

XLII.—*On a Lower Limit to the Power exerted in the Function of Parturition.*

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The dynamics of natural labour have been the field of very little successful study or investigation. The object of the present paper is to make a contribution to this subject. I purpose to show what amount of pressure per square inch is sustained by the ovum in the easiest class of natural labours, and thence to estimate the propelling power exerted in such cases.

It is well known that natural births are ever and anon occurring, in which the ovum is expelled whole, the membranes containing the liquor amnii continuing entire. Into this category many more cases would enter, were it not a generally-followed rule for the attendant to rupture the bag should it advance entire as far as the external parts. Again, as Dr POPPEL has pointed out, the attentive observer of a series of easy natural labours has no difficulty in arriving at the conclusion, that in not a few cases the same force which ruptures the bag of membranes is able to, and actually does, complete the delivery.

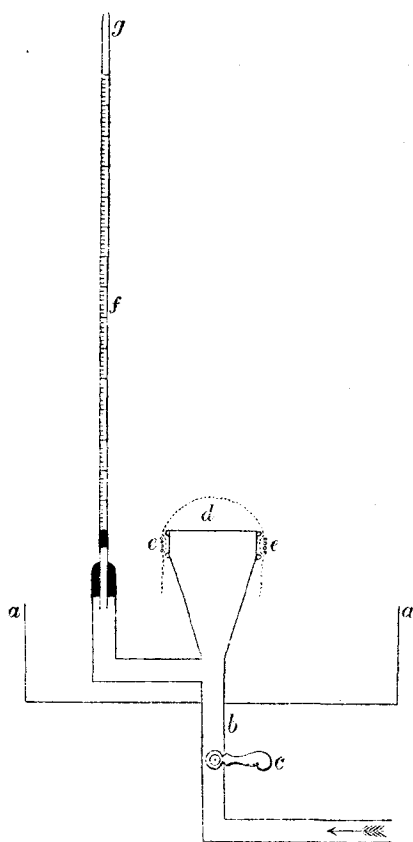
In all such cases, the strength of the membranes to resist impending rupture measures the force exerted in the process of parturition. When the bag is produced without laceration, its strength exceeds, certainly only to a small amount, the power of the labour. When the bag is ruptured at a very advanced stage of labour, as not rarely happens, its strength exceeds the power of labour exerted up till the time of its rupture. When the bag is ruptured by pains, which, without increasing in strength, rapidly and easily terminate the process, then the power of labour is probably only a little greater than the estimate, founded on the strength of the membranes, would indicate.

The strength of the membranes is thus shown to give us a means of ascertaining the power of labour in the easiest class of natural cases.

It might be suggested, that, in cases of persistent membranes, they were specially and unnaturally strong. My own experience lends no support to such a notion. Besides, so far as I know, no obstetrician has used the only means of verifying such a supposition—means such as are exemplified in the experiments to be hereafter related. Obstetricians have judged of the strength of membranes to resist a bursting force by their united thickness, or other less definite qualities, which form no criterion. It is not uncommon to read of the bag being strengthened by decidua; and that such thickening may be a source of strength is a common opinion; but as the decidua is far weaker and less extensible than the other membranes, the opinion is merely a natural delusion.

Experiments at once show that thickness of the membranes is no indication of strength. They also at once show that, for the special purposes of this paper, the amniotic membrane, being the strongest, alone requires to be observed. Long before the amnion is burst, the decidua and chorion have generally given way, and ceased to support the persistent amniotic membrane. The decidual membrane generally gives way first, under a bursting pressure applied to all three membranes. It sometimes does so with a sound as of a gentle fillip. Occasionally it bursts simultaneously with the chorion; and occasionally all three membranes burst at once. The decidua has been found, in the experiments, to burst at a tension of $\cdot 35$ lb. per linear inch, corresponding under the circumstances supposed to exist in actual labour to a forward pressure of nearly 5 lbs.

As a general statement, it may be said that the chorion behaves like the decidua. It is of more uniform strength than the decidual membrane, and is only a little stronger, the average tensile strength being $\cdot 62$ lbs. per linear inch, corresponding to a propelling power in labour of nearly 9 lbs. [In taking these averages, experiment 25 is omitted, because its exceptional value indicates almost certainly a mistake.]



The strength of the foetal membranes lies in the innermost sac, in the amniotic membrane, which appears the thinnest and most delicate of all. To try the strength of it, as well as of the others, I made numerous experiments in the following manner:—They were all performed in the laboratory, and with the apparatus, of Professor TAIT, to whose knowledge and skill I am indebted for their value and accuracy. The apparatus used was connected with a pipe in the bottom of an open cistern *aa*. Into this pipe *b* water,* under high pressure, of which there was a convenient supply, could be admitted gradually by a cock *c*. The apparatus expanded upwards from the pipe to its mouth *d*. In one apparatus used, this mouth had an external diameter of 3·35 inches, in the other it

had an external diameter of only 2·25 inches. Over the mouth of the apparatus the membranes experimented on were placed, and tied on by a waxed hempen cord, around a broad rim *ee*, immediately beneath the mouth. That the apparatus

* Water is preferable in these experiments to air, because, when it is employed, there is less violent action at the bursting of the membrane.

acted in a fair and satisfactory manner was evident, from the observation that, in almost all the trials, the membrane tested did not burst where it touched the instrument, but in an arc of a circle crossing over the bulged out membrane; or, rarely, in a starlike manner. Connected, by a hollow arm, with the apparatus was a vertical tube *g*, with scale *f* of inches and tenths of inches. This tube contained a long column of air, confined in it by a short column of mercury. The rise of the column of mercury compressing the air in the tube indicated the degree of pressure applied to the internal surface of the membrane fixed over the mouth of the conical vessel *d*. Besides my own supply, I was kindly provided with fresh membranes by Dr LINTON and Mr VACHER.

The following table gives, in a categorical form, a narration of each of 100 experiments, as well as the chief calculations founded upon the data obtained from them. The first column gives the number of the trial. The second column gives the number of the set of membranes tested; and it will be seen that generally several experiments were made with the same membranes. The third gives the length of continuance of labour till the time when the membranes were ruptured. The fourth column gives the duration of the first stage of labour. The fifth gives the duration of the second stage of labour. The sixth column contains the state of the os uteri at the time of the rupture of the membranes. The seventh states the stage of labour in which the bag of waters was broken. The eighth, ninth, and tenth columns show how many of the three membranes were tested simultaneously. The eleventh, twelfth, and thirteenth columns show what membranes gave way in each experiment. The fourteenth column states the radius of the circular mouth of the apparatus to which the membranes were tied. The fifteenth gives the barometric pressure at the time of each trial; and it will be observed that the pressure occasionally required a correction which demands explanation. The column of mercury in the apparatus was generally very short, and no correction for its weight was required, the experiments not pretending to an extreme nicety; but occasionally (in the cases noted in the column of remarks) the column of mercury was too long to be neglected, and a correction was made for its length. The sixteenth column gives the length of the column of air enclosed in the vertical tube above the mercury. The seventeenth gives the contraction of this column of air, by the pressure of water which burst the membranes, acting on the short column of mercury. The eighteenth column gives the height of the membrane as it bulged above the mouth of the apparatus, expanded by the water pressure. The nineteenth gives the effective pressure of the water, at the moment of bursting of the membrane, in inches of mercury. The twentieth gives the diameter of the sphere, of which the membrane when bursting approximately formed a portion. The twenty-first column gives the pressure per square inch of the membrane at the time of the bursting of the membrane, or at the time of the experiment's failing from some cause, such as

TABLE OF EXPERIMENTS,

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
No. of Experiment.	No. of Case.	Length of Labour till Rupture of Membrane.	Length of First Stage of Labour.	Length of Second Stage of Labour.	State of <i>Os uteri</i> at time of Rupture.	Stage in which Rupture occurred.	Membranes Tested.			Membranes Burst.			Radius of Apparatus.	Barometric Pressure.
							Amnion.	Chorion.	Decidua.	Amnion.	Chorion.	Decidua.		
		<i>h. m.</i>	<i>h. m.</i>	<i>h. m.</i>	<i>inch.</i>								<i>a</i>	<i>b</i>
1	1						x	x	x	x	x	x	1.675	29.5
2	"						x	x	x	x	x	x	"	"
3	"						x	x		x	x		"	"
4	"						x						"	"
5	2						x	x	x			x	"	"
6	"						x	x					"	"
7	"						x	x		x	x		"	"
8	"						x						"	"
9	"						x	x	x			x	"	"
10	"						x	x					"	"
11	"						x	x		x	x		"	"
12	"						x						"	"
13	3						x	x	x	x	x	x	"	"
14	"						x	x	x			x	"	"
15	"						x	x					"	"
16	"						x						"	"
17	"						x						"	"
18	"						x						"	"
19	4						x	x	x	x	x	x	"	"
20	"						x	x	x			x	"	"
21	4						x	x			x		"	"
22	"						x						"	"
23	"							x			x		"	"
24	5	28 35	28 30	0 25		2nd	x	x		x	x	x ?	"	"
25	"	"	"	"		"	x	x					"	"
26	"	"	"	"		"	x			x			"	"
27	"	"	"	"		"	x	x		x	x		"	"
28	"	"	"	"		"	x			x			"	"
29	6	6 0	4 55	1 10		2nd	x	x			x		"	"
30	"	"	"	"		"	x			x			"	"
31	"	"	"	"		"	x			x			"	"
32	7	6 0				2nd		x	x		x	x	"	"
33	"	"				"		x	x		x	x	"	"
34	8	5 20	6 25	3 15	1½	1st		x	x		x	x	"	"
35	"	"	"	"	"	"	x			x			"	"
36	"	"	"	"	"	"	x			x			"	"
37	9	7 10	7 0	1 30	"	2nd	x			x			"	"
38	10	6 15	6 5	0 20		2nd	x	x	x	x	x	x	"	"
39	11	6 15	4 10	7 15		2nd		x	x		x	x	"	29.6
40	"	"	"	"		"		x	x		x	x	"	"
41	"	"	"	"		"		x			x	x	"	"
42	12	21 0	24 0	A few minutes	2½	1st	x			x			"	29.45
43	"	"	"	"	"	"	x			x			"	"

WITH THE DEDUCTIONS THEREFROM.

16.	17.	18.	19.	20.	21.	22.	23.	REMARKS.
Length of Column of Air.	Contraction of Column of Air.	Bulge of Membrane at time of Bursting.	Effective Pressure at Bursting, in inches of Mercury.	Diameter of Sphere of Membrane at Bursting.	Pressure on Square Inch.	Pressure on a Circular Surface of 2.25 inches radius.	Tensile Strength of Membrane.	
l	λ	h	$\frac{b\lambda}{l-\lambda}$	$\frac{a^2}{h+\frac{a^2}{h}}$	$\frac{b\lambda}{l+\lambda}$	$1.78 \frac{b\lambda}{l-\lambda} \cdot \left(h + \frac{a^2}{h}\right)$	$.128 \frac{b\lambda}{l-\lambda} \cdot \left(h + \frac{a^2}{h}\right)$	
19.75	2.		3.32		1.63			
"	2.		3.32		1.63			
"	1.		1.57		.77			
"	3.25	1.5	.58	3.37	2.85	33.87	2.41	
"	.5		.766		.37			Membrane taken close to placenta.
"	1.5		2.42		1.19			Membrane slipped out.
"	.75		1.16		.57			
"	1.25		1.99		.97			Membrane slipped out.
"	1.		1.57		.77			
"	1.5		2.42		1.19			Membrane slipped out.
"	1.25		1.99		.97			
"	2.		3.32		1.63			Membrane slipped out.
20.	1.25		1.96		.96			Membrane taken close to placenta.
"	.75		1.15		.56			
"	1.2		1.88		.92			
"	.6		.912		.45			
"	.4		.602		.29			
"	.6		.912		.45			
"	1.1		1.72		.84			
"	.5		.756		.37			
"	.5		.756		.37			
"	.8		1.23		.60			
"	.2		.298		1.46			A considerable leak in the membrane.
16.5	2.5	.75	4.98	4.49	2.46	37.58	2.75	Barometer corrected by 1.6 inch.
"	2.	.75	3.78	4.49	1.85	29.36	2.09	Barometer corrected by 1.6 inch.
"	2.25	1.	4.40	3.80	2.16	28.96	2.06	Barometer corrected by 1.6 inch.
"	2.25	.9	4.40	4.02	2.16	30.76	2.17	Barometer corrected by 1.6 inch. A leak in the membrane.
16.25	2.5	1.	5.07	3.80	2.48	33.37	2.37	Barometer corrected by 1.6 inch.
"	1.5	.75	2.83	4.49	1.39	15.06	1.07	Barometer corrected by 1.6 inch.
"	1.	.75	1.83	4.49	.90	14.21	1.01	Barometer corrected by 1.6 inch.
16.5	2.25	.75	4.40	4.49	2.16	31.18	2.43	Barometer corrected by 1.6 inch.
16.4	.6	.75	1.06	4.49	.52	8.23	.58	Barometer corrected by 1.6 inch. Birth 30 min. after rupture.
16.3	.5	1.	.882	3.80	.43	5.81	.41	Barometer corrected by 1.6 inch.
16.5	.4	.75	.693	4.49	.34	5.38	.38	Barometer corrected by 1.6 inch.
"	.9	1	1.61	3.80	.79	10.60	.75	Barometer corrected by 1.6 inch.
"	.9	1.25	1.61	3.49	.79	9.73	.69	Barometer corrected by 1.6 inch.
16.2	.6	1.	1.07	3.80	.52	7.04	.50	Barometer corrected by 1.6 inch.
"	.3	.75	.526	4.49	.26	4.08	.29	Barometer corrected by 1.6 inch.
20.	.75	.75	1.15	4.49	.56	8.93	.63	
"	.75	.75	1.15	4.49	.56	8.93	.63	
"	.4	.25	.604	11.47	.30	11.99	.85	
20.5	1.8	1.	2.83	3.80	1.39	18.63	1.32	
"	.9	.75	1.35	4.49	.66	10.48	.74	

TABLE OF EXPERIMENTS,

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
44	"	"	"	"	"	"	x			x			"	"
45	13	13 0	12 45	0 45	"	2nd		x	x			x	"	"
46	"	"	"	"	"	"		x			x		"	"
47	14	11 0	10 15	0 30?	"	2nd	x			x			"	"
48	"	"	"	"	"	"	x						"	"
49	"	"	"	"	"	"	x			x			"	"
50	"	"	"	"	"	"	x			x			"	"
51	"	"	"	"	"	"	x						"	"
52	"	"	"	"	"	"	x						"	"
53	15			7 30	"	1st	x	x					"	28.8
54	"			"	"	"	x	x			x		"	"
55	"			"	"	"	x						"	"
56	"			"	"	"	x			x			"	"
57	16	6 30		"	"	2nd	x			x			"	29.0
58	"	"		"	"	"	x			x			"	"
59	17	3 30	9 30	1 0	$\frac{1}{2}$	1st	x			x			"	"
60	"	"	"	"	"	"		x	x		x	x	"	"
61	18			"	"	"	x						"	"
62	"			"	"	"	x			x			"	"
63	"			"	"	"	x			x			"	"
64	19		6 0	1 0	"	2nd	x			x			"	29.2
65	"		"	"	"	"	x			x			"	"
66	"		"	"	"	"	x			x			1.125	"
67	"		"	"	"	"	x			x			"	"
68	"		"	"	"	"	x						"	"
69	"		"	"	"	"	x			x			"	"
70	"		"	"	"	"	x			x			"	"
71	"		"	"	"	"	x			x			"	"
72	"		"	"	"	"		x	x		x	x	"	"
73	20	9 15	8 20	0 55	"	3rd		x	x		x	x	"	"
74	21		9 0	3 0	"	"	x			x			"	"
75	"		"	"	"	"	x			x			"	"
76	22	1 30	2 0	1 0	"	2nd	x			x			"	29.8
77	"	"	"	"	"	"	x			x			"	"
78	"	"	"	"	"	"	x			x			"	"
79	"	"	"	"	"	"	x			x			"	"
80	23		Long	1 0	"	"	x			x			"	"
81	"		"	"	"	"	x			x			"	"
82	"		"	"	"	"	x			x			"	"
83	"		"	"	"	"	x			x			1.675	"
84	24	32 30	30 0	4 0	"	2nd	x			x			1.125	"
85	"	"	"	"	"	"	x			x			"	"
86	"	"	"	"	"	"	x			x			"	"
87	"	"	"	"	"	"	x			x			"	"
88	"	"	"	"	"	"	x			x			1.675	"
89	25		"	"	"	"	x	x		x	x		1.125	29.84
90	"			"	"	"	x	x		x			"	"
91	"			"	"	"		x			x		"	"
92	"			"	"	"	x			x			"	"
93	"			"	"	"	x			x			1.675	"
94	"			"	"	"	x			x			"	"
95	"			"	"	"	x			x			"	"
96	"			"	"	"	x						"	"
97	"			"	"	"	x			x			"	"
98	26	10 10	8 30	2 0	"	2nd	x			x			1.125	"
99	"	"	"	"	"	"	x			x			"	"
100	"	"	"	"	"	"	x			x			"	"

WITH THE DEDUCTIONS THEREFROM—*continued.*

16.	17.	18.	19.	20.	21.	22.	23.	
..	1.3	.8	1.99	4.31	.97	14.83	1.05	
..	.5	1.	.736	3.80	.36	4.84	.35	
..	.45		.661		.32			
..	.7	1.	1.04	3.80	.56	6.85	.49	
..	.8	1.5	1.19	3.37	.58	6.94	.49	Membrane slipped out.
..	2.	2.	3.18	3.40	1.56	18.72	1.33	
20.75	1.5	1.5	3.29	3.37	1.12	13.35	.95	
20.5	1.5	1.5	2.32	3.37	1.14	13.52	.96	Membrane slipped out.
..	2.	2.	3.18	3.40	1.56	18.72	1.33	Membrane slipped out.
21.	1.5	1.	2.21	3.80	1.08	14.55	1.03	Membrane found to have been injured.
..	1.25	1.	1.82	3.80	.89	11.98	.85	
..	2.25	2.	3.45	3.40	1.69	20.31	1.44	
..	1.25	1.	1.82	3.80	.89	11.98	.85	
..	2.7	1.1	4.28	3.65	2.10	27.03	1.92	Child born 30 minutes after rupture.
..	2.5	1.	3.92	3.80	1.92	25.80	1.83	
21.2	.5	.5	.700	6.11	.34	7.40	.53	
..	.3	.5	.416	6.11	2.04	4.40	.31	
20.4	1.1	.8	1.65	4.31	.81	12.29	.87	Membrane slipped out.
..	1.25	1.	1.89	3.80	.93	12.44	.88	
20.5	2.3	1.5	3.66	3.37	1.79	21.34	1.52	
19.4	1.5	1.	2.45	3.80	1.20	16.13	1.15	
..	1.6	1.5	2.62	3.37	1.28	15.27	1.09	
22.3	2.	.75	2.87	2.44	1.41	12.10	.86	
..	1.7	.5	2.41	3.03	1.18	12.64	.90	An ill-conducted experiment.
..	2.3	1.1	3.36	2.25	1.65	13.08	.93	
..	1.9	.75	2.72	2.44	1.33	15.68	1.11	
..	2.5	.75	3.69	2.44	1.81	15.56	1.11	Burst by air contained between the membrane and water.
..	1.7	.55	2.41	2.85	1.18	11.88	.84	Burst by air contained between the membrane and water.
..	.9	.5	1.23	3.03	.60	6.45	.46	
..	1.2	.6	1.66	2.71	.81	7.78	.51	Membranes not ruptured till after birth of head.
22.2	1.2	.6	1.67	2.71	.82	7.83	.56	Membranes ruptured with first pain of labour.
..	1.7	.8	2.42	2.38	1.19	9.97	.71	
22.	2.	.5	2.98	3.03	1.46	15.62	1.11	A large leak in the membrane.
..	2.4	.65	3.65	2.60	1.79	16.40	1.17	A small leak in the membrane.
..	3.2	.75	5.07	2.44	2.48	21.37	1.52	
..	2.85	.6	4.43	2.71	2.17	20.76	1.48	
..	2.3	.7	3.48	2.61	1.70	15.10	1.07	
20.	1.8	.6	2.91	2.71	1.43	13.64	.97	
..	2.1	.5	3.49	3.03	1.71	18.30	1.31	A small leak in the membrane.
19.3	1.5	1.05	2.51	3.72	1.23	16.16	1.15	
19.8	1.	.6	1.58	2.71	.77	7.40	.53	Membranes ruptured in labour by attendant.
19.5	1.4	.7	2.30	2.51	1.13	9.98	.71	Membranes ruptured in labour by attendant.
..	1.7	.75	2.84	2.44	1.39	11.97	.85	Membranes ruptured in labour by attendant.
..	.9	.55	1.44	2.85	.71	7.10	.50	Membranes ruptured in labour by attendant.
19.3	1.4	.85	2.33	4.15	1.14	16.73	1.19	Membranes ruptured in labour by attendant.
22.	3.4	.65	5.36	2.60	2.63	24.08	1.71	Barometer corrected by .5 inch.
..	3.6	.8	5.74	2.38	2.81	23.65	1.68	Barometer corrected by .5 inch.
..	1.8	.9	2.61	2.31	1.28	10.41	.74	Barometer corrected by .5 inch.
..	3.9	.75	6.32	2.44	3.10	26.64	1.89	Barometer corrected by .5 inch.
19.2	1.25	.8	2.08	4.31	1.02	15.50	1.10	A leak in the membrane.
19.	1.3	.8	2.19	4.31	1.07	16.32	1.16	
..	1.45	.85	2.46	4.15	1.20	17.66	1.26	
..	2.	1.5	3.51	3.37	1.72	20.46	1.45	Membrane slipped out.
..	1.7	1.	2.93	3.80	1.44	19.29	1.37	Same piece as used in last experiment.
22.	1.5	.6	2.15	2.71	1.05	10.07	.72	Barometer corrected by .5 inch.
..	1.6	.7	2.30	2.51	1.13	9.98	.71	Barometer corrected by .5 inch.
..	1.8	.6	2.61	2.71	1.28	12.23	.87	Barometer corrected by .5 inch.

the slipping of the membrane. The twenty-second column gives the pressure on a circular surface of 2·25 inches radius, or equal to the assumed dimensions of the lumen of the passage through which the child is expelled. The twenty-third column gives the tensile strength of the membrane, or, in other words, the weight which a band of it, an inch broad, would bear without giving way.

Professor TAIT has supplied the following formulæ from which the columns of the tables are computed:—

Let b be the height of the barometer, corrected for the short column of mercury in the gauge;

l the length of the air-column before pressure is applied;

λ the contraction of the column, when the membrane bursts.

Then, since the weight of a cubic inch of mercury, at ordinary temperatures, is about 0·49 lbs., we have, for the difference of pressures on opposite sides of the membrane when it bursts, the expression

$$p = 0\cdot49\ b \left(\frac{l}{l-\lambda} - 1 \right) = 0\cdot49\ \frac{b\lambda}{l-\lambda}, \quad (1)$$

in pounds per square inch. No sensible correction is required for the length of the water-column, when the mercury in the gauge and the membrane were not exactly at the same level.

If T be the force in pounds weight which will just snap a band of the membrane an inch broad, ρ the radius of curvature when the membrane bursts, we have, by a known theorem, the membrane being supposed to form approximately a portion of a sphere,

$$\frac{2T}{\rho} = p \quad (2).$$

To find ρ , we remark that the external semidiameter of the apparatus a is the radius of the base of a spherical segment, whose height h is measured; and geometry gives at once the equation

$$2\rho = h + \frac{a^2}{h} \quad (3).$$

Hence, the tensile strength of the membrane is

$$T = 0\cdot123\ \frac{b\lambda}{l-\lambda} \left(h + \frac{a^2}{h} \right) \quad (4).$$

If we assume that the membrane is usually burst, by natural processes, when a portion of it forms a hemisphere of 2·25 inches radius, the requisite pressure in pounds per square inch will be, by (2) and (4)

$$\frac{0\cdot245}{2\cdot25} \frac{b\lambda}{l-\lambda} \left(h + \frac{a^2}{h} \right) \quad (5).$$

and the effective pressure, on a circular surface of 2·25 inches radius, will then be

$$\pi (2\cdot25)^2 \frac{0\cdot245}{2\cdot25} \frac{b\lambda}{l-\lambda} \left(h + \frac{a^2}{h} \right) = 1\cdot73\ \frac{b\lambda}{l-\lambda} \left(h + \frac{a^2}{h} \right) \quad (6).$$

In making such experiments, a small given error in the estimate of the depth of the approximately spherical segment will be of least consequence, when the membrane bursts in a nearly hemispherical form, for by (3)

$$2\delta g = \delta h \left(1 - \frac{a^2}{h^2}\right)$$

and the error in the estimated radius vanishes, if $h = a$. Hence, also, the assumption that, in nature, the rupture takes place when the protruded portion of the membrane is hemispherical, gives a *minimum* value of the whole extruding force.

For the purposes of this paper the greatest value of the Table lies in the twenty-second column, which gives the power of the labour at the time of the rupture of the membranes and evacuation of the liquor amnii, on the supposition that the lumen of the passage opened up was circular, and of $4\frac{1}{2}$ inches in diameter, and that the bulge was hemispherical at bursting. The first striking observation to be made, is the great variation in the strength of the bag of membranes. The force required to rupture the weakest amnion showed that the power of the labour was at least 4.08 lbs.; that for the strongest, a power of 37.58 lbs.; and the average power indicated by the experiments on the amnion, was 16.73 lbs. The average tensile strength was 1.19 lbs. Next, it is to be remarked, that in the cases whose membranes were tried, the power of labour almost certainly exceeded the power required to burst the bag, for it is not probable that a particularly weak small portion, unlike the rest of the membrane, was ruptured in the labours.

In cases 5, 6, 10, 14, 16, 26, the labour did not last above half an hour after the rupture of the membranes; and the greatest power indicated experimentally by rupturing the membranes was in each case respectively 37.58 lbs., 31.18, 4.08, 18.72, 27.03, 12.23.

In case 22, it was particularly observed by me that, so far as I could judge,* the pain rupturing the bag was stronger than any that followed; it may therefore be supposed, that the power terminating labour little exceeded 21.37 lbs., the greatest power indicated by the experiments as rupturing the membranes.

It was only after conceiving the means above described for arriving at the conclusions of this paper, and after the plan of the apparatus had been made by Professor TAIT, that I fell in with an interesting and valuable paper by Dr J. POPPEL of Munich—"Ueber die Resistenz der Eihäute, ein Beitrag zur Mechanik

* The same contractile force of the uterus at different periods of labour, or, to be more exact, at different dimensions of the uterus, will produce greater internal pressure, and, consequently, greater expulsive force, as the uterus is smaller (*vide* equation (2), p. 646); and, the amount of muscular contraction being supposed to be the same, there may be no sign to the attendant or patient of the increase of power. On the other hand, the application of the same principle shows, that, when the curvature of the extruded portion of the membranes is greatest, the difficulty of rupturing them is also greatest. This occurs when the extruded portion is hemispherical; and it is on this supposition that the numbers in column 22 are calculated.

der Geburt," contained in the first part of the twenty-second volume of the "Monatsschrift für Geburtskunde" for 1863. This paper anticipates to a very great degree the plans and results here related. But it may be pointed out that Dr POPPEL has neglected to note some conditions of the experiment, which cannot be omitted without damaging materially the accuracy and value of the trials; especially, he has always supposed the membrane to burst when in a hemispherical form, which is certainly an error, and one whose tendency is always to make the strength of the membrane too little (*vide* equation (2)). He has attached some weight to the part of the amnion tested, considering that greater strength would accompany proximity to the placenta; but my experiments did not confirm this opinion.

Dr POPPEL's apparatus may be sufficiently, though not fully, described as follows:—The membrane to be tried he ingeniously fixed over one or other of two glass vessels, of the diameter of five centimetres or two inches, and of ten centimetres or four inches, respectively. The glass vessels were reagent glasses, from which the bottoms were taken off. The affixed membranes represented the bottoms of the reagent glasses. Into the corks of the glasses a long glass tube was passed. Through this tube mercury was poured into the bottle till it filled it, and mounted into the tube. Its height in the tube at the time of the bursting of the membranes was carefully noted, because from it was estimated the pressure that burst the membrane. In adding the mercury fitfully, Dr POPPEL erroneously supposed that he imitated the pains of labour, a point, it appears to me, of no importance; and besides, his idea was manifestly erroneous, for each succeeding pain is not an addition to a force previously in action—it may even be weaker than its predecessor. In every natural case it is an entirely new force, rising in strength from zero to its acme, and again gradually fading to zero. Dr POPPEL made allowance for the weight of mercury contained in the reagent glass, over and above what was in the vertical glass-tube; but he neglected the important element of the degree of bulging of the membrane or radius of its curvature at time of bursting, with a view to arriving at the diameter of the globe, of which it formed a section at the time of rupture. With this he connects also a statement, that the bulging of the membranes through the mouth of the womb rarely exceeds a hemispherical form, which, though perhaps nearly true, is misleading, if held to be true in regard to the class of cases of persistent membranes specially studied in this paper.

The average strength of the amnion found by POPPEL was, keeping an aperture of 2.25 inches in radius in view, 19.21 lbs.; in my experiments it was 16.73 lbs.

POPPEL experimented on the membranes in seven cases in which they burst "with the birth." The following table gives the strength of the membranes in these cases, according to POPPEL's method of calculating, and the same changed

into lbs., as well as increased proportionally from what appertains to a radius of 5 centimetres to what appertains to a radius of $2\frac{1}{4}$ inches, the dimensions used in our experiments:—

No.	Belastung bei 10 Centimeter Durchmesser Kilogramm.	Pressure for Diameter of 2.25 inches in lbs.
	Kilogrammes.	lbs.
1	9.876	27.232
3	2.346	6.469
12	2.134	5.884
13	7.608	20.979
22	4.709	12.985
23	9.461	26.088
28	7.001	19.305

This table gives us, in seven cases, a figure of strength nearly equalling the whole power of labour in these cases. If, in any of the cases, the membranes had persisted after the birth, then the figure in the last column would have certainly exceeded the whole propelling power of labour at any moment during the whole of the labour. Speaking of them, POPPEL remarks, that “if we reflect that the table expresses only the minimum of power for the easiest labours, the figures appear to be quite trustworthy, even though they exhibit great variations. It may therefore be assumed that in a very easy labour a power, varying from 4 to 19 lbs., presses the head through the pelvis.” As Dr POPPEL gives the passage transmitting the head a diameter of 4 inches, and as I prefer regarding it as nearer $4\frac{1}{2}$, so I, using meantime POPPEL’s experiments and calculations, make the power exerted in an easy labour vary from about 6 lbs. to about 27 lbs., instead of from 4 to 19. I shall not meantime attempt to show whether POPPEL’s assumed 4-inch diameter or my assumed $4\frac{1}{2}$ -inch diameter is the more likely to be nearest the truth, because it would lead me into a class of questions remote from the subject matter of this paper.

If we observe, that in POPPEL’s table of experiments and in mine the power shown to be sufficient to terminate an easy labour was often far exceeded in the course of other labours, we may enunciate the almost certain conclusion that a great mass of easy, and not merely of the easiest, labours is terminated by a power little in excess of that required to rupture the bag of membranes. The strongest membrane found in the experiments indicated, by the pressure required to burst it, an extruding force of $37\frac{1}{2}$ lbs. We may therefore, I think, safely venture to assert as a highly probable conclusion, that the great majority of labours are completed by a propelling force not exceeding 40 lbs.

If we regard the figure of 4 lbs. given by POPPEL as equal to the power exerted in the easiest labour he has observed, or the corresponding figure of 6 lbs. according to my calculations, and keep in mind that the average weight of the

adult foetus exceeds either of these weights, we are led to the conclusion that in the easiest labours almost no resistance is encountered by the child; that it glides into the world propelled by the smallest force capable of doing so; that, with the mother in a favourable position, the weight of the child is enough to bring it into the world—a result which many clinical facts at least appear to confirm.

Having thus given POPPEL'S and my own estimate of the force exerted in natural parturition of the easiest kind, I can at present offer nothing positive from which to calculate the strength of labour in the general run of cases. My belief is that in ordinary labours the power exerted is not in general much above the lower limit; but other accoucheurs may see reason to entertain different opinions.

The higher limit of the power exerted in natural parturition has been variously estimated. There is an easy and obvious method of arriving at it. Cases are frequently occurring in which labour is artificially terminated by forceps, in circumstances which leave no doubt that, under delay, they would have come with difficulty to a spontaneous conclusion. The power exerted by the forceps in such cases can be measured. Such measurements are not to be at once taken as the power of labour necessary to finish such cases; but when all of the various sources of error are considered and included, they are of much value. The chief of such sources of error are the neglect of the assistance that may be afforded to the operator by the natural expulsive efforts, and the including of such forces exerted by the forceps as may be unnecessary for carrying on the process; for example, prematurely applied force, or force applied so as to advance the birth too hastily, or force lost by being used in a wrong direction. For the making of observations of this kind by the forceps special instruments have been invented by KRISTELLER and JOULIN.

But forceps-cases do not afford the only evidence available as to the higher limit. Experiments can be made on the dead subject which can be very well relied upon, as reproducing correctly the difficulty encountered in the living, and the power required to overcome it. Such experiments have been made by JOULIN,* and when suitably arranged, give us the power exerted in cases which may be spontaneously terminated by the most powerful parturient efforts; and, it may be added, with great risk of the mother's life.

Speaking of these experiments, JOULIN makes the following remarks:†—“Spontaneous delivery has been sometimes observed in circumstances almost identical. It appears to me, therefore, possible to admit that the figure of 50 kilogrammes (about a hundredweight) of force represents very nearly the maxi-

* *Mémoires de l'Académie Impériale de Médecine*. Tome xxvii. p. 90, &c. See also his *Mémoire sur l'emploi de la Force in Obstétrique*. *Archives générales de Médecine*: numéros Février et Mars 1867.

† *Traité complet d'Accouchements*, p. 477.

num of the contractile power of the uterus; for it is necessary to take into account the accessory contingent furnished by the abdominal muscles, which in these instances was wanting. But as this force has not a direct action, it is probable that its actual product scarcely rises above a few kilogrammes."

Having had extensive and varied experience in the use of the forceps in difficult labours, and having also made some rough experiments with the dynamometer, to ascertain the power I have applied by the instrument, I regard M. JOULIN'S estimate of a hundredweight as the maximum force of the parturient function as far too high. I do not deny that, in very rare cases, such a force may possibly be produced; but I am sure that it is nearer the truth to estimate the maximum expulsive power of labour (including, with the uterine contractions, the assistant expulsive efforts) as not exceeding 80 lbs.

At present, I can divine no method of arriving at an estimate of the expulsive power of ordinary labours, except the following; and I must guard myself from being supposed to recommend its use, in the meantime at least. A fine tube, filled with water and of resisting material, may be introduced into the small pool of liquor amnii which remains after the rupture of the membranes filling up the spaces otherwise vacant on the anterior aspect of the foetus. This tube should be provided with an aperture at its uterine end; it should be curved, so that when introduced it may lie easily in the pelvis, occupying the least possible space, so that no unnecessary resistance be offered to the advance of the foetus; its wall should taper to either side, a cross section of it having a long pointed fusiform outline, in order that its presence may not produce on either side of it a channel for the running off of the pool of liquor amnii; lastly, its external end should be in communication with a column of mercury in a vertical tube, enclosing a column of air under only ordinary barometrical pressure. During the pains the rise of the mercury in the tube may be measured, and calculations from these measurements might be made identical with those already given in an earlier part of this paper. By this means, if successfully applied, the force of any labour may be exactly known. And it is scarcely necessary even to suggest how immeasurably valuable to the accoucheur such an estimate would be, substituting, as it would, an experimentally accurate statement of awful importance for the vague notions at present relied on, even when the wisest and most experienced practitioner lends his counsel.

I have already expressed my opinion as to the great practical importance of the inquiry entered upon in this paper. Although it is, as yet, far from completed, there is enough demonstrated to enable Dr SLOP, if he have an opportunity, to cast ridicule on the father of Tristram Shandy, who, founding on the statements of LITHOPÆDUS SENONENSIS, asserts, that the force of a woman's efforts is, in strong labour-pains, equal, upon an average, to the weight of 470 lbs. avoirdupois, acting perpendicularly upon the head of the child !!