: with Pettenkoffer's test it likewise gave,
 not the characteristic pink, but a brownish colour.

I believe that several other tests were app-

It is curious that these two solutions should give practically the same result when there is such a difference between the 0.24 and the 0.48% solutions.

April 2nd.	<u>XLIII. Serum-Albumin</u> Albumin 2.0% NaCl. 0.5% T° of room: D.B. 62. W.B. 55. T° of fluid. (a) 16.5°C. (61.7°F.) (b) 17.0°C. (62.6°F.) Time. 1.1 - 1.25. Rate. (a) 26. (b) 23.	<u>Drops.</u> 557.
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As this 2.0% solution of albumin gives a result that is practically within the range of normal the urine and water, it is probable that weaker solutions, which I had intended to try, would give a similar result.

Sir T. Grainger Stewart, in his lectures on Albuminuria, gives the case of a patient excreting 20 grms. per litre (2%) of albumin and remarks that this is an extreme case.

Therefore it is probable that serum-albumin in the percentage in which it is usually found in the urine produces no effect on the surface tension.

This coincides with the result I obtained with the albuminous urine which gave the same result after removal of the albumin as before.

It will be seen that the two solutions of globulin which I obtained by concentration of that used in Experiment LVI, give a great increase in the number of drops, i.e. a marked diminution in the surface tension.

But these solutions are of a strength that is not likely to be met with clinically, ^{and} therefore need not be taken into account.

As a matter of scientific interest I thought it would be worth while to test the effect of concentrating the solution of serum albumin.

I have therefore set 500 c.c. of the 2% solution to evaporate down at 37°C. in a flask plugged with cotton-wool. A piece of thymol has been put in the fluid to prevent the development of bacteria.

As this process of evaporation will take several weeks the result cannot be included here.

For ease of reference and comparison I now give these results in tabular form.

In the tables I have grouped the substances according to their nature. The rate and T° as given are the averages which I obtained throughout the experiment.

The former is deduced from the total time and the number of drops, and the latter from the initial and final readings of the temperature of the fluid.

No. of Expt.	Substance	Strength %	Time. Minutes	Rate. Per min.	T ^o °C.	Defect of Saturation	Drops	Remarks.
I.	Distilled Water.	-	22.5	22.4	-	.219	506	
IV.	"	-	20.5	24.6	-	.217	505	
VI.	"	-	-	-	-	.181	517	
XIV.	"	-	22.5	23.8	16	.223	536	
XIX.	"	-	23.	21.8	15.5	.181	503.	
XXIII.	"	-	24.	22.9	13.5	.219	551	
XXX.	"	-	23.	23.	14.5	.226	531	
XXXI.	"	-	23.	23.2	16.	.217	534	
XXXIV.	"	-	24.	22.6	14.5	.219	543	
XLII.	"	-	22.	24.3	16.75	.150	535	
XLIX.	"	-	21.	24.9	18.5	.300	524	
LVIII.	"	-	20.	24.8	19.	.316	497	
XIII.	"	-	18.	33.9	37.5	.229	611	Note the T ^o .
II.	Sodium Chloride.	0.75	21.	23.4	-	.202	492	
III.	"	5.0	24.	20.3	-	.162	488	
IV.	"	10.0	23.	22.4	-	.167	516	

No. of Expt.	Substance	Strength %	Time	Rate	T ^o	D.S.	Drops	Remarks
VII.	Urea	3.0	21.	23.7	14.5	.141	499	
VIII.	"	5.0	20.	25.8	19.5	.214	517	
XV.	Glucose	2.0	21.	25.3	19.5	.289	532	
X.	"	5.0	25.5	21.7	15.	.298	555	
XX.	"	5.0	23.5	22.	16.5	.274	518	
XVI.	"	7.5	24.	22.5	19.	.237	542	
XI.	"	10.0	24.	21.7	19.5	.267	521	
IX.	Extr. of Human Bile.	0.5	22.	29.2	19.5	.278	643	
XII.	" "	2.0	22..	37.3	18.5	.290	822	
XXIV.	Glycocholate Sol.	0.025	23.	30.1	14.75	.274	694	
XXV.	" "	0.05	23.	32.3	16.75	.270	745	
XXII.	" "	0.1	24.	34.6	14.75	.243	832	
XLVI.	" "	0.1	22.	27.7	19.75	.354	830	
XXI.	" "	0.25	23.	38.9	13.5	.197	895	
XVIII.	" "	0.5	24.	38.5	15.5	.209	926	
XLV.	" "	0.5	21.	44.7	20.5	.354	940	

No. of Expt.	Substance.	Strength %	Time	Rate	T ^o	D.S.	Drops	Remarks
IXIII.	Serum-Albumin.	2.0	24.	23.2	16.75	.222	557	
LVI.	" Globulin.	0.24	23.5	25.2	15.5	.284	594	
LXI.	" "	0.48	22.5	32.1	19.	.293	723	
LXII.	" "	0.72	22.	32.2	19.	.305	710	
XI.III.	Deutero Albumose.	1.0	22.5	33.6	18.5	.201	758	
XLIV.	Peptone.	0.25	20.	27.7	20.75	. -	555	
XVII.	Tap Water.	-	23.	21.6	15.	.184	498	
L.	Urine (normal)	-	21.	26.4	18.5	.300	556	Same case as XXXVII.
XXXVI.	" "	-	22.	26.5	17.75	.259	585	
XXXII.	" "	-	24.	26.1	17.	.214	631	Lead Poisoning.
XXXV.	" "	-	23.5	29.5	17.	.229	694	Note the No. of drops.
XL.	" (diabetic)	4.3	26.	22.4	19.5	.289	583	
XXVI.	" "	6.1	26.5	21.2	18.	.277	562	
XXVIII.	" (albumin)	trace	24.	25.1	16.	.128	603	
XXIX.	" "	0.25	24.5	27.1	17.	.274	665	
XXXIII.	" "	-	23.5	28.9	16.5	.240	681	XXIX with alb. removed.

No. of Expt. .	Substance.	Strength %	Time	Rate	T ^o	D.S.	Drops	Remarks.
XXXVII.	Urine(albumin)	trace	23.	31.6	18.	.236	727	Same case as L.
EVII.	" "	0.36	27.	24.3	16.75	.245	658	" " " XLVII.
XLVII	" "	0.36	22.5	29.5	19.25	.289	664	Same as preceding, but during a febrile attack.
LI.	" "	trace	23.5	33.1	17.	.274	779	Acute Pneumonia.
IV.	"(alb.& blood)	-	23.	26.7	17.5	.285	615	
XXXVIII	" " "	Alb. 3.0%	25.	24.5	16.	.228	613	
XXXIX.	" " "	" "	24.5	25.3	14.75	.240	622	Same as preceding, but albumin removed
LIX	" " "	-	22.	31.1	19.	.327	685	A large amount of blood.
XXVII.	" (bilious?)	-	23.	27.3	17.25	.229	630	Same use as following.
XLI.	" (bilious)	-	23.5	26.5	18.	.254	624	
LII.	" "	-	23.5	29.2	17.	.274	688	
LIII.	" "	-	23.	30.9	17.	.199	711	
LIV.	" "	-	26.	30.1	15.75	.184	783	Same as preceding, but mucin removed.
IX.	" (bilious?)	-	23.5	31.6	18.75	.327	744	(?altered bile)

In the above tables I have left out the readings of the Dry and Wet Bulb Thermometer, and have given only the Defect of Saturation.

As I stated above, I had to correct the readings of the Dry Bulb by the final temperature of the fluid. Before doing this, however, I made a strict comparison of the two thermometers, both when the Wet and Dry Bulb Thermometer was dry and when it was wet. I found that when evaporation was going on freely the Dry Bulb registered on the average 1.5 - 2°F. below the average temperature of the room. I also made comparisons to satisfy myself that the fluid in the jar had acquired the room T° by the time of the final reading. I found that it did so unless the T° of the fluid were unusually low at the beginning.

I append the humidity tables as they shew the corrected readings of the Dry Bulb and the relation of Defect of Saturation to Relative Humidity.

HUMIDITY TABLES.

Dry.	Wet.	D.P.	A.H.	R.H.%	D.S.	Drops.	Substance.
64.	57.	51.2	.377	63	.219	506	Distilled Water.
63.5	57.	51.7	.384	65	.202	492	Saline 0.75%.
57.5	51.5	46.	.311	65	.162	488	" 5.0%.
58.5	52.5	47.1	.324	65	.167	516	" 10.0%.
59.	52.5	46.7	.319	63	.181	517	Distilled Water.
63.5	56.5	50.6	.369	62	.217	505	" "
61.	56.5	52.5	.396	73	.141	499	Urea 3%.
68.	62.	57.3	.470	68	.214	517	" 5%.
69.	61.	54.8	.430	60	.278	643	Extr. of Human Bile.
68.	59.	51.9	.386	56	.298	555	Glucose 5%.
65.5	57.	50.0	.361	57	.267	521	" 10%.
65.5	56.	48.2	.338	53	.290	822	Extr. of Human Bile.
63.5	56.	49.7	.357	64	.329	611	Distilled Water (Hot).
64.5	57.5	51.7	.384	63	.223	536	" "
67.	58.	50.8	.372	56	.289	532	Glucose 2%.
67.	60.	54.4	.424	64	.237	542	" 7.5%.
62.	56.	50.8	.372	67	.184	498	Tap Water.
62.	55.	49.0	.347	62	.209	926	Glycocholate 0.5%
61.5	55.	50.3	.365	66	.181	503	Distilled Water.
62.5	53.	44.9	.292	51	.274	518	Glucose 5%.
60.	53.	46.8	.321	62	.197	895	Glycocholate 0.25%.
66.	58.5	52.5	.396	61	.243	832	" 0.1%



					52.		
Dry.	Wet.	D.P.	A.H.	R.H.%	D.S.	Drops.	Substance.
64.	57.	51.2	.377	663	.219	551	Distilled Water.
65.	56.	48.6	.343	55	.274	694	Glycocholate 0.025%
66.	57.5	50.6	.369	57	.270	745	" 0.05%.
65.5	56.5	49.2	.351	55	.277	562	Urine (diabetic).
63.5	56.	49.7	.357	64	.229	630	" (?bile).
61.5	57.5	54.	.418	76	.128	603	" (albumin).
62.5	53.	44.9	.292	51	.274	665	" "
61.	53.	46.	.311	58	.226	531	Distilled Water.
61.5	54.	47.5	.329	60	.217	5534	" "
63.	56.	50.1	.362	63	.214	631	Urine (normal).
61.5	53.	45.6	.306	56	.240	681	" (albumin)
60.	52.	45.0	.299	58	.219	543	Distilled Water.
63.5	56.	49.7	.357	64	.239	694	Urine (Normal):
64.5	57.	50.8	.371	61	.236	727	" (albumin).
61.5	53.	45.6	.306	56	.240	622	" (albumin).
61.5	53.5	46.6	.318	58	.228	613	" (albumin).
67.	58.	50.8	.372	56	.289	583	" (diabetic).
65.5	57.5	51	.374	59	.254	624	" (bile).
63.5	59.	55.2	.436	74	.150	535	Distilled Water.
69.	58.	49.4	.353	50	.354	940	Glycocholate 0.5%.
69.	58.	49.4	.353	50	.354	830	" 0.1%
67.	58.	50.8	.372	56	.289	664	Urine (albumin)
65.5	59.5	54.6	.427	67	.201	758	Deutero-albumose.
65.5	55.	47.4	.328	52	.300	524	Distilled Water.
65.5	55.	47.4	.328	52	.300	556	Urine (Normal).

Dry.	Wet.	D.P.	A.H.	R.H.%	53. D.S.	Drops.	Substance.
62.5	53.	44.9	.292	51	.274	779	Urine (Pneumonia)
62.5	53.	44.9	.292	51	.274	688	" (Bilious).
62.5	56.	50.5	.367	64	.199	711	" "
62.	56.	50.8	.372	67	.184	783	" "
63.5	53.5	45.1	.301	51	.285	615	" (alb. & blood).
63.	53.	44.5	.292	51	.284	594	Globulin 0.25%.
63.5	54.	46.8	.321	56	.245	658	Urine (albumin).
66.0	55.5	47.	.323	50	.316	497	Distilled Water.
66.	55.	46.1	.312	48	.327	685	Urine (Alb. & blood).
66.	55.	46.1	.312	48	.327	744	" (Bile?).
66.	56.5	48.9	.346	54	.293	723	Globulin .48%.
66.	56.	47.9	.334	52	.305	710	" .72%.
62.5	55.	48.7	.344	60.	.222	557	Albumin.

As the term "Defect of Saturation" does not usually appear in English books, perhaps I should explain how it is obtained.

Absolute humidity indicates the amount of water vapour, expressed in terms of the pressure it exerts (in inches of Hg.) which is actually present in the air at the time of observation.

Only when the vapour is saturated does this amount coincide with the amount which the air

can take up at that temperature. In all other cases the amount of vapour present is less than the amount which the air can take up at the temperature of the dry bulb. The difference between them is the defect of saturation.

It is found by subtracting the vapour pressure corresponding to the dew point from the vapour pressure corresponding to the temperature of the Dry Bulb. That "Defect of Saturation" is of more value than Relative Humidity is well seen in the above tables.

For example compare samples 1 and 5. In both the Relative Humidity is 63% but in the former the Defect of Saturation is 0.219 while in the latter it is 0.181, showing that the air has considerably greater evaporative power in the former case.

My object in taking these concomitant observations was to determine, if possible, the chief factor in producing the variation in the number of drops, and then by allowing for this factor to make results of the different experiments more strictly comparable. The only experiments in which we can hope to determine the influence of T° , Defect of Saturation, etc. are those in which the same solution is used more than once, e.g., Distilled Water, the two 5% Solutions of Glucose, the 0.5% and 0.1% solutions

of Glycocholate.

In connection with the variation in Distilled Water, I have made out a chart (See Chart I) showing the variation in the number of drops with the concomitant variations in the temperature of the fluid, the barometer and the Defect of Saturation. It does not appear that the number of drops is directly or chiefly controlled by any of these factors. In fact, the number of drops falls off when we should expect it to rise.

For it is well known that rise of temperature diminishes the surface-tension. "Andrews showed that, as liquid Carbonic Acid is gradually raised to its critical temperature, the curvature of its surface in a capillary tube gradually diminishes." (Tait's "Properties of Matter", p.267)

Also the experiment that I did with hot water shows this. In samples of distilled water 4-11 (inclusive) the average temperature is 16°C. and the average number of drops is 529. The maximum temperature in the same experiments is 19°C. The rise of temperature from 16°C. to 37°C.5 is 21.5. Taking this rise of 21.5° as equal to an increase of 82 drops, then an increase of 3° should give a rise of 11 drops.

This is supposing that temperature is the chief factor but we see that there is a marked fall below the average.

Again, as regards Defect of Saturation: theoretically one would expect that an increased evaporation of the fluid would diminish the tension of the surface film. Thus we should expect the number of drops to increase with the Defect of Saturation. It will be seen from the chart that when both temperature and Defect of Saturation go up, the number of drops may go down.

Again, as regards Viscosity: Diminution of viscosity should, if it affected the number of drops at all, increase them. Poiseuille and others have shewn that the viscosity of water and other fluids falls off directly with the rise of temperature.

Thorpe and Rogers have shewn (Philosoph. Transactions of R.S. Vol.185A (1894) that the viscosity of water falls off as follows:-

<u>Temperature.</u>	<u>Pressure.</u>	<u>Coeffic. of Viscosity.</u>
1.13°C.	130.16	C.C17094
13.52	182.65	C.C11814
22.04	128.64	C.C09544
99.97	128.90	C.C02859.

The range of T° which we have to deal with in connection with the experiments in Distilled Water

is 13.5-19, which corresponds to a diminution in the coefficient of viscosity from C.Cl18 to C.ClC2, a difference of C.CCl6 which is very slight.

Alterations in barometric pressure would hardly be expected to produce an appreciable effect in such coarse experiments as these, but I give the curve in the chart for comparison.

Thorpe and Rogers have shown (loc.cit.) that not only is viscosity affected by the nature of the molecules of which the fluid is composed, but also by the nature of the atoms comprised in the molecule and by the arrangement of these atoms.

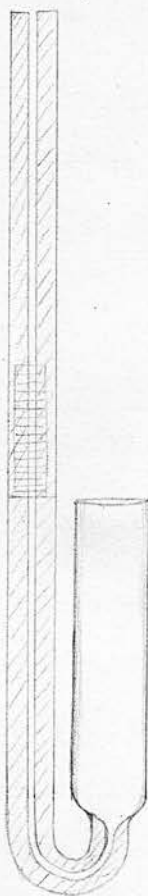
Thus they say:- "As has already been stated, viscosity may be taken as the measure of attractive forces in play between molecules. Now the preceding tables, more especially those given later, go to show that an increment of CH_2 , or the substitution of an atom of Cl, Br or I for an atom of H, brings about a definite change in the viscosity magnitudes. It is therefore made evident that viscosity or intermolecular attraction is in reality a property of the atoms of which the molecules are composed".

Taking these facts into consideration, it seems probable that surface-tension will also be affected by the nature of the molecules and their mode

of composition, and therefore it should be affected by changes in the physical conditions under which it exists.

Therefore, one can only conclude that the above experiments are too coarse to show the influence of these physical conditions and the variations which occur must be put down to the interaction of various factors which have not been determined.

As a check on this method of measuring surface-tension, I performed a separate set of experiments in which I made use of capillarity. In order to do this I contrived and had made for me by the glass-blower, an instrument of the following form:-



It consists of an *l*-shaped glass tube; the long limb is composed of a piece of medium bore thermometer-tubing, and the short limb of a piece of ordinary $\frac{1}{2}$ in. tubing. The mouth of the wide tube is ground so as to be even all round.

The long limb bears a series of graduations in millimetres, beginning at the level of the mouth of the wide tube and about 40 in number.

The method of using the instrument is to dip it into the fluid and lift it out slowly and read the height to which the fluid rises in the capillary tube above the level of the mouth of the wide tube. If the tube is lifted out of the fluid slowly it will be found that the fluid in the wide limb is exactly level with the ground surface of the mouth of that limb, while if it is lifted out quickly a dome of fluid, which varies in size with the speed at which the tube is withdrawn, forms at the mouth of the wide tube.

The fluid in this dome tends to creep down gradually and therefore no two readings are the same.

If, however, the fluid is perfectly even with the ground edge you are sure that it is at the same level and the readings in the capillary limb are strictly comparable.

In using the tube in this way the width of the wide limb is of no consequence and is taken at $\frac{1}{2}$ in. for convenience.

The bore of the capillary tube should not be too small, (though, of course, the finer the bore the more marked the differences,) because it becomes very difficult to clean thoroughly and moreover shows a great tendency to the formation of bubbles in it

which vitiate the readings.

The tube should be rinsed 10 or 12 times with running tap-water immediately after it is used, to prevent fluids drying in it, and if then it does not give a normal reading with tap water, it should be washed in dilute acetic acid.

Another precaution which is necessary for accurate readings is that all the fluids should be carefully filtered, preferably through a double filter paper of fine quality.

I have made out a chart comparing the results obtained by this instrument with those obtained with the dropper. It is constructed by making the maximum and minimum correspond and it will be seen that the coincidence of the intermediate points is fairly close. There are some discrepancies, but as the observations with the dropper are not averages, but single observations, and, as we have seen, the dropper varies somewhat, it is probable that it contributes in part to the discrepancies.

I append a table comparing the number of drops with the reading of the capillary tube, giving the T° of the fluid in each case.

I found that with the capillary tube there was a slight variation, in the course of a week or so, in the reading of the tap water, e.g. 29.5-30.0, and I tried the effect of T° with the following results.

Tap Water.	10°C.	29.0 m.m.
" "	39°C.	28.5 m.m.
" "	50°C.	27.5 m.m.

Hence it is obvious that ordinary temperature changes should not produce much variation.

Comparison of Capillary Tube and dropper.

Substance.	Drops.	T ^o	Cap.Tube.	T ^o
Urine (alb.)	622	14.75	26.0	14.
" (alb.)	613	16. *	26.0	16.
" (diabetic)	583	19.5	29.0	19.5
" (bile?)	624	18.	27.0	18.5
Distilled Water.	535	16.75	29.5	16.
Deutero-alb. 1%.	758	19.5	22.	19.5
Glycocholate .5%.	940	20.5	16.	20.5
" .1%	830	19.75	18.5	19.0
Urine (alb.)	664	19.25	24.5	18.
Distilled Water.	524	18.5	29.5	17.5
Urine (normal)	556	18.5	29.	19.
" (pneumonia)	779	17.	23.	17.
" (bilious)	688	17.	23.5	16.
" "	711	17.	24.5	17.
" (mucin↓)	783	15.75	22.	16.5
" (alb.& bld.)	615	17.5	25.	17.5
Serum-Globulin .29%	594	15.5	28.	15
Urine (alb.)	658	16.75	23.	16.5
Distilled Water.	497	19.	29.75	13.5
Urine (blood).	685	19.	24.	18.75
" (bile?)	7744	18.75	22.	19.
Globulin .48%.	723	19.	21.5	18.75
" .72%.	710	19.	21.5	18.5
Albumin 2.0%.	557	16.75	28.5	16.5

GENERAL SUMMARY OF RESULTS.

1st. As to the method of measuring surface-tension by drops.

I think it will be granted from the above experiments, especially those in which the control with the capillary tube was performed, that this method of estimating the surface-tension of a fluid by the number of drops formed from a given quantity under definite conditions gives fairly accurate indications.

At the same time it is evident that they are only approximate, that is to say that a certain amount of latitude must be allowed for variation.

The lower the surface tension the greater will be the amount of variation.

Water, we have seen, varies from 497 to 551, normal urine, diabetic urine etc. lie between 550 and 600; so that I have come to look upon any fluid giving a result below 600 as not much altered.

I have endeavoured to reduce the variations so as to get even more approximate results, but without success.

As regards the capillary tube, I think it will be allowed that, if carefully used with the pre-

cautions I have given above, it gives nearly as good approximate results as the method by dropping, and of course is not so laborious in application.

2nd. As regards the clinical value of surface-tension.

A. Pure Solutions.

Of these the only one which gives any marked result is bile. Neither sodium chloride, urea nor glucose produce any effect, and of the proteids we may say that probably none of them produce any effect in the proportions in which they occur clinically. At the same time it is interesting to note that stronger solutions of Deutero-albumose and Serum-globulin do produce a marked effect.

B. Urines.

In connection with the urines we must note in the first place that a urine may occur with a surface-tension within the "normal limits".

In the second place we find that diabetic urines lie approximately within the "normal limits".

In the third place those urines in which bile is known to be present always give a high result. But it is also seen that urines which are returned as

normal and which to all the ordinary tests are normal, may yet have their surface-tension markedly reduced. Again, the albuminous urines have generally a lower surface tension than normal. It is possible that this is not due to the albumin itself, but to something associated with the albumin.

In this connection it is of interest to note that Sir T. Grainger Stewart in his lectures on Albuminuria has called attention to the association of bile salts with albuminuria. He points out that there is a diurnal cycle in the amount of bile excreted, the maximum (in the case he records) occurring before breakfast in the morning and the minimum in the evening. (See "Lectures on Albuminuria, p.161) He gives a case in which the amount of bile excreted, taking 100 as the normal, varied from 30-160.

The normal amount of bile salts found in the urine by Vogel and Dragendorff (See Halliburton's Chemical Physiology and Pathology, p.779) was 0.8 gm. per 100 litres - .008%. Hence the maximum in the case given by Grainger Stewart would be equivalent to .024%. This is about 1/10 of the strength of the weakest solution of glycocholate which I used and therefore would probably not be sufficient to account for such a marked lowering of the surface tension as I found in some of the albuminous urines.

Still it is possible that there was sufficient bile present in those urines to produce such a result though it was not revealed by the ordinary tests.

On the other hand, the number of substances with which I have experimented is unfortunately very limited, and there may have been in those urines some substances, other than bile, which was producing the effect.

The febrile urine from the case of pneumonia gave a high result. As I remarked above it was very dark in colour and looked like a bilious urine but did not give the reactions. There was a small amount of albumin present, but only a trace. Sample LX also shows a reduced surface-tension, though bile could not be detected in it.

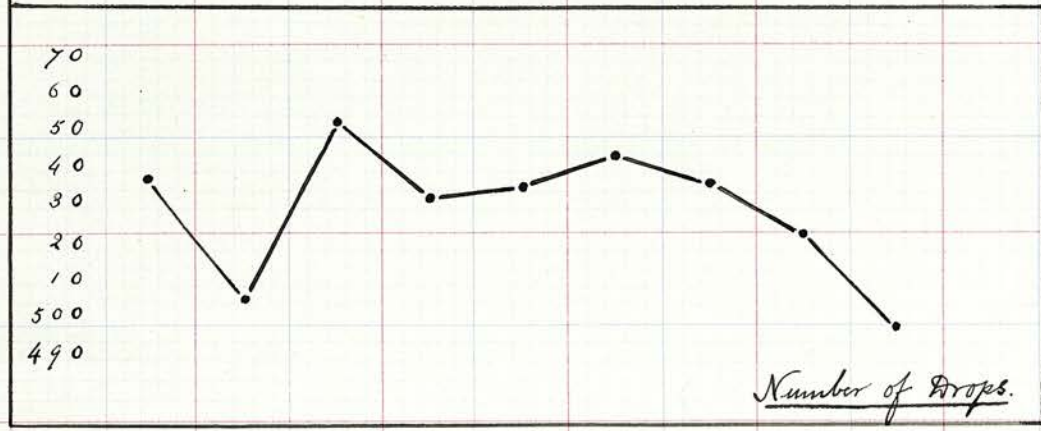
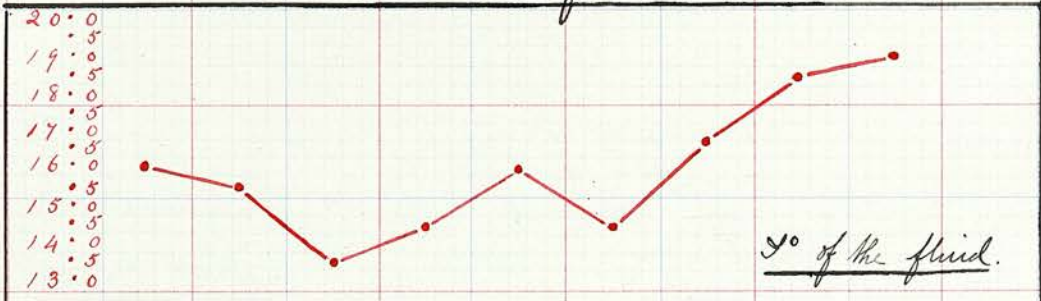
Those urines also which contained both blood and albumin gave a low surface-tension but it is impossible at the present stage to say what, if any, was the effect of the blood.

I regret that the time at my disposal has not allowed me to go more fully into this matter. I think the subject might be pursued with advantage and I would suggest that it should be followed up by means of the capillary tube.

By this means it might be found that the diminution in surface tension was always associated with certain pathological states of the system and then a more thorough examination of the urine by the physiological chemists might determine the association of some of the rarer constituents of the urine with those pathological states.

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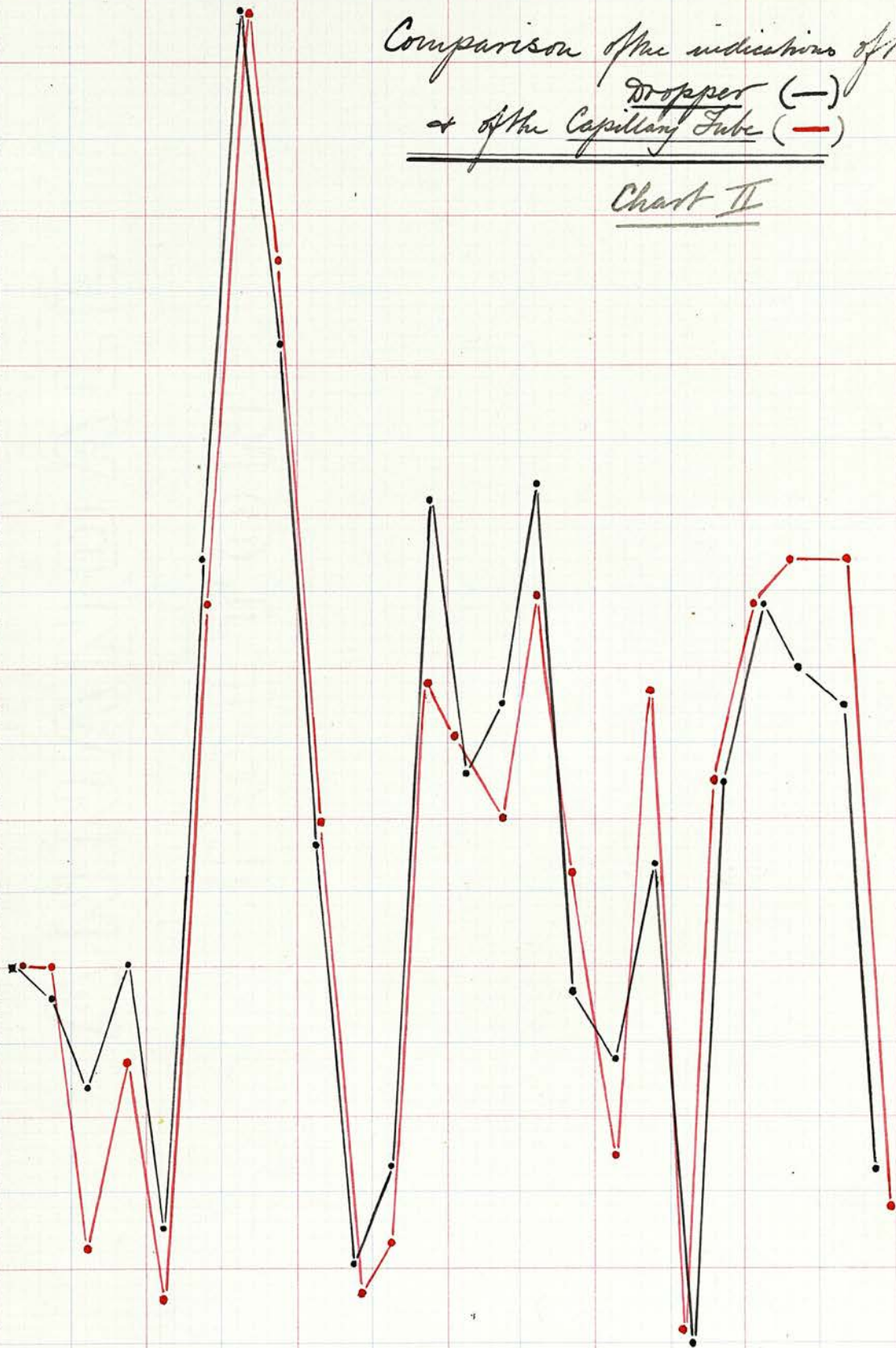
Variation of Distilled Water.

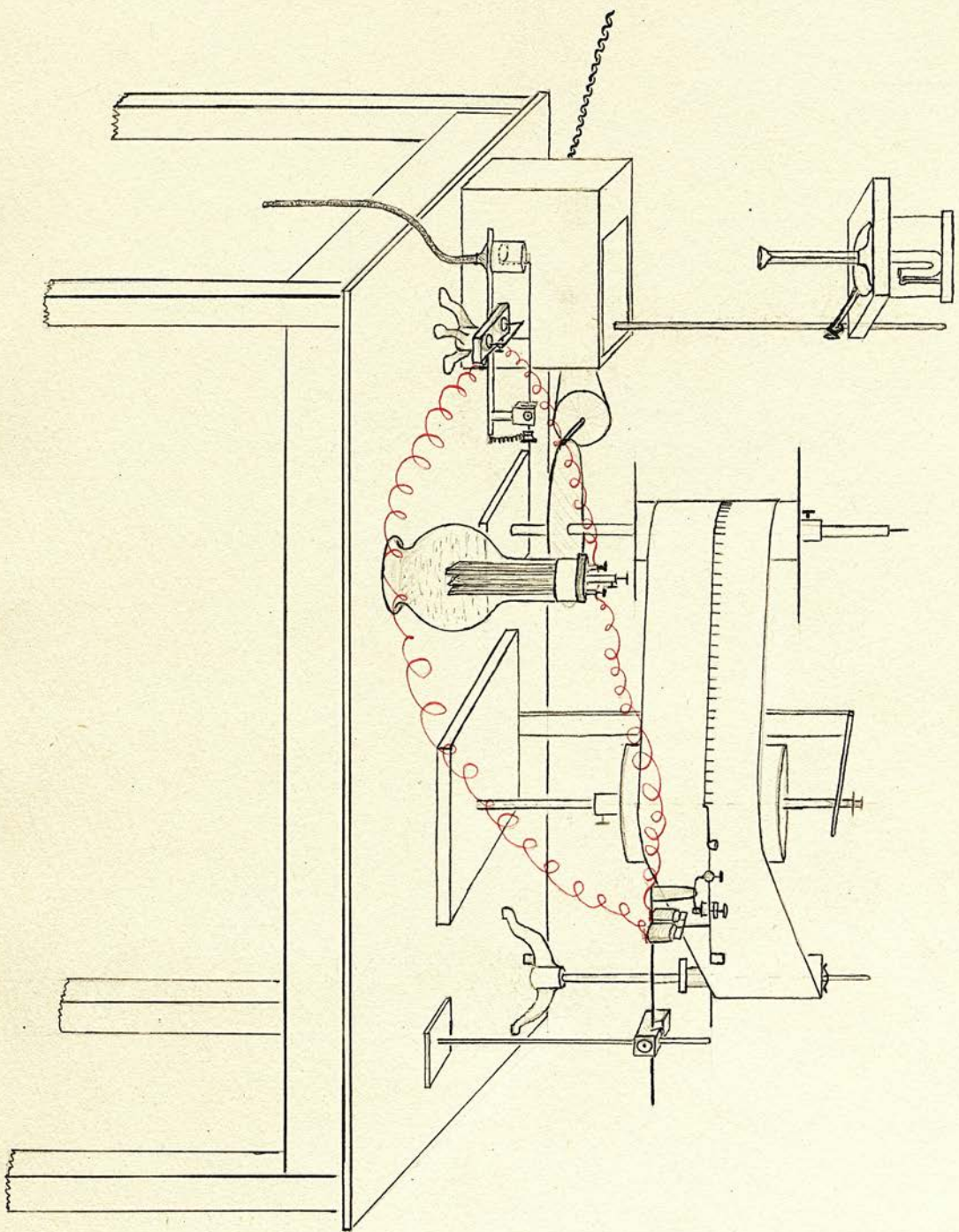


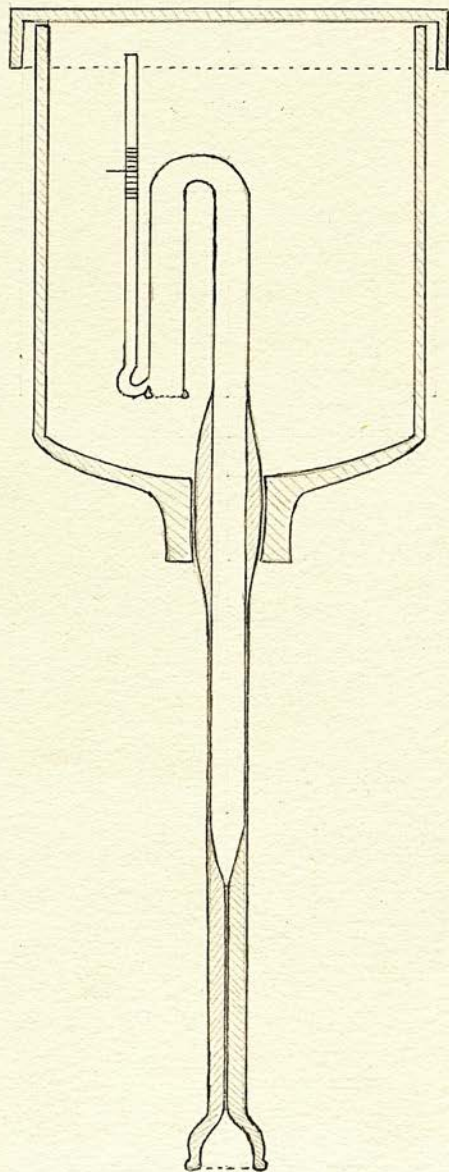
Comparison of the indications of the
Dropper (-)
 & of the Capillary Tube (-)

Chart II

40	16.0
30	
20	16.5
10	
900	17.0
90	17.5
80	
70	18.0
60	18.5
50	
40	19.0
30	19.5
20	
10	20.0
800	20.5
90	
80	21.0
70	
60	21.5
50	
40	22.0
30	22.5
20	
10	23.0
700	23.5
90	
80	24.0
70	
60	24.5
50	
40	25.0
30	25.5
20	
10	26.0
600	26.5
90	
80	27.0
70	
60	27.5
50	
40	28.0
30	28.5
20	
10	29.0
500	29.5
490	30.0







x 3/4