A LABORATORY GUIDE IN PHYSIOLOGY

CHAPTERS I. AND II. ON CIRCULATION AND RESPIRATION

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PREFACE.

American laboratories of physiology have usually been established in medical schools after these institutions have already associated histology with pathology, and physiological chemistry with general chemistry. The problems presented in those American laboratories of physiology which are departments of medical schools are, therefore, essentially the physical problems of physiology. It is, then, quite unnecessary to burden the student with the purchase of a voluminous manual largely devoted to morphology and to the chemical problems of physiology. The student who has but four years to devote to the study of medicine cannot consistently be assigned more than 100 hours to 120 hours of laboratory work in physical physiology. How to most profitably spend this brief period is a question which has engaged the attention of the writer for a number of years. In the choice of the work to be assigned to the student it has been taken for granted that he has entered upon his study of medicine with a knowledge of, at least, the rudiments of physics and of algebra, and that laboratory work in physiology is not begun until the student has made considerable progress in gross and minute anatomy. Courses in anatomy and physiology should be so coördinated as to enable the student to gain a thorough knowledge of the morphology of an organ before he experiments upon its function.

INTRODUCTION.

THE METHOD OF PRESENTING THE SUBJECT.

THE QUESTION OF ILLUSTRATIONS.

The profuse illustration of a text-book is in perfect accord with the principles of pedagogy; that the profuse illustration of a laboratory manual is the reverse is evident from the following considerations:

The laboratory student receives from the demonstrator the material with which he is to work. If he receives a piece of apparatus which is new to him, a few questions or hints in his laboratory manual will lead him to discover, from an examination of the *apparatus itself*, the physical and mechanical principles involved and utilized in it. Most students will spontaneously make drawings showing the essential parts of the instruments; all students will willingly do so if required. This is a most valuable exercise for the pupil, which is likely to be omitted if the manual contains cuts of the apparatus.

Nearly every exercise requires the preparation of some simple appliance—e. g., a frog board or a recording lever—whose construction will be much facilitated if the student is guided by a figure in his manual, but a model which the demonstrator has made will be a better guide.

I have often seen students read their text descriptive of some organ—e. g. a frog heart—and verify its statements from the accompanying figures, leaving almost unnoticed the *object itself*, which lay before them. A few brief questions or hints would have led them to discover on the object all of its essential features. Diagrammatic anatomical figures are sometimes useful in a laboratory

manual, but true anatomical figures are worse than useless—they bar the student's independent progress. If his laboratory manual contains illustrations of all apparatus and tissues, and of such experiments as admit of graphic records, the student makes similar drawings in his notes, either unwillingly or dependently—frequently both. The laboratory work is thus robbed of much of the benefit it is intended to give the student. Independence and originality are completely defeated or aborted, except in the case of the rare student.

If the laboratory manual contains graphic records of an experiment, much of the time of the demonstrator will be consumed in explaining to the students individually why the same physiological functions observed with slightly different apparatus and under slightly different circumstances, may differ in minor detail from the tracings in the book. The energies of the demonstrator will thus be partially diverted from their legitimate channel. If there is no tracing in the text, students will naturally, by comparison of their tracings, discover the essential and the nonessential, and the cause of the essential features of these tracings. After the student has made these independent discoveries he is in a position to gain the maximum profit from the comparison of his own tracings with those which others have taken, and from any explanations which the demonstrator may choose to add.

It is evident then, that, from a pedagogical standpoint, the laboratory guide should be very sparsely illustrated, if at all. On the other hand, the student's notes should be profusely illustrated.

THE QUESTION OF EXPLANATION.

What has been said regarding the illustrations of apparatus and of results applies, in principle, to the ex-

planation of physiological observations. As wheat is more valuable than chaff, so is the independent discovery of a principle by the student more valuable to him than its explanation by a book or instructor. If the facts to be observed and the principle involved be detailed and explained in advance, the student's power of independent observation and investigation remains undeveloped.

THE FUNCTION OF THE DEMONSTRATOR.

It may be well to introduce this topic by a statement of what the function of the demonstrator is not. It certainly is not to rob the student of the pleasure, exhilaration and benefit of independent investigation of a problem by introducing each laboratory period with an enumeration of the facts and principles which the work of the day is expected to establish. Such an introduction is worse than useless. The desirability of even asking the attention of the entire class to introductory remarks on the general bearing of the problem in hand is to be questioned. If the problem is well chosen and the work in the physiological laboratory properly coördinated with that in the recitation room and lecture room and that in other departments, its significance will at once be evident to the intelligent pupil. If the introductory talk is omitted the prompt student may begin at once, upon entering the laboratory, the problem of the day and will have a clear gain of ten to twenty minutes. Any supplementary instruction or hint may most profitably and economically be written upon the blackboard.

Most of the experiments given in this book cannot conveniently be performed by one individual working alone. After some experimentation it has been found most advantageous to divide the class into sections not exceeding thirty students, and to subdivide these sections into

divisions of three students each. Each division is assigned a table. The assistant demonstrator places the material needed for any day's work either upon the tables or where it is readily accessible.

Nothing should be done for the student which he can profitably do for himself. A small class with less limited time may easily construct much apparatus in the work-shop. No class is so large as to debar the members from the privilege of constructing frog-boards, tracing levers, etc., (which may be done at the tables) and of setting up, adjusting and readjusting all apparatus.

Nothing should be told a student which he can readily find out for himself. The function of the demonstrator is to guide the student by questions and by hints to discover facts and to formulate principles. Extended explanations on the part of the demonstrator may instruct the student, but they do not educate him.

HINTS TO THE STUDENT.

It is a general principle that a student gets out of a course what he puts into it, and with interest. If he invests (1) intellectual capacity, (2) the spirit of inquiry and investigation, (3) the power of logical reasoning, and (4) the power to formulate conclusions ; he will promptly receive interest upon the investment. Further, the greater the investment the greater the rate of interest. This may seem inequitable, but it is inevitable.

The value of taking full notes of laboratory experiments is unquestionable. The following hints regarding note taking may be advantageous :

1. Make a careful description of each new instrument with which you work.
2. Formulate each problem definitely.
3. Describe the means used in the solution of the problem.

4. Enumerate the facts observed through the help of the means employed.
5. Seek for and note causes and inter-relations of the facts as far as possible.
6. Differentiate the essential from the incidental.
7. Formulate conclusions from the collected data.
8. Make generalizations as far as they are justifiable.

A good notebook should possess the following qualities:

a. It should be complete, containing an account of every problem studied.

b. It should be full, containing a sufficient amount to guide another in performing the same experiments and in verifying the facts and conclusions noted.

c. It should be logically arranged.

d. It should be as neat and artistic as the student can make it in the time which he can devote to it.

Such a notebook is a most valuable addition to any library, but the simple making is still more valuable to the one who does it.

A. CIRCULATION.

I. THE CIRCULATION AND ITS ULTIMATE CAUSE.

a. To observe the capillary circulation :

1. Appliances needed.—Cork-board 8 cm. wide by 20 cm. long and about ½ cm. thick; cover glasses, 18 mm. in diameter and 10 mm. in diameter; normal salt solution; camel's hair brush; pins; compound microscope; sealing wax; thread; filter paper; 2 per cent croton oil in olive oil.

2. Preparation.—Pith two frogs the day before the observation is to be made. At the beginning of the laboratory period when the observation is to be made curarize the frog lightly by the hypodermic injection of one drop of a 1 per cent solution of curari. Make a frog-board by cutting a hole 1.5 cm. in diameter near one corner of the cork-board and fasten a large cover glass over the hole with sealing wax.

3. The operation.—After the frog becomes curarized, pin it out ventral surface downward in such a way as to bring one of the hind feet over the hole in the board. Tie thread, not too tightly, to the third and fourth digits, loop the threads over pins and gently separate the digits until the web is quite flat and closely approximated to the surface of the fixed glass which covers the hole. Run a film of normal salt solution under the web; place a drop of the same liquid upon the upper surface of the web; place a small cover glass over it; fix the board upon the microscope stage so as to admit of illumination by transmitted light; illuminate; focus.

4. Observations.

(1) Is there evidence of matter in motion? Is the moving matter liquid or solid? If the matter is confined to particular channels; are they all alike? If not, describe differences.

(2) Observe whether the motion is equally rapid in all channels; if not, observe whether the slower currents are in the larger or the smaller channels. Determine which of the channels are arterioles, which capillaries, and which venules.

(3) Have you seen evidence of an intermittent force acting upon the moving bodies? If so, describe its influence and location minutely.

(4) Do the moving bodies change shape? If so, under what circumstances?

(5) Remove the cover glass, dry the web with filter paper, touch a point with a pin that has heen dipped into dilute croton oil. Observe whether the presence of the croton oil effects any change in the diameter of the vessels, or in the rate of the blood flow. If there is a change in both, has one a causative relation to the other?

(6) Note and describe minutely all changes which take place at and near the place touched with the croton oil. If no marked change is produced by the croton oil, touch the point with a glass point which has been dipped into HNO_3.

(7) Have you noted diapedesis of white or of red corpuscles; if so, describe the process minutely.

2. *b. To observe the action of the frog's heart:*

1. Appliances.—Dissecting board; fine scissors; heavy scissors; pins; forceps; watch glass; camel's hair brush; normal salt solution; fine silk thread; ice, in a beaker.

2. *Preparation.*—Pith a frog, lay it with its dorsal surface upon the dissecting board; stretch out its legs and pin the feet to the board.

3. *Operation.*—Make a median incision through the skin from the pelvis to the mandible; make transverse incisions and pin out the flaps. Raise the tip of the episternum, insert a blade of the fine scissors under it and divide it transversely, about ½ cm. anterior to the tip. Raise the anterior segment of the sternum at the point of the transverse incision; insert the blade of the strong scissors under it and divide it longitudinally in the median line. Withdraw from the board the pins which fix the anterior extremities, make gentle lateral traction upon the fore feet until the split sternum is sufficiently separated to afford a convenient working distance and to plainly expose the whole heart.

4. *Observations.*

(1) Note rate of systole.

(2) Note sequence of contraction of auricles, ventricle and bulbus.

(3) Note change in shape of different parts.

(4) Note change in color and the position of this color change in the heart cycle.

(5) Carefully excise the heart including the sinus venosus and the bases of the posterior and two anterior venæ cavæ, also the bases of the two aortic trunks. Place the excised heart in a watch glass. Observe whether the pulsation continues. If so, what is your conclusion regarding the relation of the heart movements to the central nervous system.

(6) If the pulsation continues, note whether the rate of pulsation has been noticeably changed by the excision.

(7) Bathe the heart with a few drops of NaCl solution, hold the watch glass in the palm of the hand and note whether the rate changes.

(8) Float the watch glass upon ice water and note the results.

(9) If the heart seems vigorous (otherwise procure a fresh one), carefully sever the sinus venosus with the fine scissors. Does the sinus continue to beat? Does the heart continue to beat? Interpretation.

(10) If the heart beats, sever the auricle from the ventricle through the auriculo-ventricular groove. Note results.

(11) If the auricles beat, divide them. If they continue to beat, do they follow the same rhythm?

(12) If the ventricle becomes quiescent, stimulate it either mechanically or with a single induction shock. How does it respond to a single stimulus? Continue to subdivide the heart until the parts refuse to respond to stimuli.

(13) Repeat the experiment and see if the same results are reached on subsequent trials. Note results and give your interpretation.

II. THE GRAPHIC RECORD OF THE FROG'S HEART BEAT.

1. *Appliances.*—Frog-board; a straw or strip of bamboo 20 cm. long; a cork about 2 cm. in diameter and height; pins; needles; sealing wax; parchment paper; a kymograph, stand and lamp.
2. *Preparation.*—Pith a curarized frog. Make a heart lever after the model shown by the demonstrator.
3. *Operation.*—Open the abdomen of the frog as described under I-b-3 and expose the heart. Open the pericardium, place some resistent object—a cover slip, for instance—under the ventricle. So adjust the heart lever that the cork foot of the long arm of the lever will rest upon the juncture of the auricles and ventricles. If the weight of the lever seems to be too great for the heart to move easily, the long arm may be made lighter by placing a counterpoise upon the short arm. If the tracing point of the long arm has a sufficient excursion to make a good tracing, bring the kymograph to a position where the point will lightly touch the carboned surface of the drum. The lever should be nearly tangent to the surface of the drum, and so arranged that the rotating surface of the drum turns away from the tracing point of the lever rather than toward it.
4. *Observations.*

   (1) Note whether the curve is a simple one or composed of a major wave, with crests superimposed upon it.

   (2) In either case closely observe the phases of the heart-cycle and determine the relation of each part

of the cycle with each part of the tracing. If the tracing has a single crest, more delicately counterpoise the lever and more carefully adjust the narrow foot of the lever to the auriculo-ventricular groove and repeat the experiment.

(3) Take tracings of the auricle alone. Compare these with those of the auriculo-ventricular notch and determine the causes of variation.

(4) Without altering the counterpoise take a tracing of the ventricle and compare it with the two preceding curves and account for all the differences.

(5) Try to take a double tracing with one lever foot resting upon the auricle and the foot of the second lever resting upon the ventricle. The tracing points must touch the drum in a vertical line. Are the crests synchronous? If not, why?

(6) If a time tracing be added one may determine the time relations of the different phases of the heart cycle.

III. THE APEX BEAT. THE HEART SOUNDS.

1. *Appliances.*—A cardiograph and a transmitting tambour (Marey) or materials for constructing them. A stethoscope; a stand and support; clamps; a kymograph; two tambour pans Nos. 1 and 2 thin; sheets of rubber; thread; corks; sealing wax; tambour holder; straws; needles; parchment paper.

2. *Preparation.*—Any laboratory will have different forms of cardiographs for demonstration purposes, but not every laboratory is able to afford numerous duplicates. An expert tinsmith will make the tambour

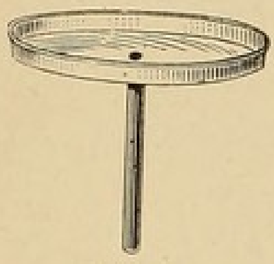

Fig. 1

pans at very moderate cost, and the student can do all the rest. Pans may be made of two sizes No. 1, diameter 5 cm., depth 4 mm., outside diameter of tube 3 to 4 mm., length of tube 3 to 4 cm. No. 2, diameter 4 cm., depth 3 mm., tube as in No. 1, see Fig. 1. To make the cardiograph: Take a tambour pan No. 1, stretch the sheet rubber across the pan and tie in place with thread. A few drops of sealing wax will keep the thread in place after it is tied. Mount the tambour as follows: From any well seasoned, close-grained hard wood in boards, about 1 cm. thick, cut small triangular pieces about 10 cm. on a side. In the center of each triangle bore a hole to receive a medium sized cork (about 1.5 cm. in diameter) the upper edges of the triangle may be beveled and each corner may be furnished with a leg by screwing into each corner from the lower surface, a round headed

screw, leaving about 1 cm. of the screw out to serve as the leg. If the class is large, the demonstrators should prepare these tambour boards in advance. The tambour is mounted by fitting a cork to the hole in the tambour board, boring the cork and pressing the tambour tube through the hole from below upward. Fix a button of cork to the membrane with sealing wax. The completed cardiograph will present in section the relations shown in Fig. 2. As will be seen from the cut, the position of the button may be varied by varying its shape or by changing the adjustment of the tambour tube in the cork.

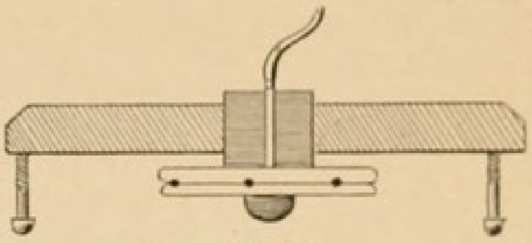

Fig.2

To construct a transmitting or recording tambour use a No. 2 tambour pan, stretch the rubber less tightly than for the receiving tambour and mount similarly in a triangular tambour board, omitting the screw legs. Make a recording needle like the frog's heart lever, except that the foot, which rests upon the middle of the tambour membrane, may present a larger surface. The cork which forms the fulcrum of the lever should be fixed to the tambour board in such a position that the long arm of the lever is vertically above a diameter of the tambour. Any change of pressure upon the air in the tambour will cause the membrane to rise or fall, thus producing in the tracing point of the lever a corresponding rise or fall differing from those of the membrane only in their greater extent. It is evident that if the tube of the receiving tambour be joined to the tube of the transmitting tambour through a thick rubber tube any movements which affect the button of the first will be

manifested by a rise or fall of the lever which rests upon the second.

3. *Operation.*—Let a student remove the clothing from the region of the apex beat of the heart and take, upon the table, a recumbent dorso-sinister position. Place the button of the receiving tambour upon that point of the thorax most affected by the apex beat of the heart. The movements of the chest wall will be faithfully transmitted and magnified by the two tambours. Fix the recording tambour with clamp, and support and bring into the above described relation to the kymograph. (See section II.)

4. *Observations.*

(1) Note the exact point upon the chest where the apex beat is most distinctly marked. Is it the same for different members of the class?

(2) Take several cardiograms from the same individual, being careful so to adjust the apparatus as to gain the maximum excursion of the lever. What features have all of these tracings in common? What features seem to be accidental and nonessential? What is the cause of the essential features? What are the sources of the nonessential features?

(3) Take cardiograms of several individuals. Do all of them possess the features which seemed essential in the first series, taken from one individual. If not, how would you account for the difference?

(4) With a stethoscope, whose construction you have carefully described in your notes, listen to the heart sounds while the cardiograph is tracing the record of the heart movements. Note that two sounds are audible and that there is a noticeable pause follow-

ing the shorter, sharper sound; let us call the sound which succeeds the pause the first sound.

(5) With what part of the cardiogram does the first sound seem to correspond? With what part of the cardiogram does the second sound seem to correspond? Give reasons for this correspondence.

(6) As far as the data will admit, enumerate causes for the first sound; for the second sound; for the essential features of the cardiogram.

IV. THE FLOW OF LIQUIDS THROUGH TUBES. LATERAL PRESSURE.

1. Appliances.—Reservoir with short discharge nozzle whose lumen is 6 mm. in diameter; 5 pieces of glass tubing whose lumen is about 6 mm. in diameter and whose length shall be 60 cm.; two lengths of glass tubing whose lumen is about 3 mm. in diameter and whose length shall be 60 cm.; rubber tubing for joining up the apparatus; 3 T tubes of 6 mm. tubing; short tube with capillary point from each size of tubing; 2 one liter flasks; 2 supports; a light pine stick about 6 feet long; stopcocks.

2. *Preparation.*—A resourceful demonstrator will have no difficulty in contriving reservoirs. It is sometimes not easy to provide a large class with suitable and convenient reservoirs. The following form has proven very satisfactory: A glass tube about 3 cm. in diameter may be readily furnished with a glass nozzle of the required size by any glass blower. The nozzle should be about 3 cm. from one end of the tube. That end may be closed with plaster of Paris and filled with hard paraffine to the lower margin of the nozzle opening. This reservoir may be held upright by a support. When complete it presents the appearance indicated in Fig. 3.

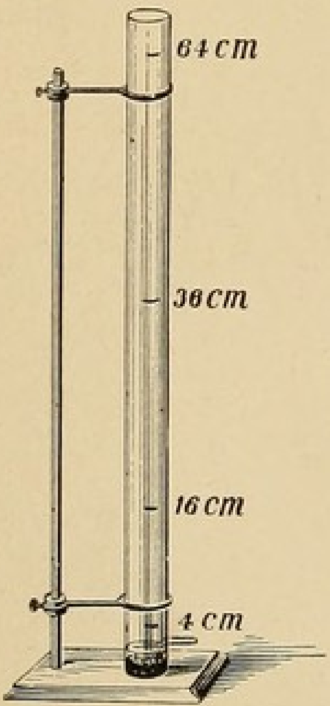

Fig. 3

3. *Operation.*—Mark upon the side of the reservoir a point 36 cm. above the center of the nozzle, also a point 64 cm. above the nozzle. While the reservoir is filled from one flask the water may be caught in the other. Assume some convenient unit of time, as ten or fifteen seconds.

4. *Observations.*—Fill the reservoir to the height of 64 cm. Allow the water to flow from the nozzle freely into the flasks. Note the distance to which the jet is thrown when the water begins to flow. Note distance when the upper level of the water passes the 36 cm. mark; the 4 cm. mark. What are your conclusions?

   (*a*) *Velocity.*—How does the velocity of the discharge vary with the varying height of the column of water? Why does it so vary? Does it verify the law of Torricilli? *The rate at which a fluid is discharged through an orifice* [better a nozzle] *in a reservoir is equal to the velocity which would be acquired by a body falling freely through a height equal to the distance between the orifice and the surface of the fluid.*

   Recall the law of falling bodies: Let g equal the distance through which a body will fall in one second under the influence of gravitation alone, h the total height fallen through, t the time in seconds and v the velocity; derive from the facts the following equations:

   (1) $v = g\,t$. (2) $h = \frac{gt^2}{2}$.

   From these equations derive (3) $v = \sqrt{2gh}$; (approximately $= 4.429\sqrt{h}$.) Expressed as a variation the constant may be discarded and the variable would read (4) $v \propto \sqrt{h}$. Verify the truth of this mathematically derived law.

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* g=9,809 meters.

b. Discharge.—If we let D equal the quantity discharged from the nozzle in a unit of time, will D vary with the velocity? If so, it varies with the h. Does D vary as the velocity. If so, we may write $D \propto \sqrt{h}$.

Verify as follows: During a unit of time allow the water to flow from the 6 mm. nozzle, meantime maintaining a fixed level—e. g., at 64 cm.—by pouring water into the reservoir from a flask. Note the amount of discharge (D). Repeat the experiment after having fixed to the nozzle a very short piece of 3 mm. tubing. Note that the height (h) remains the same. Is D the same? Does the formula $D \propto \sqrt{h}$ express the facts? If not, make a formula that will bear verification.

Derive the formulæ (5) $D = 4.429 \pi r^2 \sqrt{h}$, (6) $D \propto r^2 \sqrt{h}$ when r = the radius of the discharging tube. Attach to the nozzle one length of 6 mm. tubing. Note the discharge in the unit of time. Attach a second length of the 6 mm. tubing, taking care that the tubing is approximately horizontal, note the discharge in a unit of time. What is your conclusion? Why does the discharge increase when the length is increased?

If R equals resistance, and L length of tubing, does the following expression represent the facts: (7) $R \propto L$?

Join two lengths of 3 mm. tubing and note discharge in a unit of time. What is the variable factor in this experiment? Does a tube of small radius afford more resistance than one of large radius? If not, the discharge, all other things being equal, will vary as the square of the radius. $D \propto r^2$, i. e., the 3 mm. tube would discharge one-fourth as much in fifteen seconds as would the 6 mm. tube.

Is the relation of discharge to resistance direct or reciprocal?

Verify the following formula: (8) $D \propto \frac{1}{L}$.

Now we already have found the formula $D \propto r^2\sqrt{h}$.

Verify the formula (9) $D \propto \frac{r^2\sqrt{h}}{L}$.

c. Pressure: Disjoin all tubes from the reservoir. Join a T-tube to the nozzle in this position ⊥; join a segment of large glass tubing to the perpendicular arm of the T-tube and support it in an upright position.

(1) Fill the reservoir to the 36 cm. mark, allow the water to escape from the distal end of the T-tube during a unit of time, meantime maintaining the height of the water in the reservoir. Carefully note the height at which the water stands in the upright tube—the *piezometer*.

(2) Repeat with water maintained at 64 cm. height in the reservoir.

(3) Join a length of large tubing to the distal end of the T-tube; repeat the experiment using only the 64 cm. height.

(4) Join a T-tube to the distal end of the segment of tubing just added and repeat the experiment. Does the addition of the last T-tube make any essential change in the height, at which the water stands in piezometer No. 1? Does the reading of piezometer No. 2 agree with the reading of piezometer No. 1 in experiment (2).

(5) Add a second segment of large tubing. Repeat the experiment. Does reading of piezometer No. 2 correspond with reading of piezometer No. 1 in experiment (3)?

(6) Add piezometer No. 3. (Note: The piezometers

may be held in position by using the two supports and the pine stick.) Repeat the experiment. Does reading of piezometer No. 3 correspond with that of No. 2 in experiment (4) and with No. 1 in experiment (2)? Does reading of piezometer No. 2 correspond with that of No. 1 in experiment (4).

(7) Attach a large capillary, repeat observations.

(8) Attach a fine capillary and repeat observations. What is the relation of pressure to height of column? Does pressure vary as height or as the square root of height; i. e., which of the following formulæ represents the facts?

(10) $P \propto h$.

(10′) $P \propto \sqrt{h}$.

What is the relation of pressure to the central resistance (Rc)?

What is the relation of pressure to distal resistance. (Rd)?

Which of the following formulæ represents the facts:

(11) $P \propto Rc$.

(11′) $P \propto Rd$.

V. THE FLOW OF LIQUIDS THROUGH TUBES, UNDER THE INFLUENCE OF INTERMITTENT PRESSURE. THE IMPULSE WAVE.

1. *Appliances.*—Two glass tubes of about 6 mm. lumen and about 75 mm. long; a thin elastic tube,—thin walled black rubber—of about the same lumen as the glass tube and about 150 cm. long; a double valved strong rubber bulb (about 7.5 cm. long); elastic tubing, large size; very thick walled rubber tubing for joining up the apparatus; Y-tube; two flasks, or water receptacles; heavy linen thread; a wide capillary and a fine capillary; a piece of glass tubing 10 cm. long; 500 cc. graduated cylinder.
2. *Preparation.*—Join the large elastic tube to the entrance valve of the bulb. Couple the two glass tubes closely and join one end to the exit valve of the bulb. Make all joints as close as possible and tie tightly with thread. Draw a coarse and a fine capillary tube from the 10 cm. piece of glass tubing.
3. *Operation.*—Clasp the bulb in the hand and make rhythmatical contractions at the rate of about fifteen in ten seconds. The process will, of course, pump the water from one flask into the other.
4. *Observations.*

   a. *Intermittent force and inelastic tubes.*

   (1) Does the stream of water which is ejected from the exit tube flow in a constant or in an intermittent jet?

   (2) Attach a wide capillary and repeat. What is the character of the stream?

(3) Attach a fine capillary and repeat. Note the results.

b. Intermittent force and elastic tubes.

(4) Disjoin the glass tubing from the bulb and join the elastic tube. Work the bulb as directed above, and observe the character of the flow.

(5) Join on the coarse capillary and repeat, noting the change.

(6) Replace the coarse capillary by the fine capillary and repeat. Sum up the results and formulate conclusions.

c. Quantitative tests.

(7) How much water will be ejected through a fine capillary tube in ten seconds in experiment (3)?

(8) How much through a fine capillary in the same time in experiment (6).

NOTE: In performing experiments (7) and (8) great care should be used to exert exactly the same force upon the bulb. The same capillary should be used in the two experiments.

What is the significance of these two experiments?

d. The impulse wave. Graphic tests.

Appliances.—Support; cork-board (about 8 by 10 cm.); small glass rod about 20 cm. long; corks; needles; kymograph; piece of sheet lead 1 cm. wide and 5 cm. long; copper wire No. 16. Make a tracing lever from the glass rod by drawing out one end to a rather fine point and drawing the other to about one-half its original diameter and bending it to make an angle of 135. Bend up 1.5 cm. of each end of the sheet lead so that it will stand at right angles to the middle two cm., bore the cork and pass the larger end of the tracing lever through it. Fix the cork-board to a ring of the support with copper wire; fix the sheet lead to

one end of upper surface of the cork-board with copper wire and pass a needle through the limbs of the lead bearings and the lever-cork in such a way as to bring the lever over the middle of the board. The completed apparatus will have the relations indicated in the accompanying cut. [See Fig. 4.]

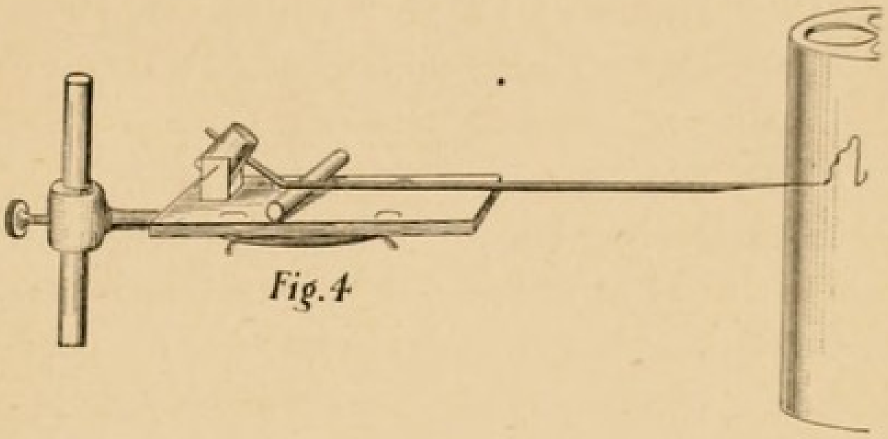

Fig. 4

(9) If the finger be held upon the elastic tube while the bulb is being rhythmatically squeezed, a series of impulses or pulsations will be felt by the finger. Place one finger upon the elastic tube near the bulb, and another three or four feet from the bulb. Let the bulb be pumped with sudden, but infrequent contractions. Do you note a difference in the time of pulsation felt by the two fingers? If so, which is felt first? Why? What is the cause of the pulsation?

(10) To get a tracing of this pulse, pass the rubber tube across the cork board under the tracing lever [See Fig. 4]; adjust to kymograph and take tracing. Vary the character of the bulb contractions as follows: Taking one complete rotation of the drum for each variation:

(I) Slow initial contraction of bulb and slow relaxation.

(II) Slow initial contraction of bulb and quick relaxation.

(III) Quick initial contraction of bulb and slow relaxation.

(IV) Quick initial contraction of bulb and quick relaxation.

(V) Same as IV with slow rhythm.

(VI) Same as IV with rapid rhythm.

Make a careful study of these tracings and determine :

First, the characteristic and essential features.

Second, the accidental and nonessential features.

Third, what is the cause of the essential.

Fourth, what is the cause of the nonessential features.

VI. THE LAWS OF BLOON PRESSURE DETERMINED FROM AN ARTIRICIAL CIRCULATORY SYSTEM.

1. Appliances.--Two large Y tubes of about 6 mm. lumen; four medium Y tubes, lumen about 4 mm.; eight small Y tubes, lumen about 2 mm.; six thick walled capillary tubes, about 3 mm. outside measurement, and lumen not to exceed 1 mm. These capillary tubes should be about 15 cm. long. Two T-tubes of medium lumen; two medium sized glass tubes about 75

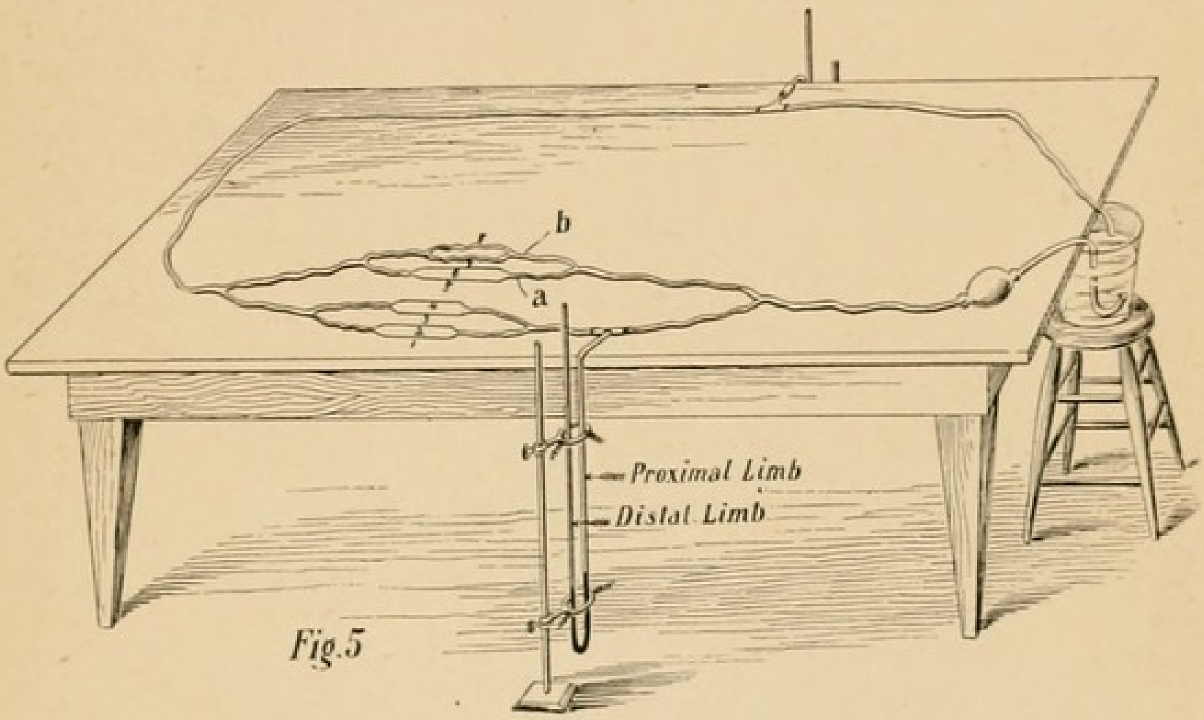

Fig. 5

cm. long. All rubber tubing should be thin walled and very elastic, and should be in three sizes, corresponding to the glass tubes. Two pieces of large size, 75 cm. long, and two pieces about half that length; four pieces of medium size, about 40 cm. long; ten pieces of small size; bulb, thread, heavy linen, mercury, large glass receptacle for water, two medium sized rubber couplings.

2. *Preparation.* — First, make two manometers whose distal limb shall be 40 cm. long, and proximal limb 30 cm., with a horizontal shoulder 5 cm. long. Second, draw out the two limbs of the medium Y tube until they are about the same in size as the small tubing (see Fig. 6). Third, construct the artificial circulatory system according to Fig. 5.

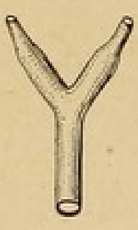

Fig. 6

3. *Operation.*—First, supply the monometers with mercury so that there shall be 12 to 15 cm. in each limb of the arterial manometer, and 5 to 10 cm. in each limb of the venous manometer. If the class is not familiar with the use and interpretation of the manometer, the demonstrator should lead them to discover all of its essential features. Second, the whole system should be filled with water and freed from air before the observations begin. Third, care should be taken that no stoppage in the system occurs ; otherwise the mercury may be thrown out of the manometers and lost.

4. *Observations.*

   a. *The manometer* (mercurial).

      (1) Find the actual pressure when the mercury in the distal column stands 6 cm. higher than that in the proximal column.

      (2) Find the pressure per square cm. where the observation is the same.

      (3) Which of these data would be the more valuable to record ?

      (4) After the arterial circulatory system has been freed from air and is at rest, do the proximal and distal columns of mercury stand at the same level ? If not, why? What allowance, if any, should be made for this ?

   b. *Arterial pressure.*

(5) With capillaries 1 to 6 open and tubes 7 and 8 closed, let one member of the division make strong rhythmatical contractions of the bulb at the rate of about 20 per second. Note effect on manometer. Account for all of the phenomena.

c. Venous pressure.

(6) Note the effect of the contraction upon the venous manometer. If there is any change in the manometer, compare in rhythm and in extent with the changes in the arterial manometer.

d. Relation of arterial to venous pressure.

(7) Make very slow contractions. Note results.

(8) Make rapid, strong contractions. Note results.

(9) Make rapid, weak contractions. Note results:

(10) Remove the clamps from vessels 7 and 8 (local dilation of arterioles) and repeat experiments 7, 8 and 9, noting and interpreting results. What effect does a dilatation of arterioles have upon venous pressure? What effect does it have upon arterial pressure?

e. Pressure formulæ.

Let: P = pressure,
Pa = arterial pressure,
Pv = venous pressure,
Hd = strength of contractions,
Rd = distal resistance,
v = velocity,
r = radius of vessel,

will your observations justify the following formulæ?

1. $Pa \propto H$.
2. $Pv \propto H$.
3. $Pa \propto Rd$.
4. $Pv \propto Rd$.
5. $Pa > Pv$.
6. $Pa \propto Pv$.
7. $Pa \propto H \times Rd$.
8. $Pa \propto r^2$.
9. $Pa \propto H \times Rd \times r$.
10. $Pa \propto v$.
11. $P \propto H \times Rd \times r^2 \times V$.

Does V depend upon H, do Rd and r^2 have any relation either incidental or essential? Would Pa $\propto$ H $\times$ Rd practically mean as much as formula 11?

f. Graphic record of pulse tracing from the arterial circulatory system.

With the recording apparatus used in Chapter V. or with a sphygmograph, or better, with both pieces of apparatus, make tracings of the pulsations of the arterial tubes "a" and "b." (See Fig. 5.) Compare all tracings carefully and interpret all the features of the record, differentiating the essential from the nonessential, as before.

VII. THE PULSE, SPHYGMOGRAPHS AND SPHYGMOGRAMS.

1. Appliances.—A sphygmograph; tracing slips; a fish tail gas jet, or kerosene lamp; a fixing fluid of 2 per cent gum damar in benzole. If each division has a wide mouthed bottle of this solution the tracing may be quickly dipped, drained and dried upon a piece of filter paper, or newspaper. (A fixing fluid after this formula is excellent for the kymograph tracings.) It may be kept in a large museum jar and the tracings dipped into it whole, or in sections.

2. Preparation.—Smoke about two dozen tracing slips.

3. Operation.—The adjustment of the sphygmograph. That the sphygmograph is so little used by the general practitioner may be attributed to the fact that hurry of business, or some other cause, has hindered him from making himself thoroughly conversant with the adjustment and use of the instrument, with its limitations and with the interpretation of the tracings.

First. Let the observer stand with his right foot on a chair. This brings his thigh into a horizontal position.

Second. Let the subject stand at the right of the observer, resting the dorsal surface of the left forearm upon the observer's knee.

Third. Let the observer with pencil or pen mark the location of the radial artery.

Fourth. Let the observer wind the clockwork which drives the tracing paper; adjust the latter in readiness for tracing; rest the instrument upon the

subject's arm with its foot upon the radial artery and adjust the position, tension and pressure, in such a manner as to obtain the maximum amplitude of swing of the tracing needle. Take the tracing. Study.

4. Observations.

a. The location, etc., of the radial artery.

(1) What are the relations of the radial artery at the distal end of the radius?

(2) How may the relations vary?

(3) Is there any variation, among the members of the division, in the location of the radial artery?

(4) May excessive muscular development effect the ease with which the artery may be located and its pulsations studied?

(5) May excessive deposit of adipose hinder the observations of the pulse?

(6) May faulty position of subject or of his clothing effect the pulse?

b. The observation of the radial pulse.

(7) Feel the pulse with the side or back of the finger; then with volar surface and tip of each finger of each hand and note the finger or fingers with which the feeling is most acute. It will be wise to always use these fingers in all tactile examinations. Their acuteness will increase with practice. One may thus acquire the educated touch—TACTUS ERUDITUS.

(8) How much may be learned of the pulse by means of the touch alone. Observe and note (*a*) frequency; (*b*) character; (*c*) rhythm; (*d*) size; (*e*) compressibility. (*f*) What else may be determined by this method?

(9) Take at least three pulse tracings of each individual in the division. (*a*) Compare the trac-

ings taken from one individual; if they differ, determine the cause of the difference. (*b*) Compare tracings of different members of the division. Determine, if possible, the causes of differences.

(10) Does location or relations of the artery effect the sphygmogram? Does the adjustment of the instrument effect the sphygmogram? Does the elasticity of the artery effect the tracing? How does strength or rate of heart beat effect it?

Make a list of the facts regarding the condition of the circulatory system which may be determined with the help of the sphygmograph. Make a list of the precautions necessary to observe in the use of the sphygmograph.

VIII. TO DETERMINE THE GENERAL INFLUENCE OF THE VAGUS NERVE UPON THE CIRCULATION.

(Let six students work together.)

1. Appliances.—Student operating case containing scissors, scalpel, artery forceps, 3 serre-fines, silver probe; and a pair of barber's clippers; a rabbit board; large sheet of heavy paper; sealing wax; cotton; ether; thread; 1 Daniel cell; inductorium; vagus electrode; 2 Du Bois keys; 7 wires; stethoscope; a strong, adult rabbit.

2. Preparations.—Let the six students be subdivided into three groups of two students each.

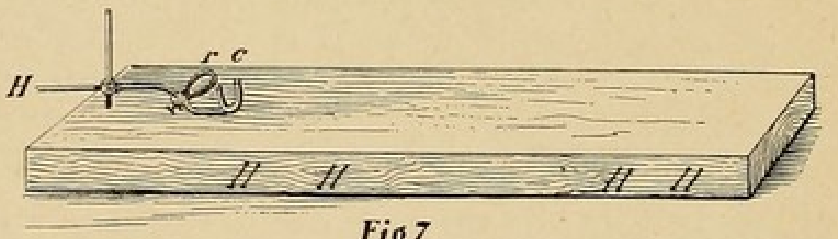

Fig. 7

Let group "*a*" be responsible for the anæsthesia. Use the sheet of heavy paper to make a conical hood, whose spiral turns may be held in place with sealing wax. Place a wad of cotton loosely in the mouth of the cone.

Let group "*b*" perform the operation. Fix the rabbit, back downward, upon the holder; fix the nose in special holder (see Fig. 7); with the barber's clippers remove the hair from ventral side of thorax and neck; make hands and instruments *clean*, place instruments in a shallow basin of warm, 1 per cent carbolic acid solution; cut two or three ligatures of thread and place them in the instrument-basin.

Let group "*c*" arrange the electrical apparatus for stimulation of the nerves. Fill the cell; join up with key in the primary circuit, and a short circuiting key in the secondary circuit. Test the apparatus to see if everything is in order.

3. Operation.—

Group "*a*." (1) Pour 2 cc. or 3 cc. of sulphuric ether upon the cotton in the cone; place the cone over the rabbit's nose; observe, and note carefully every step in the anæsthesia.

(2) Carefully note the rate of the heart beat before beginning anæsthesia.

(3) Keep the cotton moist with ether; watch the respiration and pulse, and be careful not to give the animal too much and interrupt the experiment.

Group "*b*." Wash the clipped surface of the throat.

After the rabbit is completely anæsthetized, make with scissors a median incision through the skin, beginning at the apex of the sternum and cutting anteriorly for about 5 or 6 cm., divide the subcutaneous connective tissue over the middle of the trachea. Carefully separate from the median line on either side laterally the subcutaneous connective tissue with the associated adipose tissue.

How many pairs of muscles come into view? What two muscles approach the median line to form the apex of a triangle at the anterior end of the sternum? Observe a pair of thin muscles lying dorsal to the muscles just mentioned and joining in the median line to form a thin muscle sheet covering the trachea on its ventral side? What muscles are these?

Carefully lift up the median edge of the sterno-mastoid muscle and separate with the handle of a

scalpel or a seeker the delicate intermuscular connective tissue. A blood vessel and several nerves come into view.

Is the blood vessel an artery or a vein? How many large nerves accompany the blood vessel?

Take hold of the sheath of the vessel, lift it up and note in the connective tissue accompanying the blood vessels two nerves, one large and one small. When the artery is in its normal position, what relation do these two nerves sustain to it? Which of the two nerves is external and which is dorsal to the blood vessel? Which is in close relation to the artery? What is the name of each of the nerves?

In preparing the nerve for stimulation one should neither grasp it with the forceps nor with the fingers. It may be separated from the delicate connective tissue in which it lies by use of a blunt seeker. Far better than any metallic instrument is a small glass rod drawn to a point, curved and rounded in the Bunsen lamp. Prevent the tissues drying up by occasionally pressing them lightly with pledgets of cotton moistened in salt solution (0.6 per cent).

Adjust the electrode carefully upon the vagus and see that no unnecessary tension is allowed to be exerted upon the nerve. It is usually necessary to hold the electrode in place during the observation.

Group "*c*." The preparatory step in making stimulation is the closure of the primary circuit. Why? The next step is to ascertain for certain that there is an inductive current. How? Now with the induction current, short circuited, how may you stimulate? Will it probably be better to stimulate with a strong or with a weak current at first? If with a weak current first, give reason. How would you verify your posi-

tion by experiment? If you adopt a weak stimulation at first, how will you arrange the apparatus to obtain it?

4. *Observations.*—

a. Anæsthesia.

(1) Are you able to make out different stages in anæsthesia?

(2) How many stages did your animal manifest?

(3) Give the characteristics of each stage.

(4) What effect did the ether have upon the rate of heart beat.

(5) What effect did the ether have upon the respiration?

b. The stimulation of the vagus.

(6) Stimulate one vagus. Note with a stethoscope whether the rate of the heart is increased.

(7) Cut both vagi high up in the neck. Note the rate of heart beat at intervals of five minutes for fifteen minutes.

(8) Stimulate one vagus. Compare the result with that obtained under experiment 6.

(9) Will very strong stimulation bring the heart to a standstill?

(10) If the heart was brought to a complete standstill by the stimulation, will it start up again spontaneously when the stimulus is removed? Will the rate reach the degree of acceleration observed in experiment 7?

(11) Sum up the observations into a concise statement as to the influence of the vagus upon the heart.

(NOTE: Dispatch the rabbit with chloroform.)

B. RESPIRATION.

IX. EXTERNAL RESPIRATORY MOVEMENTS—INTRA-THORACIC PRESSURE.

1. Appliances.—Operating case; clippers; rabbit board; rabbit; cone for anæsthesia; ether; kymograph; cardiograph, which may, in this case, be called a rabbit stethograph; two recording tambours; 10 cm. of glass tubing, 3 mm. lumen; rubber tubing to match.

2. Preparation.—

(1) Fix and anæsthetize rabbit.

(2) Clip and shave ventral aspect of rabbit's thorax.

(3) Make thorax of rabbit, instruments and hands clean.

(4) Prepare a thoracic cannula by drawing the glass tube slightly in the center, cutting diagonally at the middle, smoothing diagonally on an emery stone.

(5) Join a 30 cm. piece of rubber tubing to the cannula at the larger end, and clamp it near the cannula.

(6) Cleanse cannula thoroughly.

3. Operation.—

a. External respiratory movements.

Place the button of the rabbit stethograph upon the ventral surface of the rabbit as near as possible over the junction of the diaphragm with the body wall, and a little to the right or left of the median line. So adjust the stethograph as to obtain the maximum excursion of the recording lever. The stethograph may be held in position through the agency of a clamp and support; sometimes, however, better results may be

secured by holding the stethograph in the hands, supporting the wrists on the edge of the rabbit board.

b. Intra-thoracic pressure.

Locate an intercostal space to the left of the sternum and opposite its middle point. Make an incision 0.5 cm. long, parallel with the intercostal space and 1 cm. from the sternum. Dissect through the intercostal muscles, taking care not to cut the pleura. Insert the point of the glass cannula into the wound, press it carefully through the pleura into the left pleural cavity or mediastinum as may frequently chance, turn the distal end of the cannula sharply outward until the instrument has a nearly horizontal position. Pass the cannula through the intervening pleural membranes into the right pleural cavity. Join the rubber tube to a recording tambour and unclamp. Slowly and gently manipulate the cannula until there is evident communication through the lumen of the cannula and tube from the pleural cavity to the tambour.

So adjust the cannula that the recording lever makes the maximum excursion. Bring the levers into such a relation to the kymograph that the tracing point of the stethograph lever shall be vertically over that of the lever which is to record intra-thoracic pressure, and about two centimeters from it. At the end of the observations close the wounds and dress it aseptically.

4. Observations.—

a. External respiratory movements.

(1) During one revolution of the drum—5 minutes—note the rate and rhythm of the respiratory movements as recorded by the stethograph.

(2) Does the stethogram show anything more than rate and rhythm ?

(3) What phase of a respiratory cycle does a rise of the lever indicate?

(4) What is the relative duration of inspiration and expiration as indicated by the stethogram.

(5) Does the stethogram indicate any variation in different parts of the inspiratory act? Of the expiratory act?

(6) Differentiate the essential from the nonessential in the stethogram and determine as far as may be, the cause of each.

b. *Intra-thoracic pressure.*

(7) Does the rhythm of varying pressure correspond to the rhythm of the respiratory movements?

(8) If so, does that necessarily establish the relation of cause and effect between them?

(9) What change of pressure is indicated by the rise of the pressure lever?

(10) What movement of the pressure lever corresponds to a rise of the stethograph lever?

(11) What is the condition of intra-thoracic pressure during inspiration? During expiration?

(12) Stop the entrance of air into the respiratory passage by closing the rabbit's nostrils. What effect does this have upon the respiratory movements?

(13) Is the intra-thoracic pressure affected by the experiment? If so, explain the effect.

(14) If two phenomena involving the same matter, correspond perfectly in their cycles, and if a variation of one is always accompanied by a variation in the other, can there be any reasonable doubt that they sustain to each other the relation of cause and effect?

(15) Which of the phenomena studied is the cause and which the effect? Demonstrate.

c. To measure intra-thoracic pressure.

(16) Clamp the rubber tube of the pressure apparatus. Replace the recording tambour with a water manometer. Unclamp.

Is the pressure during inspiratlon positive or negative, and how much?

(17) Is the pressure during expiration positive or negative, and how much?

(18) If the whole apparatus were filled with water instead of air and water, would it make any essential difference in the result? What effect do the variations of the intra-thoracic pressure have upon the circulation? Upon the respiration?

X. RESPIRATORY MOVEMENTS IN MAN.

1. Appliances.—Kymograph; stethograph; spirometer; tape measure; wooden and steel calipers. A simple but efficient stethograph may be made as follows: Materials: support, three large clamp holders, iron rod, 8 or 10 mm. in diameter and 50 cm. long, two wooden rods, 1 cm. in diameter and 40 c. long, a receiving tambour, a transmitting tambour with support.

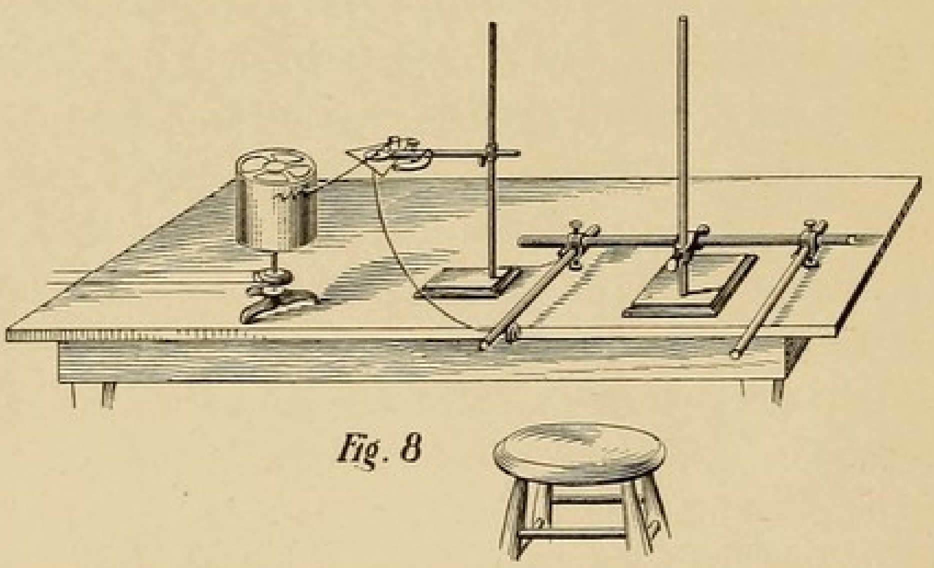

Fig. 8

2. Preparation.—To make a stethograph: Clamp the center of the iron rod to a heavy-base support. Clamp the wooden rods to the iron rod so that they will extend out to one side of the iron rod in a horizontal plane. (See Fig. 8.)

A receiving tambour may be constructed especially for this purpose as follows: Let a tinsmith construct, from small brass wire, (½—¾ mm. in diameter), spiral springs which shall present the outline of truncated cones (See Fig. 8 *a.*), and fit inside the larger tambour pans.

If the student be supplied with tambour pans, spring, sheet rubber, thread, sealing wax and cork, he may construct his receiving tambour by placing the spring in the tambour pans, stretching the sheet rubber over the spring, tying and sealing. The now conical diaphragm of the recording tambour should be provided with a cork button, and adjusted by passing its tube through a horizontal hole near the end of one of the wooden rods (see Fig. 8), and connecting to the transmitting tambour through a small rubber tube.

Fig. 8 a

3. Operation.—Each member of the division should in turn remove all clothing above the waist and be the subject of observation for the other members. In making observations with the stethograph the subject should sit with his back or side to the table. The observer may readily adjust the stethograph to record the changes of any lateral or dorso-ventral diameter of the thorax. For all observations, whether with the stethograph, calipers or tape, the subject should keep the parts of the body symmetrically disposed.

4. Observations.—

a. Inspection.

(1) How much may be learned of man's respiratory movements by simple inspection? Make a careful enumeration and record.

b. The stethographic observations.

(2) Adjust the stethograph and make a record—a stethogram—of the changes of the lateral diameter of the thorax at the ninth rib.

Does the stethograph show more than could be learned from inspection? If so, what?

(3) Take a stethogram of the lateral diameter at the sixth rib. How does it differ from the ninth rib stethogram? Why?

(4) Take a stethogram of the dorso-ventral diameter of the thorax over the lower end of the gladiolus. Compare.

(5) Take these typical stethograms while the subject reads a paragraph, sighs, coughs, and laughs. Account for the peculiarities.

(6) Take the three stethograms after the subject has taken vigorous exercise. What changes are to be noted?

(7) After a similar series of stethograms have been taken for others, compare; determine the essential features; give causes of these.

(8) Seek the causes of the differences which exist between stethograms of different individuals. May they be accounted for by stature, condition, occupation or habit?

c. The spirometer.

(9) Test the lung capacity of each member of the division. May differences in lung capacity be accounted for by difference in stature, condition, occupation or habit?

d. The girth of the chest.

(10) Take the girth of chest in a horizontal plane over the nipple.

(*a.*) With chest in normal repose.

(*b.*) At the end of forced expiration.

(*c.*) At the end of forced inspiration.

(11) Take the girth of chest in a horizontal plane over the juncture of the ninth rib with its cartilage with the chest normal, empty and full.

(12) With calipers measure (*a*) horizontal dorso-

ventral diameter in plane of nipples, normal, empty and full.

(*b*) Lateral diameter; normal, empty, and full.

(*c*) Lateral diameter over ninth rib; normal, empty and full.

(13) Tabulate results for the whole class including name, age, height, weight, condition (fat, medium or lean), previous occupation, home, (whether in a hilly or flat country), habit, (whether inactive or active); if the latter, what sort of activity (tennis, bicycle, etc.) Make a careful study of this table and state your conclusions.

XI. THE ACTION OF THE DIAPHRAGM.

1. Appliances.—Operating case; clippers; rabbit board, or dog board; rabbit or dog; ether; ether cone; absorbent cotton ; kymograph ; recording tambour ; beaker with warm water ; medicine dropper or bulb. (If a dog be used, the medicine dropper will not be large enough, its place may be taken by a soft spherical rubber bulb about 2 cm. in diameter.) Inductorium, 1 cell, 2 keys, vagus electrode, 5 common wires and 2 fine wires.

2. Preparation.—Fix the animal to the board, anæsthetize, clip anterior median region of abdomen. Put the bulb into the warm water, join the glass tube of the bulb to the recording tambour through a rubber tube. This apparatus thus joined may be called a phrenograph and its record a phrenogram.

Set up electrical apparatus with short circuiting key in secondary coil.

3. Operation.—From the posterior extremity of the xyphoid appendix make a median incision through the abdominal walls from 3 cm. to 5 cm. according to the size of the animal. Clamp with your serre-fines any small vessels which may be oozing. After having clamped the rubber tube, which connects the bulb to the tambour, carefully insert the warm, wet bulb between the diaphragm and the liver. The liver will usually afford sufficient resistance to cause alternate compression and relaxation of the bulb and a consequent rise and fall of the recording lever; if such be not the case, the liver may be held in place by two fingers inserted into

the wound. In the meantime let another member of the division dissect out the left phrenic nerve. Fig. 9 shows the relation of the phrenic at the base of the neck, in the rabbit.

4. *Observations.*—

a. Tactile observation of the diaphragm.

(1) In what condition is the diaphragm during inspiration? Expiration?

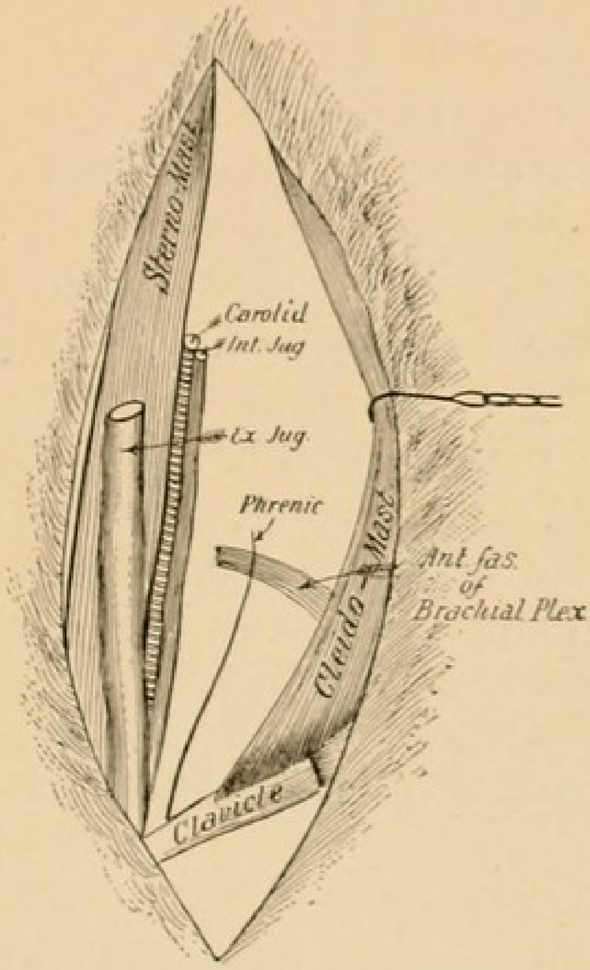

Fig. 9

(2) In what position is the diaphragm during these two phases of respiration?

(3) What parts of the diaphragm make the greatest change of position during inspiration?

(4) What causes the diaphragm to arch anteriorly during normal expiration? During the present observations?

(5) Are the diaphragmatic movements synchronous with the costal movements?

b. *The normal phrenogram.*

(6) Take a phrenogram. What may be learned from it?

(7) Without varying the adjustment of the phrenograph bulb, take a tracing while repeatedly interrupting the respiration by holding the nostrils. What does the phrenogram show? What is the interpretation?

If you had taken a tracing of intra-thoracic pressure, what would it have shown?

c. *The phrenic nerve and its function.*

(8) Describe minutely the relations of the nervus phrenicus in the neck.

(9) Cut the nerve while tracing a phrenogram from the left side of the diaphragm. Note the result.

(10) Take a phrenogram from the right side of the diaphragm. Does it differ essentially from the normal?

(11) While taking a left phrenogram stimulate the distal end of the left phrenic nerve. Interpret the result.

(12) While taking a right phrenogram stimulate the distal end of the left phrenic nerve. Interpret the result.

(13) Dissect out and cut the right phrenic nerve.

Does the diaphragm cease to move? If it moves, is its movement active or passive? Account for the phenomena.

Kill animal with chloroform.

XII. *a.* RESPIRATORY PRESSURE.

B. STIMULATION OF PULMONARY VAGUS THROUGH INCREASE OF INTRA-PULMONARY PRESSURE.

1. Appliances.—Operating case; clippers; rabbit board; ether; ether cone; absorbent cotton; rabbit stethograph; kymograph; a small mercury manometer, to the proximal limb of which is attached a thick walled rubber tube, a piece of glass tubing for a mouthpiece; a screw clamp.

2. *Preparation.*—Fix and anæsthetize the rabbit, and clip the ventral surface of the neck. Join up the manometer as shown in Fig. 10.

3. Operation.—Make a longitudinal incision over the trachea. Carefully pass a strong linen ligature under the trachea. Make a median ventral slit in the trachea anterior to the ligature. Pass through the slit, the limb of the Y-tube marked 1. (Fig. 10.) Ligate.

4. Observations.

a. Respiratory pressure.

(1) After the ligature is tied how does the rabbit breathe? Are the thoracic and abdominal movements of respiration accompanied by other respiratory movements?

(2) With tube "n" (see Fig. 10) open is there any variation of the mercury during respiration?

(3) With a screw clamp slowly close tube "n." As the resistance to the flow of air increases what change is noted in the manometer?

(4) Quickly clamp tube "n" at end of expiration and carefully note the manometer reading. Is it positive or negative?

(5) Clamp tube "n" at the end of inspiration. Is the pressure positive or negative?

(6) You have been determining certain facts regarding RESPIRATORY PRESSURE. Are the causes of the changes of respiratory pressure the same as the causes of the changes of intra-thoracic pressure?

(7) In what way does respiratory pressure differ from intra-thoracic pressure?

b. Stimulation of the pulmonary vagus.

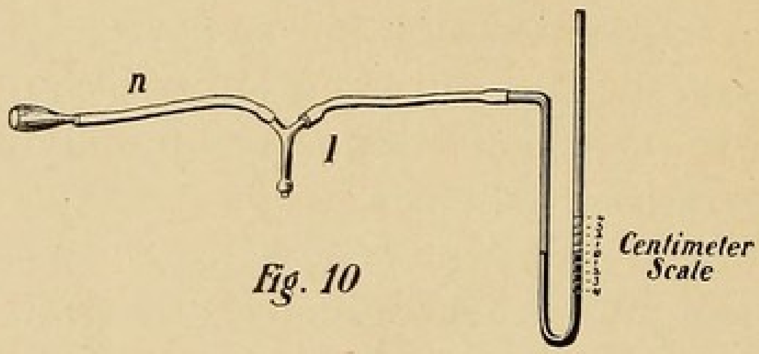

Fig. 10

(8) Count the pulse. Adjust the stethograph, and mouth over the glass mouthpiece; quickly blow into the tube "n" until the manometer indicates two during the tracing of a stethogram place the centimeters of intra-pulmonary pressure; clamp, count the pulse. After a few seconds release the clamp and let the rabbit breathe normally for a few minutes.

Repeat the experiment. Vary by producing in turn 3 cm., then 4 cm. and finally 6 cm. of intra-pulmonary pressure. Fix the stethogram and compare.

(9) Compare your results with those obtained from other rabbits. What are the essential features of

the modified stethogram? Formulate the results.

(10) What effect has a sudden increase of intra-pulmonary pressure upon the rate of the heart's action.

(11) What nerve is distributed to both lungs and heart? Admitting that it is possible for the observed effects to be produced through the agency of the nerves just named, state how this action may be accomplished.

(12) Could the effects be produced in any other way than in that which you have given?

(13) Is the demonstration unassailable, if not, what experiments would lead to results conclusive for or against the theory?

(14) Is the minimum intra-pulmonary pressure, which typically modified the stethogram, greater or less than the respiratory pressure of forced expiration?

(15) What effect upon intra-thoracic pressure would the induction of high intra-pulmonary pressure have?

(16) What effect upon blood flow would high intra-pulmonary pressure accompanied by repeated acts of forced expiration have? What incident effect upon the rate of heart beat?

XIII. RESPIRATION UNDER ABNORMAL CONDITIONS.

1. Appliances.—Three small animals, e. g., mice, rats, guinea pigs or squirrels. Two wide-mouthed bottles or jars which may be sealed; scales or large balances; CO_2 generator; water bath; operating case; dissecting boards.

2. Preparation.—Determine the weight of each animal. Choose a receptacle whose cubic contents is about three to five times as many c. c. as the weight of animal "a" in grams. Choose second and third receptacles whose contents represent about 15 to 18 c. c. to one gram of animals "b" and "c," respectively.

3. Operation.—

I. Preliminary.

b. Put animal "b" into jar "b." Before closing count respirations; close air-tight.

c. Fill jar "c" one-third full of water and displace the water with CO_2. Put animal "c" into the jar, taking care to allow as little loss of CO_2 as possible; close; count respirations.

a. Put animal "a" into the small jar "a"; count respirations; close the jar.

II. Post-mortem examination.

After an animal dies fix it to the dissecting board and open the abdominal and thoracic cavities; take great care not to cut a large blood vessel; pin the flaps out so that all of the organs will be exposed and in place.

4. Observations.—

a. Respiration in small closed space.

(1) Make careful record of number of respirations and general condition of animal "a" in the normal state, and at the end of every five minutes after the closure of the jar.

What changes in rate or depth of respiration have been noted?

(2) Note all abnormal signs and symptoms.

(3) On post-mortem examination record condition of heart, large blood vessels, lungs, liver, kidneys and of the general appearance of the tissues.

(4) Compare the conditions with those found in a normal animal, prepared by the demonstrator.

b. Respiration in a larger closed space.

(5) Note all symptoms of animal "b" every five minutes after confinement in the jar.

(6) Make a post-mortem examination; record in detail the condition of the organs as in the case of animal "a."

(7) Compare animal "b" with the normal animal.

(8) Compare animal "b" with animal "a."

c. Respiration in an atmosphere of one-third CO_2.

(9) Note all symptoms at intervals of five minutes.

(10) Compare these observations with corresponding ones from animal "a" and animal "b." What are your conclusions?

(11) Make a post-mortem examination; make a record as before.

(12) Compare appearances in animal "c" with those in the normal animal; with those of animal "a;" with those of animal "b."

(13) Make a generalized statement of the facts discovered in the experiments.

(14) What is the cause of death when an animal is inclosed in a small space?

(15) What is the cause of death when an animal is inclosed in a large space?

(16) Have the relations which you have discovered any bearing upon the future development of animal life upon the earth?

XIV. RESPIRATION IN ABNORMAL MEDIA.

1. Appliances.—Three small animals; three jars; water bath; hydrogen generator; large test tube of hard glass; support with tube clamp; Bunsen burner; delivery tube; bichromate of potassium; ammonium chloride; operating case; dissecting boards.

2. Preparation.—Construct a nitrogen generator as indicated in Fig. 11.

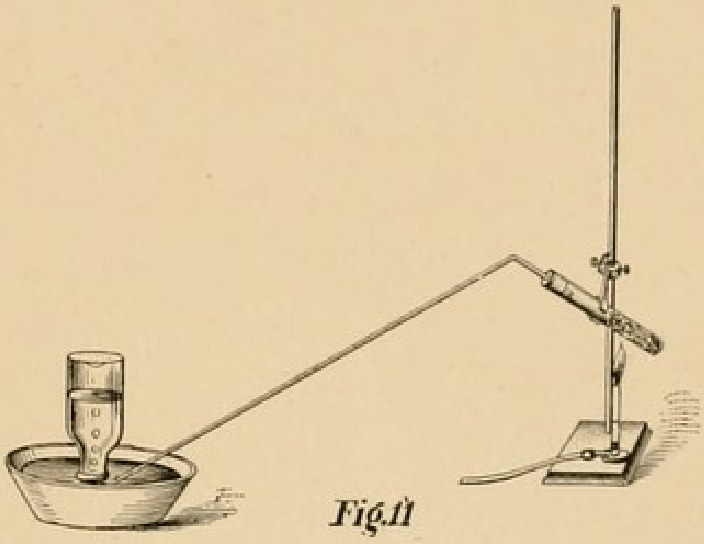

Fig. 11

3. Operation.—

I. Preliminary.

a. Fill a jar full of water; displace the water with nitrogen, generated from 6 gms. of powdered $K_2Cr_2O_7$ + 3 gms. of NH_4Cl in the apparatus shown in Fig. 11. Put animal "a" into the atmosphere of nitrogen; close the jar.

b. Fill a jar full of water, displace it with hydrogen gas. Put animal "b" into the jar and close it.

c. Fill a jar one-third full of water; displace the water with illuminating gas. Put animal "c" into the jar and close it.

II. Post-mortem examination—See XIII. 3 II.

4. Observations.—

a. Respiration in an atmosphere of nitrogen.

(1) Note all symptoms.

(2) How do these compare with those of death by oxygen starvation?

(3) Record post-mortem appearances.

(4) Compare with previous cases.

b. Respiration in an atmosphere of hydrogen.

(5) Note carefully every abnormal appearance and symptom.

(6) Make a record of the post-mortem appearances.

(7) Compare these with the appearances after death by oxygen starvation; by CO_2 narcosis.

c. Respiration in an atmosphere of one-third illuminating gas (CO+).

(8) Record all symptoms.

(9) Record post-mortem appearances.

(10) How does death in an atmosphere of CO compare, as to symptoms, with death in an atmosphere of nitrogen?

(11) Compare it in turn with other forms of death as induced in XIII. and XIV.

(12) Compare the post-mortem appearances in this case with those in preceding cases.