B.—VISCOSITY.

Viscosity and its Variations.

	Normal Horses.				Horses Suffering from Horse-sickness.		Horses Immune against Horse-sickness.			Normal Donkeys.			Normal Cattle.	Normal Sheep.		Normal Goats.
	Blood.	Defibrinated Blood.	Plasma.	Serum.	Blood.	Serum.	Blood.	Plasma.	Serum.	Blood.	Plasma.	Serum.	Serum.	Blood.	Serum.	Serum.
Number of examinations	90	9	16	81	85	83	14	8	14	18	18	18	4	10	19	8
„ animals	72	9	11	71	58	67	12	4	14	8	8	8	4	10	19	8
Average viscosity	*3·80*	*2·89*	*1·92*	*1·83*	*3·68*	*1·78*	*3·8*	*2·04*	*1·9*	*3·74*	*2·01*	*1·8*	*2·04*	*4·27*	*1·65*	*1·75*
Maximum	5·27	3·45	2·25	2·13	7·39	2·77	4·7	2·27	2·18	4·83	2·5	2·3	2·15	4·8	1·87	1·98
Minimum	2·95	2·55	1·73	1·55	2·7	1·49	3·05	1·85	1·72	2·7	1·7	1·6	1·87	3·8	1·5	1·58
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Total variation	61·1	31·2	27·4	31·8	127·3	72·1	43·5	22·7	24·3	57	39·8	38·9	13·7	23·4	22·4	22·8
Variation above average	38·7	19·4	17·2	16·7	100·6	56·06	32·7	12·4	14·7	29·2	24·4	27·8	5·4	12·4	13·3	13·1
„ below „	22·4	11·8	10·2	15·1	26·7	16·06	10·8	10·3	9·5	27·8	15·4	11·1	8·3	11	9·1	9·7
Percentage of values above and on average	41·1	44·5	37·5	37	40	51·8	57·2	87·5	43	55·5	50	55·5	50	40	52·5	37·5
Percentage of values below average	58·9	55·5	62·5	63	60	48·2	42·8	12·5	57	44·5	50	44·5	50	60	47·5	62·5
Percentage of values above normal average	—	—	—	—	34	35	57	37	79	—	—	—	—	—	—	—
Percentage of values below normal average	—	—	—	—	66	65	43	63	21	—	—	—	—	—	—	—

The following table shows the mathematical relations between the viscosities of blood, plasma, and serum :—

	Normal Horses.	Horses Suffering from Horse-sickness.	Immune Horses.	Normal Donkeys.	Normal Sheep.
Viscosity of blood / Viscosity of serum =	2 ·08	2 ·07	2 ·0	2 ·08	2 ·59
Viscosity of blood / Viscosity of plasma =	1 ·98	—	1 ·86	1 ·86	—
Viscosity of plasma / Viscosity of serum =	1 ·05	—	1 ·07	1 ·12	—

If we take the viscosity of serum = 1 we obtain the following table :—

	Serum.	Plasma.	Blood.
Normal horses	1	1 ·05	2 ·08
Horses suffering from horse-sickness	1	—	2 ·07
Immune horses (against horse-sickness) ..	1	1 ·07	2 ·0
Normal donkeys	1	1 ·12	2 ·08
Normal	1	—	2 ·59

The figures of the three tables above are expressions of the following biological facts :—

I. Blood.—The internal friction of the entire blood of each species examined is much higher, nearly double, that of the blood liquid (the plasma) and a little more than double that of serum. At first sight it appears that the cause of this phenomenon is the presence of blood corpuscles. A certain relation between volume of blood corpuscles and viscosity of blood is shown by the following comparison of the respective figures :—

	Viscosity of blood.	Volume % of blood corpuscles.
Normal donkeys ..	3 ·74	33
Normal horses	3 ·8	33 ·8
Normal sheep	4 ·27	40 ·3
Sick horses	3 ·68	34 ·3
Immune horses ..	3 ·8	31 ·1

Comparing horses, donkeys, and sheep, the viscosity of the blood which contains the greatest quantity of blood cells is highest. On the other hand, comparing the values of sick and immune horses, we note a slight disproportionality between internal friction and volume of blood corpuscles. The number of erythrocytes is, of course, though the main, not the only factor of the internal friction of blood under pathological conditions. Further specially arranged quantitative experiments, demonstrating the influence of the concentration of red blood corpuscles on the internal friction of a system, are the following :—

1. *Suspension of Erythrocytes in Serum.*

Vol. of corpuscles. %	Number of corpuscles in millions.	Viscosity of the suspension.
40·0	8·4	4·5
36·6	7·5	3·95
31·1	6·55	3·5
26·7	5·6	3·15
22·2	4·65	2·8
17·8	3·75	2·45
13·3	2·8	2·15
Serum alone	—	1·8

Remark.—Temperature 23 C. Defibrinated blood from horse 3250, previously concentrated by centrifugalising and then diluted with serum from the same horse.

2. *Suspension of Erythrocytes in Physiological Water.*

Vol. of corpuscles. %	Number of corpuscles in millions.	Viscosity of the suspension.
56·0	11·9	5·8
50·7	10·8	4·55
47·5	10·1	4·6
39·0	8·3	3·5
32·5	6·9	2·83
29·0	6·2	2·7
25·8	5·5	2·35
21·2	4·5	2·2
17·0	3·6	1·8
13·5	2·9	1·5
10·0	2·1	1·33
Physiological water	—	1·0

Remark.—The blood corpuscles were washed twice with 0·9 per cent. Na Cl. The number of corpuscles was found by division of the volume by the constant figure 4·7 which was derived from a great number of parallel examinations of volume and number of erythrocytes.

Graphically shown—ordinates representing the viscosity of the suspension, abscissae its content of erythrocytes—both series of figures give curves which are slightly concave towards the abscissae.

The following table contains the average values of the volume of blood corpuscles in ascending order with the respective average viscosities from various examinations on normal horse blood :—

Volume of blood corpuscles. %	Viscosity.	$\frac{\text{Volume \%}}{\text{Viscosity}}$.	Volume % blood corpuscles calculated.
23	2·81	8·2	—
24	2·7	8·9	—
25	3·18	7·9	25·1
27	3·31	8·2	27·4
28	3·33	8·4	27·8

Volume of blood corpuscles. %	Viscosity.	Volume %. / Viscosity.	Volume % blood corpuscles calculated.
29	3·32	8·7	27·6
30	3·43	8·75	29·4
31	3·45	9·0	29·8
32	3·62	8·85	32·7
33	3·66	9·0	33·5
34	3·66	9·3	33·5
35	3·80	9·2	36·1
36	3·78	9·5	35·7
37	3·82	9·7	36·5
38	4·13	9·2	—
39	4·11	9·5	—
41	4·56	9·0	—

On a curve-table the viscosities from 3·18 to 3·82 lay on a straight line, and accordingly the quotient $\frac{\text{Vol. \%}}{\text{Viscos.}}$ is almost regularly increasing, hence it is possible to calculate the volume of the blood corpuscles from the viscosity by means of the simple formula—

$$\text{Volume \%} = (\text{Viscosity})^2 \times 2\cdot5.$$

As it can be seen in the last column of the table, this formula permits of calculating the volume of blood cells with satisfactory approximation.

The very close relation, almost proportionality, between quantity of erythrocytes and internal friction of the blood enables us to obtain indications on the degree of eventual destructions of blood cells in the organism by measurement of the viscosity of the blood. On the other hand, when we find a subnormal viscosity a diminution of erythrocytes must have taken place. This deduction can be elucidated by means of three examples.

1. *Haemolysis.*—In all horses suffering from haemolysis due to the injection of an isolytic serum the percentage of the volume of blood corpuscles and the viscosity of the blood were lower than normal.

Horse 3028.

	November, 1907.			December, 1907.							
	28.	29.	30.	1.	2.	3.	4.	5.	6.	7.	8.
Viscosity of blood... ...	—	—	2·7	2·75	2·9	3·0	2·9	2·95	2·7	2·75	Died.
Volume % of blood corpuscles	—	—	—	17·0	19·0	17·0	14·0	15·0	15·0	21·0	—
Clinical Remarks ...	Urine red, conjunctiva yellow.	Conjunctiva yellow. Urine dark red, contains blood corpuscles.	Conjunctiva yellow. Urine brown, corpuscles.	Conjunctiva yellow.			Conjunctiva normal.				
				Urine normal.							

Horse 3126.

	28.	29.	30.	1.	2.	3.	4.	5.	6.	7.	8.
Viscosity of blood	—	—	3·25	2·95	2·9	3·2	2·95	2·9	3·1	3·0	Recovered.
Volume % of blood corpuscles	—	—	—	13·0	12·0	15·0	13·0	13·0	14·0	14·0	—
Clinical Remarks ...	Conjunctiva yellow.					Conj. nearly normal. Urine normal	Conjunctiva normal.				
	Urine red, contains blood corpuscles.			Urine red.			Urine dark red.			Urine normal.	

2. *Artificial Anaemia.*—From the following horses the quantities of blood opposite their numbers had been drawn during a month :—

Horse 2959 .. .. .. 14 ·000 c.c.
Horse 2110 .. .. .. 24 ·000 c.c.
Horse 2603 .. .. .. 24 ·000 c.c.

Examinations made six days after the last tapping :—

Horse.	Volume of Blood Corpuscles.	Viscosity of.		
		Blood.	Plasma.	Serum.
2110	20 ·5	2 ·4	1 ·6	1 ·5
2603	22 ·5	2 ·45	1 ·55	1 ·46
2959	22 ·5	2 ·7	1 ·75	1 ·54

Loss of blood amounting to about a quarter of the total blood quantity of an animal causes a considerable decrease of the blood viscosity. (Compare later the tables of experiments on serum-horses.)

3. *Equine Piroplasmosis.*

This disease is accompanied by a breaking down of red blood cells, and we find, of course, similar results as above. (See tables on piroplasmosis later.)

Stagnation (stasis) of the blood in the body increases the quantity of carbonic acid in the blood and also its viscosity and the volume and number of erythrocytes (several authors). We must be very careful, therefore, when experimenting that in taking the blood from the jugular vein no stasis is caused by pressure.

The following experiments were made :—

	Volume of Blood Corpuscles.	Viscosity of.		
		Blood.	Plasma.	Serum.
	%			
1. Horse 3256, normal	34	3·95	2·0	1·75
Fifteen minutes' gallop, five minutes vein strangulated	43	5·5	—	—
2. Horse Nera, normal	—	4·6	—	—
Vein five minutes strangulated	—	7·0	—	—
After fifteen minutes' gallop, no strangulation	—	5·4	—	—
Fifteen minutes' gallop, then strangulation for three minutes	—	7·2	—	—
3. Horse 3249, normal	46	4·95	—	—
Vein strangulated for five minutes ..	53	6·7	—	—
4. Horse 3260, normal	32	3·7	1·9	1·7
Fifteen minutes' gallop, then vein strangulation for five minutes	—	5·08	2·0	1·9
5. Horse 3260, (*a*) Defibrinated blood	30	3·15 of def. blood.	—	—
Twenty minutes' treatment with CO_2 ..	30·5	3·2 of def. blood.	—	—
(*b*) Defibrinated blood	28·8	3·4 of def. blood.	—	—
Twenty minutes' treatment with CO_2 ..	33·0	3·6 of def. blood.	—	—

By stopping the flow of blood (1) the volume of the corpuscles increases and, of course, (2) the viscosity of the entire blood, and (3) the viscosities of plasma and serum increase. These results correspond with those of Limbeck, Hamburger, and others, viz., that by the introduction of CO_2 into defibrinated blood the volume of the erythrocytes increases and that the serum becomes richer in albumen, sugar, and fat. We must consider that this latter fact is the cause of the rise of internal friction in our experiments with stagnated blood, plasma, and serum, and that the accumulation of carbonic acid in the living animal by the stagnation is also responsible for the increase of viscosity of blood, plasma, and serum. The highest value of blood viscosity can be observed in very severe cases of horse-sickness, when pulse and respiration are strongly affected. In these cases generally dikkop is present.

As a rule it is a bad prognosticum when viscosity and volume of corpuscles rather suddenly increase; it mostly points to death. On the other hand again death may occur without having been previously signalised by increase of the viscosity of blood.

The question as to how the red blood corpuscles can increase the internal friction of a system so considerably is of physical and pathological interest.

There are three possibilities:

1. The erythrocytes moving forward leave vortices in the medium behind them, and these are obstacles for the straight movement of the following globules.

2. The cells make a double movement (like a wheel)—(*a*) straight forward in the direction of the main stream, (*b*) round their own axis in any possible direction. This latter motion again takes parts of the liquid, attached by adhesive forces with it, and thus produces small secondary streams which might be opposed to the main stream.

3. On the enormous total surface of the erythrocytes—as on every surface—condensations and absorptions take place. These processes are variable and dependent on the membrane and contents of the cell and also on the physico-chemical properties of the outside liquid, i.e. briefly on the kind and concentrations of electrolytes and physical properties of the colloids in the plasma. (See chapter on surface tension.) Condensation causes an increase of the internal friction, and, since the physico-chemical properties of serum and plasma are considerably altered in horse-sickness and piroplasmosis (see tables later), we find under pathological condition alterations of the viscosity of blood, which are not simply corresponding with the alteration of the volume of the red blood corpuscles, because the physical conditions for absorption and condensation are changed.

The following experiments prove that not only the absolute extent of surface, but also the properties of the membrane of the erythrocytes influence the internal friction of the suspension:—

		Viscosity.
26/11/07	Defibrinated blood, horse 3161, filtrated	**3·7**
	Centrifugalised. Serum cleanly taken off	1·9
	Deposit filled up with 0·9 Na Cl to original volume, mixed. Suspension	2·65
	Centrifugalised. Liquid taken off	1·08
	Deposit filled up as above. Suspension	2·7
	Centrifugalised. Liquid taken off	1·0
	Deposit filled up as above. Suspension	2·65
	Centrifugalised. Liquid taken off	1·0
	Deposit filled up with the serum	**3·45**
13/11/07	Defibrinated blood, horse 2915, filtrated	**4·0**
	Centrifugalised. Serum cleanly taken off	1·8
	Deposit filled up with physiol H_2O to original volume, carefully mixed. Suspension	2·4
	Centrifugalised. First washing liquid taken off	1·05
	Deposit filled up as above. Suspension	2·4
	Centrifugalised. Second washing liquid taken off ..	1·0
	Deposit filled up as above. Suspension	2·22
	Centrifugalised. Third washing liquid taken off	1·0
	Deposit filled up with the serum	**3·35**
	Centrifugalised serum	1·7
	Physiological water	1·0

The defibrinated blood, which is made with washed corpuscles, has a much lower viscosity than the original defibrinated blood. I consider, therefore, that by the washing process the membrane is so altered that its adhesion to the serum decreases. The isotonic salt solution (0·9 per cent. Na Cl) does not affect the volume of the globules (Hamburger) and subsequently not the total extent of surface, but it creates new irreversible conditions of the membrane with regard to absorption and condensation.

II. Defibrinated Blood has a viscosity which is about a quarter lower than that of original blood. Blood is physically a suspension of erythrocytes in plasma, defibrinated blood a suspension of the cells in serum ; the difference between defibrinated and not defibrinated blood lies in the presence or absence of the fibrine-forming components. Notwithstanding this the differences between the viscosities of defibrinated and not defibrinated blood on one side and of serum and plasma on the other side are not equal. The latter difference of the internal friction (between plasma and serum) is about ten times smaller than that between whole blood and defibrinated blood. The reason is probably the destruction of blood corpuscles by the manipulation of defibrinating, and the loss of these cells which are retained by the fibrine by absorption or adhesion and by the paper or muslin filter.

III. Plasma.—The internal friction is very little higher than that of serum, the limits of variations are much narrower, the latitudes being only about half of those of the viscosity of blood (for horses).

IV. Serum is blood without corpuscles and fibrine components and its internal friction is, of course, comparatively low, and its variability is also small. The limits of variations to the viscosities of blood and serum of horses suffering from horse-sickness are about twice as wide as those of normal animals. Roughly speaking, serum consists of water, salts, and proteids. It is especially the latter which dominate the internal friction of the system. After elimination of the majority of them by boiling the viscosity of serum is considerably decreased, as the following experiments demonstrate :—

		Viscosity.
13/2/08	Serum horse 3249, normal	1·7
	Boiled, coagulum filtered off, liquid	1·18
	Serum 2904 (normal horse)	1·8
	Boiled, filtrated liquid	1·3
16/11/07	Serum horse 2917, normal	1·8
	Heated at 80° C., filtrated liquid	1·55

A smaller amount of albuminoids is precipitated at 80° C. than by boiling, therefore the remaining liquid (which looks slightly opalescent) has still a remarkable viscosity.

Ions have undoubtedly an influence—like on other peculiarities of colloids—so on their internal friction, but the role of each ion of the serum in this respect has not yet been thoroughly studied.

Heat, especially when acting for a certain time, greatly affects the serum-colloids, thus altering the viscosity of the system :

		Viscosity.
30/9/07 —1.—	Serum horse 2915, normal	1·75
	Heated half an hour at 60° C.	5·25
	Serum horse 2917, normal	1·75
	Heated half an hour at 60° C.	4·10

		Viscosity.
8/10/07—2.	Serum horse 2915, normal	1·87
	Heated half an hour at 45° C.	1·86
	„ „ 50° C.	1·9
	„ „ 55°–58° C. ..	2·4
	Serum horse 2917, normal	1·72
	Heated half an hour at 45° C.	1·75
	„ „ 50° C.	1·8
	„ „ 55°–58° C. ..	2·0
9/10/07—3.	Serum horse 2915, normal	1·7
	Heated half an hour at 55°–56°	2·05
	„ „ 60°	4·2
	Serum horse 2917, normal	1·7
	Heated half an hour at 55°–56°	2·0
	„ „ 60°	2·8

The effect of the heat differs on various sera, though they have been treated exactly in the same way.

These results are in accordance with those of French authors, who also observed an increase of viscosity (and opalescence) when inactivating serum by heat.

(Effect of heat on surface tension and co-efficient of optical refraction, see later.)

The influence of the concentration of the OH ion in the serum is shown by the following preliminary experiments (order of figures: increasing OH concentration) :—

		Viscosity.	Surface tension, 37°
11/5/08—1.	Serum horse 3524. T=21°.		
	5 c.c. + 5 drops n. H_2SO_4 acid reaction, opalescent	5·4	5·31
	Serum normal	1·90	6·14
	5 c.c. Serum + 5 drops nKOH	1·83	6·14
2/6/08—2.	Serum horse 3590. T=21°.		
	4 c.c. Serum + 2 drops $\frac{n}{2}$ H_2SO_4 acid reacting	2·57	4·94
	4 c.c. Serum + 1 drop $\frac{n}{2}$ H_2SO_4 very slight alkaline reaction	2·33	5·92
	Serum normal	2·12	5·98
	4 c.c. + 4 drops n Na OH	2·13	5·79
23/6/08—3.	Serum horse 3647. T=22°.		
	5 c.c. Serum + 2 drops $\frac{n}{2}$ H_2SO_4 very slight alkaline reaction	1·95	5·07
	Serum normal	1·83	5·82
	5 c.c. Serum + 2 drops nKOH	1·85	5·93
	5 c.c. Serum + 4 drops nKOH	1·88	5·85

In the last two experiments the viscosity is minimum at the natural concentration of the hydroxylion, and is greater at higher and lower alkalinity. The evident relation between internal friction and alkalinity seems to be reverse proportionality. The fact that the internal friction of the blood liquid is lowest at the natural alkalinity would be the most advantageous condition from the standpoint of haemodynamics.

Further experiments have to be made to draw definite conclusions.

Experiments with Colloids.

I mentioned that it is the colloidal nature of serum which causes its high viscosity compared with water. It has also been stated that the viscosity of blood is chiefly due to the globules, and I tried to explain the manner of their influence. The internal friction of blood and serum is considerably altered in diseases ; but it is not sufficient for the physiologist or pathologist to make the statement that it is so, but the reason should also be known Once we know the factors which create and alter a biophysical state we are able to recognise them in a complex of physico-pathological symptoms and then to find means to eliminate them. For instance, we know that a subnormal viscosity of blood is a sign of anaemia, or that a supernormal value of internal friction points to heart weakness. This knowledge indicates directions for the treatment.

With regard to serum, the conditions are not so simple. Concerning the factors of the viscosity of serum only the following is known :—

(1) The internal friction is dependent on the concentration and actual state of the colloids, and

(2) Ions and non-electrolytes influence the viscosity of the colloids, and the viscosity changes according to variations of the former.

(3) The disappearance of serum components, or the rise of new substances in it, under pathological circumstances, will alter the internal friction. (Bile pigments, urine components, haemoglobin, microbes, and their metabolic products.) The individual influence of these factors has not yet been ascertained. As the serum is already an enormously complicated heterogeneous system I experimented on a simple colloid, such as gelatine, to get an idea of the principles of the influences of concentration of the colloid and of some ions on the internal friction (and surface tension) of a heterogeneous system.

(1) *Gelatine.*

1·5 % Gelatine (=100 %) diluted with dist. H_2O. T=27°.

12/12/07.

Concentration of gelatine	0 H_2O	10	20	30	40	50	60	70	80	90	100
Viscosity ..	1	1·1	1·25	1·5	1·55	1·65	—	2·0	2·4	2·55	2·55

The internal friction of this colloid is a linear function of the concentration from 0 to 1·5 per cent.

(2) *Globuline.*

Serum diluted with H_2O in the proportion of 1 : 10. The globulines precipitated are washed several times and then dissolved in $\frac{n}{2}$ Na OH. T=27°.

13/12/07.

Concentration of globuline	0 (NaOH)	0·5	1·0	1·5	2·0	2·5	3·0
Viscosity	1·13	1·23	1·3	1·37	1·43	1·51	1·6

The internal friction of alkaline serum globuline is also a linear function of the concentration within 0 to 3 per cent.

(3) *Gelatine + Saponine.*

2 per cent. Gelatine = Viscosity 4·0. 4 per cent. Saponine = Viscosity 1·2. T = 27°.
12/12/07.

Parts of Gelatine.	Parts of Saponine.	Viscosity of mixture.
0	10	1·2
1	9	1·5
2	8	1·7
3	7	1·9
4	6	2·1
5	5	2·5
6	4	2·65
7	3	3·0
8	2	3·25
9	1	3·4
10	0	4·0

The viscosity of the mixture increase continually with the increasing concentration of gelatine; or in other words, saponine decreases the internal friction proportionally to its quantity, but quicker than water does, for the curves are convergent towards the concentration 0 of gelatine.

(4) *Serum + Colloidal Fe $(OH)_3$.*

11/10/07.

Serum c.c. ..	1	1	1	1	1	1	1	1	1
Fe $(OH)_3$ drops ..	2	4	6	8	10	12	14	16	18
Viscosity ..	1·7	1·6	1·55	1·5	1·5	1·5	1·45	1·45	1·4

Serum alone .. .. 1·8
$Fe_3(OH)$ alone .. .. .. 1·0

This curve differs from that of viscosity of the gelatine–saponine mixture. The first drops of $Fe_3(OH)$ decrease the viscosity more considerably than the following. Ferrihydroxyd is, of course, a colloid of a quite different kind than saponine, gelatine, or globuline.

Influence of Anions.

24/10/07—1.—Half per cent. neutral gelatine. T = 25°.
+ $\frac{n}{2}$ salt solution.

	Cl.	Br.	I.	NO_3	SO_4.
Viscosity, Na	1·5	—	—	1·52	1·8
K	1·45	1·52	1·4	1·48	—

Half per cent. gelatine = 1·82.

Na-Anions decrease the internal friction of neutral gelatine in the descending order—

Cl. NO_3. SO_4.

K-Anions decrease in the descending order.

I Cl. NO_3. Br.

20/5/08—2.—(*a*) 1 per cent. slightly alkaline gelatine T = 23°.
+ $\frac{n}{6}$ salt solution.

(*b*) 1 per cent. slightly acid gelatine
+ $\frac{n}{6}$ salt solution.

Na-Anions.	NO_3.	Cl.	SO_4.	Acetate.
Viscosity (*a*) ..	1·76	1·81	1·85	1·93
(*b*) ..	1·53	1·62	1·7	1·79

Controls :	Alkaline gelatine	2·10
	Acid ,, ...	2·13
	Neutral ,, ...	1·75

These anions decrease the internal friction of acid and alkaline gelatine in the descending order—

NO_3. Cl. SO_4. Acetate.

The order is not reversed with the change of reaction, as is the case with the order of influence of ions on surface tension (*vide* later).

The decreasing effect of the anions on viscosity is much greater in the acid than in the alkaline gelatine.

The viscosity of acid and alkaline gelatine is much higher than of the neutral colloid.

C.—SURFACE TENSION OF SERUM.*

I.

Surface tension or surface pressure is a force acting on the surface of every liquid and solid. It has the tendency of making the surface as small as possible, and therefore produces the globular form of a drop of liquid.

The surface pressure is the cause of capillary attraction and capillary depression, because it is higher on a convex, and less on a concave meniscus compared with the plane surface.

A certain relation exists between surface energies and chemical energies, hence if the surface tension of a liquid chemical compound is known, its molecular weight can be calculated. Forces of curved surfaces also influence the osmotical equilibrium, for instance, if we put a tube in a salt solution, the wall of which is easily permeable for the solvent and the dissolved body, the concentration of the latter one is always higher on the concave side of the surface, viz., in the tube (Kaufler†). Applying this theory to the organisms, the salt concentration in the cells is always higher than in the interstitial liquid, or the osmotical equilibrium for instance, between red blood cells and plasma, is not the same as it would be *ceteris paribus* in vitro with a plane separating surface.

On every surface of either liquids or solids, condensations of the neighbouring substances take place. This is called *adsorption* or *absorption.* Every absorption is dependent on the decrease of the surface tension of the absorbens by the absorbed substance (Gibbs‡).

Coal dust, powdered platinum or palladium absorb enormous quantities of gas; they also absorb dissolved bodies out of a solution. The absorbed quantity is naturally absolutely greater the larger the total absorbent surface. The importance of these facts for physiology is evident if we remember the enormous total surface the cells of the organism have, and that it is, for instance, for the total number of erythrocytes of a human being about 2800 square metres.

The eminent role of surface energies for heterogeneous systems, such as colloids, is elucidated by the fact that 1 c.c. of a substance which as a cubus has a surface of 6 square cm., if split up in particles of 0·1μ diameter would have a total surface of 60·000 square metres.§

* Appeared in the *Transvaal Medical Journal*, August, 1908.
† Kaiserl. Akad. d. Wissenschaften Wien, math. nat. klasse. *43*, 686, 1902.
‡ Transact., Connecticut Academy. *3*, 108, 343.
§ *Wolfgang Ostwald*, Zeitschrift fur Chemie und Industrie der Kolloide, *1*, 291, 1907.