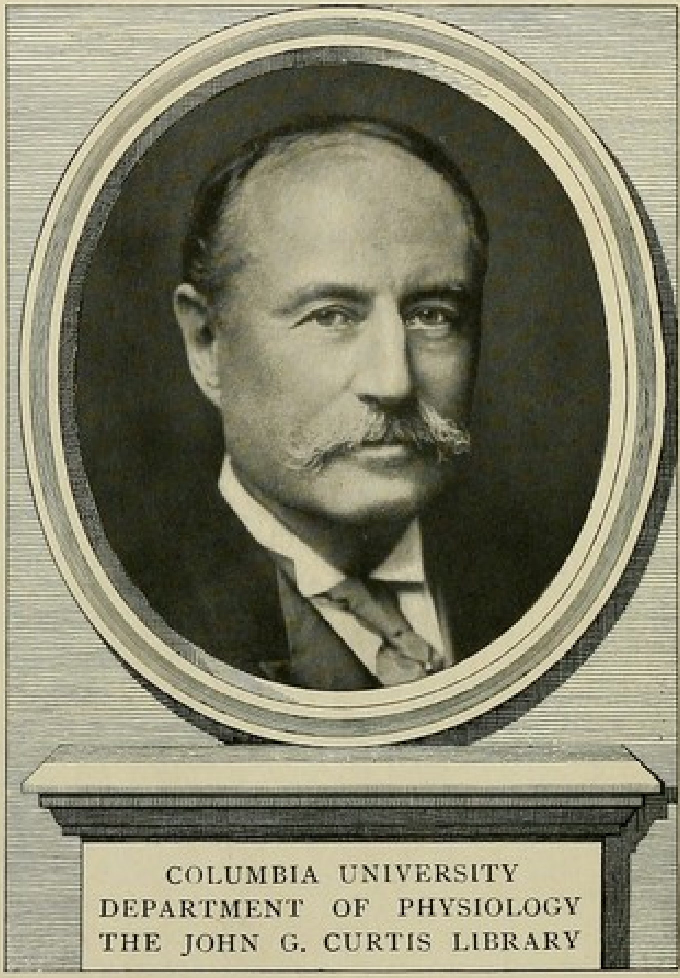
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ON THE RESPIRATORY CHANGES OF THE INTRA-THORACIC PRESSURE, MEASURED IN THE MEDIASTINUM POSTERIOR. By Dr S. J. MELTZER, *New York*. (Plates VIII. A and VIII. B.).

From the Physiological Laboratory of the College of Physicians and Surgeons of the City of New York.

It is a well-known pathological fact that tuberculosis shows a decided preference for the apices of the lungs. This was often explained by the assumption that the apex is not participating fully in the respiratory movements, and that the diminished ventilation of the said locality is the cause of its predisposition for the disease. But as it is now an established teaching that an invasion of tubercle bacilli in the lungs is at the bottom of the disease, we should rather expect, that if the apex breathes less, the bacilli will have less chances of getting in there, and in consequence this part of the lungs, instead of being predisposed for the disease, should rather show a certain immunity against it. To overcome this obstacle A. Hanau[1] undertook to modify the hypothesis, by assuming that the expiration is indeed less, whereas the inspiration is rather better in the apex than in the other parts of the lungs, therefore all corpuscular elements of microscopical dimensions, like the bacilli, dust etc., have a greater chance to get in the alveoli of the apex, while their chances to get out of these by the expiration is reduced. This hypothesis would cover indeed the pathological phenomenon satisfactorily. Unfortunately for this hypothesis, the normal breathing also has to be taken in consideration. What would be the fate of the apex, if the inspiration should considerably overbalance the expiration, if more air should get into the alveoli than could come out ?

Instead of speculating upon the normal status from pathological facts, we should endeavour firstly to study the normal process in due

[1] A. Hanau. *Zeitschrift für klinische Medizin.* Bd. XII.

manner by physiological methods. It is a matter pertaining to physiology to decide, if in normal breathing all parts of the lungs are equally sharing in the respiratory act. But there, in physiology, the point in question is even not raised to the rank of a problem. I failed to find in physiological literature, even a serious discussion of our question. In the face of the decided predilections, however, shown by certain parts of the lungs to certain pathological processes (Tuberculosis, Pneumoconiosis, Emphysema, etc.) physiology cannot afford to ignore this problem, or to solve it with mere theoretical speculations like the application of the physical laws of elasticity on the lungs, i.e. that an elastic band shows equal distensions in all its parts[1].

As it is very difficult to find an exact method to ascertain directly the degree of the distensions of the apex, as compared with those of the other parts of the lungs during normal breathing, I turned my attention firstly to a phenomenon steadily accompanying those distensions; it is the change of the intrathoracic pressure coinciding with the inspiration and expiration. There are at present three different methods for determining the intrathoracic pressure. The first, and oldest method, and as it was shown by Heynsius[2], probably the most reliable one, is that which was introduced by Donders[3] and Hutchinson[4]: to connect a manometer with the trachea of a dead animal and to open both the pleuræ. We could of course not employ this method, which informs us only of the sum of negative pressure prevailing in the whole pleural cavity while the respiratory muscles are entirely at rest. Another method which seemed to be more appropriate for our purpose, is to connect a manometer carefully direct with the pleural cavity as it was practised by Fredericq[5], Bernstein[6], Weil[7] and others. For my purpose, I should have to connect two manometers at different levels of the chest wall of a living animal. I have tried it; but soon convinced myself that, just as Heynsius supposed it to be, we never get by this method the exact intrathoracic pressure as it prevails in a normal condition. By removing carefully all the muscular tissue in one or two intercostal spaces, I could observe through intact pleura the motions of

[1] See I. Rosenthal. *Hermann's Handbuch d. Physiologie.* Bd. IV. 2 Theil, S. 180.

[2] A. Heynsius. "Ueber die grösse der negativen Drucke im Thorax beim ruhigem Athmen." *Pflüger's Archiv für Physiologie.* Bd. XXIX. 1882.

[3] *Zeitschrift für rat. Medicin.* Bd. III.

[4] Hutchinson in Todd's *Encyclopaedia of Anatomy and Physiology.*

[5] Fredericq. *Archiv de Biologie.* 1882.

[6] Bernstein, Jul. *Pflüger's Archiv.* Bd. XXVIII.

[7] Weil. *Archiv für klinische Medicin.* Bd. XXVIII.

the lungs, and thus could control the state of the lungs. In this way I found out that every attempt of mine to connect the pleural cavity with a manometer was met with some degree of retraction of the lung, which if not for the direct observation, does not manifest itself otherwise.

The third method, which was introduced by Luciani[1] and I. Rosenthal[2], and which seemed to be indeed the most appropriate for my purpose, is to measure the intrathoracic pressure in the thoracic part of the œsophagus. This can be done in a living animal without further preparation, by introducing a tube (katheter) through the mouth into the œsophagus. The tube has to be of some thickness to fill out the lumen of the œsophagus, but then on one hand it interferes with the breathing, and on the other hand it makes the œsophagus contract, which of course alters the pressure within it. I therefore made an incision in the œsophagus, pushed in through the opening a small katheter, and tied the œsophagus and katheter with a rubber thread, so as to have the œsophagus air-tight around the katheter and at the same time to be still able to push the katheter up and down within the œsophagus. This was done in three rabbits. I shall briefly state that I could not discover any constant difference in the negative pressure between the upper and lower parts of the œsophagus. At the same time these few experiments were sufficient to convince me of the correctness of the statement made by Heynsius[3], that the pressure within the œsophagus does not correspond to the exact pressure of the pleural cavity, the pressure in the œsophagus being, as it was proven by Heynsius, not only considerably less, but also inconstant, and consequently unappropriate to throw light on our subject. The thickness of the œsophagus wall, the muscular tissue and its irregular contraction provoked by the presence of a foreign body (katheter) are probably the cause, as Heynsius points out, of the reduction of the pressure and its irregularity. I may add, that every act of deglutition, which occurs quite often on account of the moving of the katheter, changes the pressure within the œsophagus considerably, the change lasting for some time.

Looking out for a new method by which I could compare the intrathoracic pressure at different levels of the thorax, my attention was turned to the mediastinum posterior, just by the last-mentioned experiments made on the œsophagus. The only objectionable features

[1] Luciani. *Archivi per le scienze medichi.* 1878.

[2] Rosenthal I. *du Bois Reymond's Archiv.* 1882.

[3] *loc. cit.*

of this locality were, as we just pointed out, the effects resulting from the thickness of the œsophagus wall and its muscular tissue. Now if we could determine the pressure alongside of the œsophagus, but outside of it, i.e. in the mediastinum posterior, there will be, we should expect, no more objections to the conclusions drawn from the results obtained in this locality as to the real state of the pressure in the pleural cavity, as the thin layer of tissue separating the mediastinum from the pleural cavity could not amount to much. The same consideration gave me at the same time an idea how to gain access to the mediastinum: alongside the œsophagus which is surrounded on its entire way by loose connective tissue; this is a convenient path, unfortunately very often preferred by the pus of retropharyngeal abscesses—why should we meet with difficulty by pushing a katheter down the same way?

It is this method and some results I obtained by it I intend to report here.

With a single exception my experiments were made on rabbits, the results therefore are so far restricted to this class of animals only. The single experiment I made on a young dog, however, convinced me that the method will be practicable in these animals also, and that the results will probably not differ materially. All the animals have been narcotized with chloral. This offers the advantage that the breathing continues regularly and is less frequent. I wish to emphasize, however, that the introduction of the katheter into the mediastinum does not alter the respiration even in the absence of narcosis. The procedure is simple, though I lost many an experiment before settling it.

The rabbit being placed on its back, the skin of the neck was cut lengthwise on the larynx, and opposite the crico-thyroideal ligament, a path was bored with a blunt instrument on the left sterno-hyoideal muscle to its outer margin, and here a narrow entrance was bored behind the lower part of the pharynx. Into this opening a katheter was introduced and pushed downward parallel and behind the œsophagus. Three centimeters, counted from the mentioned ligament, may be pushed down at once, as at this distance the blind end of the katheter is even in small rabbits still above the aperture of the chest. All further pushing has to be done carefully, groping, and in small distances, about five millimeters each. The direction should be towards the middle of the aperture, the katheter can be felt through the skin behind the trachea, and it is advisable, while pushing the katheter with one hand, to control the lower end with two fingers just above the aperture in order to keep in the right direction, and at the same time to press the end a little backward to facilitate its entrance into the mediastinum posterior, as there is a tendency for the lower end of the katheter, while entering the thorax, to stumble against the incisura sterni, on account of the convexity of the spinal column in this region. In fact, the entrance of the katheter into the chest is the main difficulty, in older animals more so than in younger ones, not only for the reason of the greater curvature of the spinal column, but also on account of the greater firmness of the connective tissue obstructing the entrance of the chest. Drawing back the katheter should be avoided, as this might, as it would be seen later, destroy the entire experiment. Elevating the outer end of the katheter, which would facilitate its entrance into the chest, should also be avoided, as this makes the channel leading to the mediastinum too wide and facilitates the entrance of air beside the katheter. This latter should be of a very small calibre; with an English katheter No. 5 (lumen about two millimeters) I never found an insurmountable obstacle in pushing it in. The katheter is blind at the end, and has one side opening near it; I made another opening opposite the first one. The lower half of the katheter was divided by marks (small cuts) in 5 millimeters distances. The amount of pressure in the mediastinum was ascertained by connecting the katheter either with a water manometer, or with a Marey's tambour. In the latter case the respiratory undulations of the mediastinum have been recorded graphically in the usual manner, on a revolving cylinder covered with smoked paper. Below the lever writing these undulations another lever was placed marking the time in seconds. The distance between the two lines traced upon the graphic table before connecting the tambour with the mediastinum, represents the atmospheric pressure; a smaller distance means a negative, a greater distance positive pressure. The manometer, or the Marey's tambour, was connected with the katheter by means of rubber tubing, which had to be long enough to facilitate the handling of the katheter. The connection was made of course before the katheter was introduced behind the pharynx; there was no clamp or stopcock between the katheter and the manometer. Before the katheter entered into the chest, there was usually no difference in the level of the water in the two sides of the manometer, but if there was any difference, it was of course taken into account. The pushing was done, as stated, in 5 millimeters distances. At each step notes of the pressure were taken as it presented itself during the inspiration and expiration, the time of observation being from 5—6 minutes. There was hardly any necessity for taking the mean of a number of observations, as at each step hardly a difference of any account between the inspirations could be noticed. At each step, besides the pressure, the number of respirations was counted. After finishing the experiment, and killing the rabbit, I made in many experiments an autopsy to ascertain the side where the katheter found its way, and some of the localities in the mediastinum corresponding to the different distances from the crico-thyroideal ligaments as they were furnished by the preceding experiment.

Passing over to the results obtained by this method, I shall say in the beginning, that we have to distinguish between the first introduction on the one hand, and the retraction and all the following reintroductions on the other hand. While in the latter cases there were hardly any constant differences among the several parts of the mediastinum, the pressure being about the same in the entire length of it, we found in all the first introductions of the katheter, the pressure differing remarkably according to the locality of the mediastinum, which latter may therefore be divided into five sections. The first section comprises the part of the mediastinum within the first ribs and first intercostal spaces; there in most of the cases, during the inspiration, either we found no change in the pressure at all, or the change was so small that it could not be measured. In a few cases the inspiratory difference in the pressure amounted to from 2—3 millimeters of water, and only in two cases the change came up to 6 or 8 millimeters of water. Nearly the same can be stated of the condition of the pressure during the expiration—"Donders' negative pressure." In most cases there was no negative pressure, at least it was hardly perceptible, but in a few cases the negative pressure was measurable, and reached in a couple of experiments from 14 to 16 millimeters! On the other hand, there were a few other cases showing at the expiration a positive pressure of from 2 to 3 millimeters. Then a section of 2—4 centimeters length follows, where the inspiratory changes are generally larger than in the first section. In many cases a gradual increase in the amount of the inspiratory change of the pressure could be observed taking place downward, the highest amount observed being 16 millimeters; but this was by no means the rule; there have been cases where the amount of the change in a deeper place was even smaller than in a higher one. The expiratory pressure in this section is in nearly all of the cases of a negative character, the amount being generally also larger than in the former section, but it exceeded only in exceptional cases the pressure of 10 millimeters water; a gradual increase was here the exception.

In 30 % of all the cases, a section of from 1—2 centimeters length now followed, wherein again no movements at all or very small movements could be observed in the manometer during the inspirations, though sometimes the heart-beat could be recognized. The level of the water on both sides of the manometer has been, while in this section, either equal or there has been a very small difference in favour of the negative pressure; in other words, while the inspiration did not show any influence there has been little or none at all of Donders' negative pressure.

The section which follows now comprises nearly the whole remainder of the mediastinum. In all the animals experimented upon a remarkable turn took place at this section. The inspiratory change of the pressure became considerably larger, and continued to be the same with comparatively small variations in the whole section. The exact amount of the inspiratory change varied considerably in different animals, as much as from 15 to 60 millimeters of water. There seemed to be a number of points causing the difference in the amount of the undulations, for instance, the size and age of the rabbit, the number of respirations per minute, and other points, which I do not care to enumerate, as I did not, for the present, make a close study of this question. The negative pressure in the expiratory state showed in this section in general the same sudden change in the increase, but the proportion of the increase was somewhat smaller, and there were a number of exceptions; as for instance, either without any, or with only a small increase, or again the increase having already occurred a little above this section. Below this section it occurred in some animals that the inspiratory change was again reduced to only a small amount, while there was some constant negative pressure. Usually the katheter could not be pushed, under these circumstances, much deeper. When the katheter was now retracted, step by step, it was found that in the entire mediastinum, even within the first ribs, such an inspiratory and expiratory negative pressure prevailed as was found in the 4th section, i.e. the highest attainable amount in the rabbit just experimented upon, a state which continued now to remain the same even at every new pushing down, as long as the katheter was not entirely taken out. In this latter case, if one waited for some time before introducing it anew, there appeared to be at the reintroduction again some differences, but they were neither so pronounced, nor so constant as they appeared at the first introduction of the katheter in the mediastinum. In some of the cases in which there was a third section, i.e. a total disappearance of the inspiratory undulations before their final increase, this state seemed to remain in the same locality even at the retractions or reintroductions; when the katheter was passing this place at any time or in any direction, the inspiratory undulations used to disappear. It is worth while to mention the fact that deep inspirations, e.g. those caused by dyspnœa, were often accompanied by transient strong undulations even in the upper part of the mediastinum.

The following few tables will sufficiently illustrate the preceding descriptions.

The numbers in the first column under the heading of distance mean the distance from the crico-thyroideal ligament, the unit being 5 millimeters; thus for instance 10 means 50 millimeters from the ligament. The 2nd and 3rd columns indicate the absolute pressure in millimeters of water at each corresponding step at the inspiration or expiration, – or + indicate if the pressure was negative or positive. In the 4th column the difference of the amount of the inspiratory increase of the pressure is given. In a 5th column (when given) are the notes from the autopsy showing the corresponding place in the mediastinum; the abbreviations being:—n. m. = no motion; s. m. = small motion; v. s. m. = very small motion; n. n. p. = no negative pressure; int. = pleura intact, the lungs not collapsed.

Experiment 1.

Large rabbit, 2800 gram.; katheter No. 6, pushed in at once to 10 (50 mm. distance from ligament), progressing in steps of 4 units (20 mm.). Number of respirations 36.

Distance.	Inspir.	Expir.	Diff.
10	– 18 mm.	– 16 mm.	2 mm.
14	– 23 „	– 19 „	4 „
18	– 71 „	– 60 „	11 „
22	– 92 „	– 72 „	20 „
26	– 116 „	– 70 „	46 „
30	– 120 „	– 65 „	55 „

Experiment III.

Rabbit, 1800 gram.; katheter No. 5, at once to 10, seemed to correspond to 2nd rib; respiration 46 p.m.

Distance.	Inspir.	Expir.	Diff.
10	– 14 mm.	– 6 mm.	8 mm.
14	– 32 ,,	– 28 ,,	4 ,,
18	– 36 ,,	– 20 ,,	16 ,,
22	– 40 ,,	– 18 ,,	22 ,,
26	– 46 ,,	– 24 ,,	22 ,,
30	– 32 ,,	– 28 ,,	4 ,,
26	– 40 ,,	– 14 ,,	26 ,,
22	– 40 ,,	– 14 ,,	26 ,,
18	– 41 ,,	– 20 ,,	21 ,,
14	– 32 ,,	– 12 ,,	20 ,,
10	– 32 ,,	– 13 ,,	19 ,,

Experiment V.

Rabbit, 1350 gram.; katheter No. 5, pushed to 6 (30 mm.); distance between steps, 2 units (10 mm.). Respiration 36 p.m.

Distance.	Inspir.	Expir.	Diff.
6	n.m.	n.n.p.	0
8	– 4 mm.	– 2 mm.	2 mm.
10	– 4 ,,	– 2 ,,	2 ,,
12	– 4 ,,	– 2 ,,	2 ,,
14	– 4 ,,	– 2 ,,	2 ,,
16	– 33 ,,	–10 ,,	23 ,,
18	– 32 ,,	– 8 ,,	24 ,,
20	– 32 ,,	– 8 ,,	24 ,,
22	s.m.	15 ,,	0 ,,
14	– 30 ,,	– 9 ,,	21 ,,
10	– 28 ,,	–10 ,,	18 ,,

Experiment VIII.

Young rabbit, 1150 gram.; katheter No. 5, pushed to 6 (30 mm.), both pleuræ intact during experiment; respiration 45 p.m.

Autopsy; katheter in the right side.

Distance.	Inspir.	Expir.	Diff.	Locality in mediastinum.
6	v.s.m.	n.n.p.	0	above aperture
8	s.m.	n.n.p.	0	1st rib
10	s.m.	n.n.p.	0	1st intercost. space
12	– 3 mm.	+ 2 mm.	5 mm.	
14	– 18 ,,	– 5 ,,	13 ,,	
16	– 24 ,,	– 4 ,,	20 ,,	
18	– 28 ,,	– 6 ,,	22 ,,	
20	– 28 ,,	– 6 ,,	22 ,,	

Experiment X.

Rabbit, 1700 gram.; katheter No. 6; both pleuræ visible and intact during experiment; resp. 64 p.m.

Autopsy; katheter found in left side of mediastinum posterior.

Distance.	Inspir.	Expir.	Diff.	Locality in mediastinum.
10	n.m.	n.n.p.	0	1st rib
12	– 10 mm.	– 8 mm.	2 mm.	1st intercost. space
14	n.m.	– 8 ,,	0	2nd rib
16	– 7 mm.	– 2 ,,	5 mm.	3rd rib
18	s.m.	n.n.p.	0	4th rib
20	s.m.	n.n.p.	0	
	slight obstacle overcome.			
22	– 35 mm.	– 20 mm.	15 mm.	
24	– 38 ,,	– 23 ,,	15 ,,	
26	– 38 ,,	– 22 ,,	16 ,,	
28	– 38 ,,	– 20 ,,	18 ,,	
30	s.m.	– 28 ,,	0 ,,	
28	– 38 mm.	– 20 ,,	18 ,,	
26	– 38 ,,	– 20 ,,	18 ,,	
24	– 36 ,,	– 23 ,,	13 ,,	
22	– 38 ,,	– 20 ,,	18 ,,	
20	– 38 ,,	– 20 ,,	18 ,,	
18	– 38 ,,	– 20 ,,	18 ,,	
16	– 34 ,,	– 15 ,,	19 ,,	
14	– 35 ,,	– 15 ,,	20 ,,	
12	– 35 ,,	– 10 ,,	25 ,,	
10	– 35 ,,	– 9 ,,	26 ,,	
12	– 35 ,,	– 10 ,,	25 ,,	
14	– 35 ,,	– 13 ,,	22 ,,	
16	– 35 ,,	– 15 ,,	20 ,,	
18	– 32 ,,	– 12 ,,	20 ,,	
20	– 38 ,,	– 18 ,,	20 ,,	
22	– 30 ,,	– 10 ,,	20 ,,	
24	– 28 ,,	– 8 ,,	20 ,,	
26	– 28 ,,	– 8 ,,	20 ,,	
28	– 25 ,,	– 15 ,,	10 ,,	
30	v.s.m.	– 15 ,,	0 ,,	

EXPERIMENT XIII.

Young rabbit, 1300 gram.; katheter No. 5, pleura intact, no obstacle in pushing; resp. 40, a little active.

Autopsy; katheter in left side of mediastinum posterior.

Distance.	Inspir.	Expir.	Diff.	Locality in mediastinum.
8	n.m.	n.n.p.	0 mm.	1st rib
10	– 5 mm.	0	5 "	1st intercost. space
11	– 7 "	+ 1 mm.	8 "	upper part of 2nd rib
12	– 7 "	+ 1 "	8 "	
13	– 7 "	+ 1 "	8 "	
14	– 7 "	+ 1 "	8 "	3rd rib
15	– 9 "	+ 1 "	10 "	
16	– 11 "	+ 1 "	12 "	
17	v.s.m.	0	0 "	
18	v.s.m.	0	0 "	5th intercost. space
19	– 30 mm.	– 3 mm.	27 "	
20	– 25 "	– 2 "	23 "	
21	– 15 "	– 3 "	12 "	
22	v.s.m.	0	0 "	
20	– 23 mm.	– 3 mm.	20 "	
18	– 30 "	+ 1 "	31 "	
16	v.s.m.	0	0 "	
14	– 28 "	+ 1 "	29 "	
12	– 25 "	+ 1 "	26 "	
10	– 25 "	+ 1 "	26 "	

EXPERIMENT XV.

Rabbit, 2500 gram.; pleura intact; resp. 54; katheter No. 5; no autopsy.

Distance.	Inspir.	Expir.	Diff.
10	s.m.	0	0
12	s.m.	0	0
14	– 16 mm.	– 8 mm.	8 mm.
16	– 15 "	– 3 "	12 "
18	– 16 "	– 9 "	7 "
20	– 12 "	0 "	12 "
22	– 46 "	– 19 "	27 "
24	– 49 "	– 14 "	35 "
26	– 37 "	– 10 "	27 "
28	– 37 "	– 10 "	27 "
26	– 30 "	– 4 "	26 "
24	– 30 "	– 4 "	26 "
22	– 30 "	– 3 "	27 "
20	– 30 "	– 4 "	26 "
18	– 34 "	– 4 "	30 "
16	– 34 "	– 10 "	24 "
14	– 30 "	– 10 "	20 "
12	– 35 "	– 10 "	25 "

Experiment XXV.

Rabbit, 2200 gram.; pleura intact; respir. 60, active; suspicion that the katheter is not air-tight in the mediastinum; paraffine applied to the wound a few times.

Distance.	Inspir.	Expir.	Diff.
8	s.m.	0	—
9	– 6 mm.	+ 3 mm.	9 mm.
10	– 3 ,,	+ 2 ,,	5 ,,
		Paraffine	
10	– 8 ,,	+ 4 ,,	12 ,,
13	– 8 ,,	+ 3 ,,	11 ,,
15	– 2 ,,	+ 1 ,,	3 ,,
		Paraffine	
15	– 2 ,,	+ 1 ,,	3 ,,
17	– 40 ,,	+ 6 ,,	46 ,,
19	– 40 ,,	+ 6 ,,	46 ,,
		Paraffine	
19	– 42 ,,	+ 2 ,,	44 ,,

Neglecting for the present the minor points, we may say in short, that according to our experiments, the main inspiratory undulations were found to appear in the mediastinum posterior only below the 4th and 5th ribs, while above this the change of the pressure during the inspiration was either hardly measurable, or it did not amount to more than a few millimeters of water. The result being a surprise to me, I distrusted it from the beginning, the more so since in some cases a certain obstacle had to be overcome just before the larger undulations put in an appearance. (See table X. at 20 distance.)

I suspected that this sudden change might be connected in some way with a perforation of the mediastinal pleura, producing a certain degree of collapse of the corresponding lung. I therefore took the precaution to lay bare both pleuræ and to control by this means the condition of the lungs. In young rabbits this is an easy task, as it requires only to bisect the large muscles of the chest-wall; the entire lung and its movements then present themselves through the transparent pleura thoracica, in a distinct and instructive manner. Indeed, it seemed to me to be an appropriate method for the demonstration of the motion of the lungs. If there is nowhere any mention of this method, I wish to direct herewith attention to it. In older rabbits I removed carefully the intercostal muscles in the 6th and 7th intercostal spaces, so as to be able to observe the position of the margin of the lungs. By this means I convinced myself that in no case was there the slightest retraction of the lung in connection with the sudden change in the inspiratory undulations. In fact, there was no degree of collapse in any case during the first introduction of the katheter. But after many retractions and reintroductions, the lung corresponding to the side in which the katheter was located, showed indeed in a few rabbits a tendency to collapse.

This fact demonstrates that the pleural cavity did not remain intact and that after many reintroductions air found access to it. To gain an insight as to the condition of the pleura in the other cases, I disconnected, after finishing the experiment, the katheter from the manometer, and allowed in this way the atmospheric air to enter the mediastinum directly. In the majority of the cases even then, the lung did not collapse, a sure proof that the pleura mediastinalis remained intact. In some other cases the lung did collapse, the mediastinal pleura, accordingly, had been severed indeed, but as the lung did not collapse before the disconnecting of the katheter, we may with safety conclude that in these cases no atmospheric air found access to the mediastinum beside the katheter; in other words, that at least in these cases the mediastinum remained air-tight while the katheter was introduced into it. As the revealed difference between the upper and the lower part of the mediastinum was observed (without exception) in all the cases studied, we may justly conclude that the discovered difference is neither a result of the laceration of the pleura mediastinalis, nor is it connected with the entrance of more or less atmospheric air into the mediastinum beside the katheter. With the last-mentioned point I shall deal more extensively.

The results obtained were in their extent not only unexpected, but were even in direct contradiction with my own experience in testing the intrathoracic pressure in the œsophagus.

The negative inspiratory undulations were found in this locality, at the very entrance of the mediastinum, to be of a considerably larger amount than was observed in the entire upper third of the mediastinum itself. And if we had objections against the œsophagus on account of the thickness of its wall and the effects of the muscular tissue, they were made on the supposition, that the amount of the negative pressure in the œsophagus falls short of the real pressure in the mediastinum. The natural suspicion that I myself entertained and which would certainly be entertained by others, was that the results I arrived at are only of an artificial nature, produced by the faulty method I employed, the fault being that the katheter was not air-tight enough in the mediastinum, that probably air could get in the mediastinum alongside of the katheter, but that the entrance of the air becomes more scanty the deeper the katheter is pushed in, and thence the difference of the negative pressure between the upper and the lower parts. I paid special attention to this possible objection, and I am now going to show the untenability of it.

First of all, it should be remembered, that the present investigation was not started to ascertain the exact amount of the intrathoracic pressure, the object was merely the comparison of the amounts as they present themselves in different localities of the thorax.

Now, finding for instance, that while the inspiratory pressure in deeper parts of the mediastinum amounted to 30 millimeters water, in the upper part the pressure amounted almost to nothing or did not exceed 4 or 5 millimeters, we may admit that these are not the real amounts, that the real amounts have been reduced somewhat by the invasion of atmospheric air; but if we should go further to explain the entire difference between the upper and the lower parts only by the interference of atmospheric air, we have then to assume that the facility for the entrance of air beside the katheter is in the upper part of the mediastinum at least 6 times greater than for the entrance through it, since the amount in the upper part is at the utmost $\frac{1}{6}$ of the amount in the lower part; an assumption which is, as it seems to me, *a priori* improbable. The katheter is in the neck behind the œsophagus in close connection with the surrounding tissue, there is no natural channel leading to the mediastinum, the katheter has to bore its way thither; it is then not likely that the imaginary space around the katheter should be a better means for the communication with the outside air than the free lumen through the katheter. Then the conditions were not changed in the upper part even if a katheter with a wider lumen was employed, which could not be the case if the entire effect depended upon the rivalry between the lumen of the katheter and the space around it. To make this latter more impermeable for air in many cases before pushing the katheter down the neck and after inserting a cannula in the trachea, I have dressed the entire wound with a tightly fitting bandage surrounding the neck, and thus pressing the tissue closer to the katheter. The results have been just the same as they were found to be without this precaution. And the results remained practically the same after employing a still safer method for occluding the wound and thus excluding the atmospheric air.

By filling out the entire wound carefully with melted paraffine, any side entrance to the mediastinum is safely closed up. I tested it by artificially increasing the negative pressure to a higher amount; it remained unaltered so long as the paraffine cover remained unbroken. Although this happens indeed when the katheter is moved, the method is perfectly reliable if applied after the katheter is at rest; and this is sufficient for our purpose, since we can occlude every time anew before testing the pressure. No matter how much air entered beforehand, after safe occlusion the inspiratory change ought to be in all parts of equal amount, that is, if the invasion of the atmospheric air is at the bottom of the manifold mentioned differences. As we just stated, the difference was not affected by the occlusion (see Exp. XXV.), and consequently it cannot be simply the result of a more convenient invasion of air through a side opening in the upper part of the mediastinum.

Aside from those experimental proofs, there is a fact in the results themselves, which speaks decidedly against the supposition, that it is the access of atmospheric air by the side-ways, which cuts down the negative pressure in the upper part of the mediastinum. It is the fact that at the retraction or reintroduction of the katheter the difference disappears; there is then in the upper part the same high amount of negative pressure at each inspiration as is found to be in the lower part of the mediastinum. And we can certainly not presume that the side-ways became narrower by the retractions or reintroductions.

After all this, there can hardly be any doubt that the smallness of the amount of the negative pressure, which was found to take place in the upper part of the mediastinum during an inspiration, is not an artificial phenomenon, produced by some defect in the experiments, but shews that it is a fact indeed, that the change in the intrathoracic pressure which prevails during an inspiration, affects but little the upper part of the mediastinum!

While thus defending the entire usefulness of the method employed, so far as concerns the main object of this investigation, I am willing to admit, that unless a safe method is found by which it would be possible to exclude positively any entrance of air beside the katheter, while this is pushed into the mediastinum, the other points of the results obtained by this method are open to criticism. The amounts of the negative pressure at the inspirations as well as at the expirations, as they were obtained in the mediastinum, have no claim on absolute correctness; they may be indeed influenced by the entrance of some air alongside of the katheter. Moreover these amounts vary with the frequency of the respiration, with the diameter of the lumen of the katheter, with the length of the tube connecting the katheter with the manometer, and perhaps with the side, on which the katheter was introduced, as the amounts from the left side seemed to be smaller than those from the right side! Concerning the negative pressure during the expiration, we should remember that in rabbits, according to Traube and I. Rosenthal, the external oblique muscles do contract in normal expirations, which would make the amount of the negative pressure in living rabbits, smaller than that given by Donders or Heynsius, who experimented on dead animals.

All these points have not received sufficient consideration in my experiments, as I was mainly interested in the comparison of the results of the different sections of the mediastinum, obtained under the same conditions. With somewhat more confidence could be regarded the result showing a constant difference in the amount of negative pressure in the different sections of the mediastinum during the expirations also. Though I shall not discuss at length this point, I wish to say that if we should even admit that air finds access to the mediastinum, and that the invaded air affects the expiratory pressure in the upper part of the mediastinum somewhat more than in the lower part, it is pretty certain that this is not the only cause of the comparatively pronounced difference in the amount of the expiratory pressure, the difference being nearly as constant and as pronounced as was the case in the inspiratory undulations!

From the very fact that there is a difference between the upper part and the rest of the mediastinum in respect to the intrathoracic pressure, it follows that, no matter what the cause of the difference may be, the mediastinum does not represent normally a connected cavity; if the cavity were so connected, there could not be any difference in its localities in respect to the prevailing pressure, since in a connected cavity the pressure is the same in all parts. It is rather to be supposed that the mediastinal walls in some way or other adhere together to such a degree, that one part can not be influenced by the pressure prevailing in another part. We can now easily understand why the mentioned difference was only present at the first introduction, and not any more at the retractions or reintroductions; because the first introduction of the katheter transforms the mediastinum into a well-connected channel, where the pressure can not be otherwise than equal in all its parts. And as the œsophagus is naturally such a well-connected channel, we see now further why we found the same pressure in all its parts, and conceive a natural explanation for the apparently singular fact, that the respiratory changes of the pressure should be larger in the upper part of the thick-coated œsophagus, than in the upper part of the mediastinum: it is not the respiratory undulations in the upper parts of the lungs directly transmitted to the upper part of the œsophagus which we measure there, it is only the propagated pressure of its lower part transmitted there from the lower parts of the lungs.

The avowed purpose of the present investigation, was to infer the amount of the respiration in different localities from the condition of the changes in the intrathoracic pressure accompanying the respirations in the corresponding localities. Now as we found indeed that the changes of the respiration are very little marked in the upper third of the mediastinum, we should proceed to conclude that the respiration is considerably diminished not only in the apices of the lungs, but even in the entire upper third at least of the back parts of the lungs. The conclusion means in particular that the pressure in the mediastinum differs not at all or very little from the pressure in the pleural cavity, and that the pressure here may be taken as an exact expression of the degree of breathing taking place within the corresponding parts of the lungs.

The assumption that in some part of the pleural cavity there may prevail a pressure different from that present in other parts, implies further the supposition that the pleura visceralis adheres to the pleura parietalis so much as to prevent the highest pressure, prevailing in some place of the cavity, from being propagated over the whole pleural cavity. As there are no such anatomical connections between the two pleuræ to establish an adherence, we shall have to look for "adhesion" in the physical sense to fill that office. Indeed it has been claimed by some authors that the "adhesion" even assists in overcoming the elasticity of the lungs. As the back part of the upper third of the lungs is just the part of the lungs which is less subject to the respiratory movements than any other part of the lungs, we may bring this point into causal connection with the assumption, that the same part takes the least share in the act of breathing, i.e., the alveoli of this part expand very little during the normal inspiration. We may assume further that the upper parts of the lungs are in the expiratory state in a less expanded condition and are better conformed to their corresponding part of the thorax than the rest of the lungs and therefore there is none or only little negative pressure in the upper part of the thorax, while it is at rest in expiration. Indeed there would be altogether no difficulty in explaining why the upper part of the lungs should show certain exceptions, if only the fact could be sure, that the conditions I observed in the mediastinum have exactly the same bearing upon the pleural cavity and upon the lungs. But having been successful in the research, I hesitate now to draw from the discovered facts, those conclusions for which I undertook the entire investigation. It seems now to me that the facts permit also the theory, that the diminished negative pressure which was observed in the upper part of the mediastinum is restricted to its locality alone and has no bearing on the pleural cavity. The upper part of the mediastinum harbours the aorta, both venæ cavæ, the trachea, and the bronchi, all of them are connected among themselves and with the œsophagus by connective tissue. The katheter is in this vicinity separated from the pleural cavity not only by the thin mediastinal pleura, but by a pretty thick wall formed by all the tubes mentioned above, while in the lower part of the mediastinum there is indeed nothing else to separate the katheter from the pleural cavity than the thin mediastinal pleura. The appearance of the mediastinum intensifies the supposition that there exists indeed a certain anatomical difference between the upper and the lower part of the mediastinum. The slight obstacle which was often met just before reaching that portion at which the strong inspiratory undulations put in an appearance, may come from some stouter structure of the connective tissue, located at this boundary line, and which may help at the same time to prevent the propagation of the pressure from the lower to the upper part of the mediastinum. The only objection that could be made against this theory is, that according to it, that part in the upper third which is least separated from the pleural cavity should show stronger undulations; but in the region next to the apex of the lungs is contained the least amount of thoracic viscera, and just here were hardly any inspiratory undulations to be noticed. There is not such an importance, however, in this objection as to be sufficient to exclude the possibility of this hypothesis. I mean to say this:—although it seems to me that my experiments on the mediastinum make it indeed probable that the apices and the back part of the upper third of the lungs do not participate in the breathing so largely as the other parts of the lungs do, in consideration of the importance of this conclusion, we should not consider it as proven, until it has been tested by experiments made on the pleural cavity, directly or within the lungs themselves.

Besides the relations to the breathing of the upper parts of the lungs, the condition discovered to prevail in the upper part of the mediastinum has an important bearing on the question of the origin of the respiratory undulations of the blood-pressure. Without entering into details of the very complex theme, it is sufficient to say, that with exception of a very few all the writers on this subject agree with the view set forward and developed by Ludwig, Donders and Einbrod, that the increase and the decrease of the intrathoracic negative pressure accompanying the respirations, have a great deal to do with the undulations of the blood-pressure. During the inspiration both venæ cavæ and the right auricle are, so it is generally assumed, under a considerably lower pressure than the veins outside of the thorax, which difference of pressure causes greater inrush of blood into the great thoracic veins and the right auricle, and thus more blood comes into the ventricle etc.; the expiration on the other hand by the diminished intrathoracic negative pressure diminishes the influx of blood into the ventricle. The same conditions have, so it is calculated, an opposite but a smaller effect on the aorta. Now we have seen in our experiments that the inspiratory changes in the intrathoracic pressure are very small in the upper part of the mediastinum, amounting only to a few millimeters of water, the main change in the pressure occurring in the lower part of the mediastinum. As the upper part reaches as far deep as the 5th or 6th rib, so this part contains the entire superior vena cava, the arcus aortæ, the auricles, and a considerable part of the inferior venæ cavæ and the descending aorta. In short, the main circulatory parts which are expected to be influenced by the considerable change in the intrathoracic pressure, are located in that part of the mediastinum where, according to my experiments, very little change occurs. Thus my experiments seem to destroy nearly the entire basis, upon which the prevailing theory concerning the respiratory undulations of the blood pressure rests!

I content myself for the present with this short reference to the subject, awaiting firstly a confirmation of the facts I have stated here. I wish only to add that by the method of introducing a tube in the mediastinum posterior without influencing the respiration, it is possible to exclude entirely the respiratory undulations of the intrathoracic pressure, and it will thus be possible to investigate directly, the share those undulations of the intrathoracic pressure have in the undulations of the blood pressure.

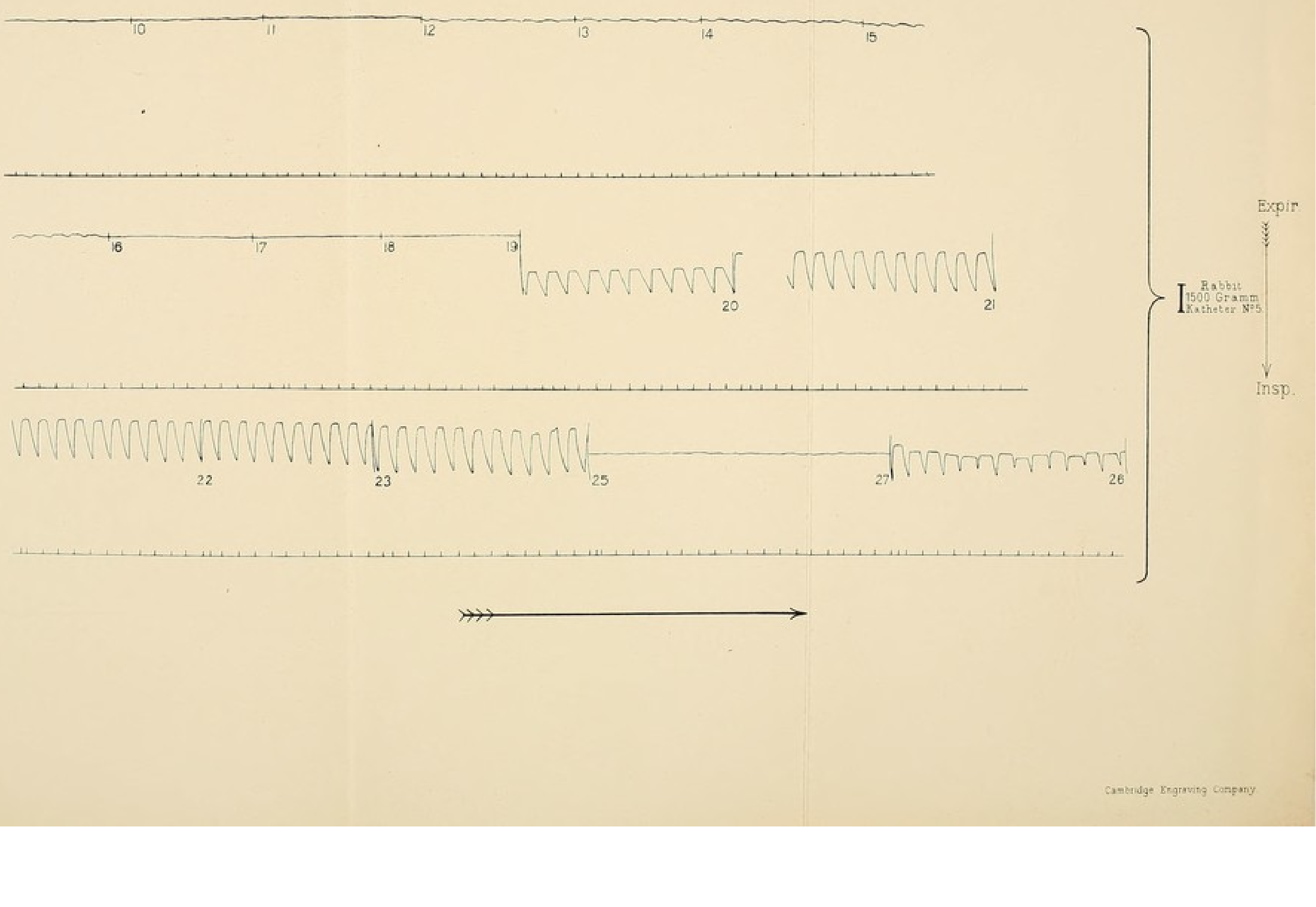
EXPLANATION OF THE CURVES.

The curves have been obtained by connecting the katheter with a Marey's tambour, the lever of which transmitted the respiratory undulations of the intrathoracic pressure on the smoked paper, which covered the revolving cylinder of a recording apparatus. The negative pressure accompanying the inspiration rarefies the air in the tambour, and thus makes the lever of the tambour descend; the ascension of the lever corresponds to the expiration. Below the inspiratory undulations the lever of a time-marker recorded the time in seconds. The distance between the lines of the two levers, traced before the katheter was introduced into the chest, represents the condition of the air in the tambour under atmospheric pressure. A smaller distance means a negative, a greater distance a positive pressure.

The Curves on Plates VIII. *A* and VIII. *B* are selected from quite a great number of curves, all of which show quite the same proportion between the undulation of the upper and lower parts of the mediastinum, the difference consisting only in the absolute dimensions of the undulations obtained from the lower parts, a difference which is even to be seen in the present two curves. Even the undulations in VIII. *B* are not nearly as large as I obtained in some animals. Each of these curves represents an entire experiment. The katheter has been pushed into the chest, in these experiments, from 6 at once to 10 units, this distance corresponding in VIII. *B* to the first ribs, and in VIII. *A* to the first intercostal spaces. The numbers on the curves mean the distances from the crico-thyroideal ligament, a unit being 5 mm. (10 means 50 mm.). After recording the undulation in one position, the cylinder was stopped and the katheter pushed one unit deeper; then the cylinder was again put in rotation, and so on until the probable end-point of the mediastinum was reached; and then the retraction followed. The position of the tambour and the time-marker remained the same during the entire experiment. The direction of the curve downward means inspiration, and upward means expiration; the marks above the undulations show the beginning, the numbers below, the end of the undulations, corresponding to the distance given in the number. In both of these experiments there has been some active expiration.

Plate VIII. *A* is obtained from a rabbit 1500 gram., with a katheter No. 5; lungs visible through pleura; *int.* means that the pleural cavity remained intact. In the distance from 10 to 12, we see hardly perceptible undulations;

from 12 to 16 they are increasing gradually; from 16 to 19 they disappear again; at 19 there is a sudden increase in the inspiratory undulation, and with only a small gradual increase remaining rather about the same to 25; at 27 there is again no motion, and at 26 they are irregular, and smaller as in the preceding section. The level of the expiratory line remained between 10 and 12 like it was before the introduction of the katheter, from 12 to 19 there was a very slight degree of negative pressure; its main increase occurs suddenly at 19 and continues to be about the same in the remainder of the mediastinum, being even a little more pronounced in the last section (27), where no more inspiratory undulations are to be seen. Plate VIII. *B* is obtained from a rabbit of 1800 gram., with a katheter No. 5, the pleural cavity remaining intact even after admitting air to the mediastinum. We meet in this curve in the main with the same conditions as in VIII. *A*, with the difference that the large undulations appear in a deeper part of the mediastinum; there is a visible increase in the inspiratory undulations at the retraction, and there is no negative pressure at the expiration, rather a little positive pressure throughout the experiment, the contraction of the expiratory muscles being pronounced.



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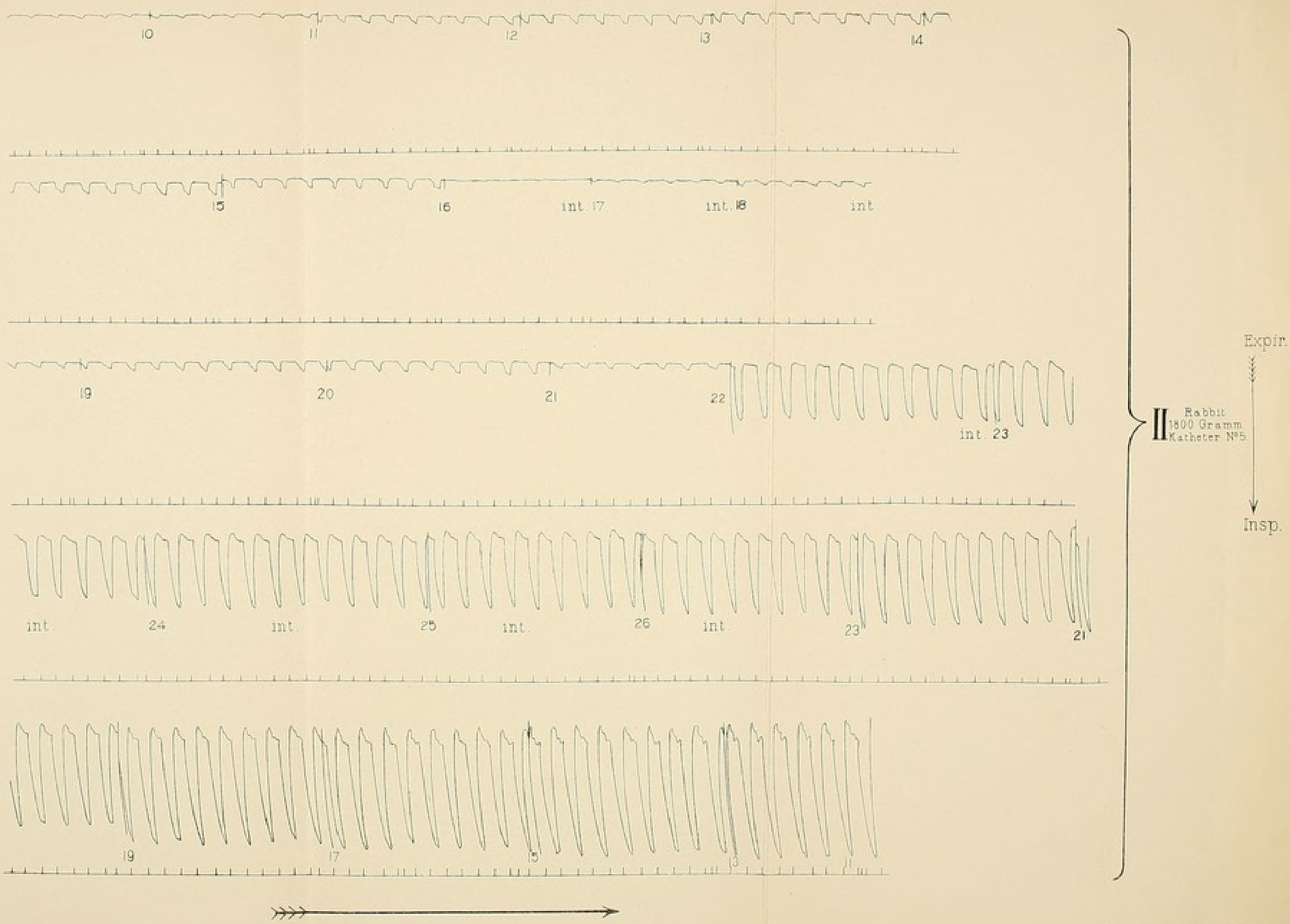

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