Frederic S. Lee

DIRECTIONS

FOR

Laboratory Work in Physiology

FOR THE USE OF

MEDICAL STUDENTS

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PREFACE

Every one who has attempted to plan a short course of physiological experiments for Medical students, has had to face the fact that only a few of the many experiments which would be desirable, can be satisfactorily performed in the alloted time. The course here outlined contains only such experiments as can actually be made and properly studied by the student himself, working three and a half hours a day for 35 days. An additional week is spent in extra work and examinations. Since the students for whose use this book has been especially prepared, have a special course in physiological chemistry, and are taught the physiology of the eye, etc., in connection with the demonstration courses devoted to the specialties, to avoid duplication, experiments dealing with these subjects have been omitted.

The experiments are arranged so as first to teach the student the use of the graphic method, time recording instruments, and the electrical apparatus employed for excitation. At the same time he becomes acquainted with the general physiology of striated, non-striated, and heart muscle and of the nerves of the frog. He then studies the reaction of his own muscles and nerves to various forms of electrical excitation. Throughout this work, special attention is called to the errors which the apparatus itself may introduce into the graphic records: the need of accuracy of measurements; the value of expressing the figures obtained in plotted curves; the importance of promptly writing up the notes taken during the experiments; and the fact that the reports given, should state what was observed by the student himself, rather than what is written in text books. The latter half of the course deals with the problems of respiration, the circulation, the central nervous system, etc.

Only two afternoons are given to experiments on warm blooded animals, but the experiments with the artificial circulation apparatus, a special quiz on the subjects to be covered, and a "dress rehersal" with the apparatus, have so prepared the way, that even in this short time, many of the most important facts relating to the circulation, respiration and peristalsis are observed.

It is believed that the medical student should as far as is possible, study the physiology of man, and during more than a third of the course, the student, himself, is the subject of the experiment. It is needless to say that the frogs are rapidly killed before being used, and that the mammals employed are thoroughly anaesthetized by the student, under the direction of an instructor.

As most of the students taking the course have no knowledge of physiological methods, the directions for the work have been made as explicit as possible with the object of saving time. Nevertheless, the harm which comes from machine-like work is fully recognized, and students are encouraged to cultivate independence, and permitted to perform the experiments in other ways than those called for in the notes. They are made to feel that the capacity to observe and correctly interpret the results of an experiment, is of even more importance than the ability to make an experiment successfully, and that one who has trained his powers of observation and has learned to accurately report the phenomena he has witnessed, can make a reliable diagnosis and keep a trustworthy case-book.

The library of the laboratory contains many journals, books, monographs and reprints, and the instrument room holds many forms of apparatus especially designed for research work. Every facility of the laboratory is placed at the disposal of those who show that they are capable of independent work.

This edition contains a number of experiments not found in the first, while the directions for many of the other experiments have been practically rewritten. Ten new illustrations have been added.

It gives me great pleasure to acknowledge the aid which I have received in developing the methods employed in this course from the former instructors and assistants

in this department, and especially, from Professor S. P Budgett, Professor A. E. Guenther, Dr. G. G. Crosier, Professor W. P. Bowen, Professor C. J. Wiggers, Dr. F. M. Abbott, Dr. N. N. Wood. and Professor W. F. Koch. I am particularly indebted to Dr. Otis M. Cope for his help in the preparation of this edition.

WARREN PLIMPTON LOMBARD.

Physiological Laboratory
University of Michigan
July 1, 1914.

CONTENTS.

ILLUSTRATIONS.

GENERAL DIRECTIONS

The laboratory hours are from half past one to five o'clock. Each student must have receipts from the Treasurer, to show that the laboratory fee and the key deposit have been paid, and each must have the following articles before beginning the work:

Laboratory text book.
2 celuloid triangles (6-inch).
Dividers.
Flesh pencil.
Forceps with fine point.
Reading glass.
MM rule, 10 cm. long.
Strong scissors with fine points.
2 towels.
Tube of office paste.
2 sheets of millimeter, cross section paper.
40 sheets of note paper, regulation size.
40 sheets of cardboard, regulation size.

Two students will work together, and students are advised to choose their partners early. A list of the following apparatus will be supplied by an instructor, when the two students who are to work together present the Treasurer's receipts, and show the instruments, etc. which are required in the course. The list is to be checked and signed by both of the students who are to use the apparatus. Larger, special pieces of apparatus will be supplied from time to time when needed.

APPARATUS SUPPLIED BY LABORATORY

Division A.

Acetic acid, 10%.
Basin.
Battery jar.
Board for frog.
Brush for salt solution.
Two cells, dry.
Clamp, burette.
2 Clamps, cabinet maker's.
Clamp, large muscle.
6 Clamps for rods.
Coil, aluminum.
Cloth to cover apparatus.
Dropper.
Drum square.

Electrodes, boot form in dish.
Electrode, brass.
Electrode, heart.
Electrode, pin.
Electrode, platinum.
Electrode, sheet of copper.
Filter paper.
Finger piece, wooden.
Fork and yoke.
2 Glasses, drinking.
Glass dish for salt solution.
Glass slide on support.
Hook for frog.
Hooks, pin.
Induction coil.
Key, mercury.
Key opener.
Kymograph and drum.
Lever, heavy.
Lever, light.
Ligatures.
Moist chamber with two clamps.
2 pads, gauze.
Pins.
Plate.
Pulley.
Rod, glass, with clips for boots.
Rod, L, nickeled.
Rod, screw in end.
Rod, zinc.
Rubber band, large.
2 Rubber bands, thin.
2 Signals, electric.
Spring, steel, with pointer.
Stand, long.
Stand, short.
Sodium chloride, 0.6%.
Sulphuric acid, 0.1%.
Thread, silk.
20 Weights, 10 gram.
1 Wire, insulated, extra long.
4 Wires, insulated, medium.
2 Wires, insulated, short.
Zinc sulphate.
2 Zincs for electrodes.

Division B.

Board for frog.
Brush for salt solution.
Cell, dry.
5 clamps, for rod.
1 Clamp, cabinet maker's.
Cloth to cover appratus.
Coil, aluminum.
Drum square.
Electrodes, pin.
Filter paper.
Fork, with yoke.
2 Glasses, drinking.
Glass dish for salt solution.
2 Hooks, pin.
Induction coil.
Key, mercury.
Key opener.
Kymograph with drum, 4 fans.
Lever, light.
Lever, heavy.
Moist chamber with clamp.
Pins.
2 Pinch cocks.
Plate.
2 Pneumographs.
Rod, L, nickeled.
2 Rubber tubes, with glass Ts.
Signal, electric.
Sodium chloride, 0.6%.
Spring, steel, with pointer.
Stand, long.
Stand, short.
Tambour, carotid with spring.
Tambour, radial.
2 Tambours, recording.
Thread, silk.
20 Weights, 10 gram.
5 Wires, insulated, long.
2 Wires, insulated, medium.

Students are to use the apparatus supplied them, and no other. In no case is apparatus to be taken from the shelves or borrowed from other students.

THE BULLETIN BOARD

The bulletin board near the door of the main laboratory is arranged as follows: Horizontal lines give the work of the successive days, each of these being marked with the number of the day in the course, and the date on which the work is to be done; vertical lines enclose spaces headed by the two desk numbers of the pair of students who work together. The numbers of the experiments are marked on colored cards in these spaces. Reference to the board will show on what day each of the experiments is to be performed. The colors of the cards correspond to the colors of the cards placed at the top of the board, giving the names of the instructors, and show to whom the notes and records of the experiments are to be given.

METHOD OF WORK

Each student is expected to perform each experiment, and to make out a full report of the results, accompanied by graphic records which he himself has obtained, when such were demanded by the experiment. He must be prepared to be quizzed on the experiment at the time it is made, and to pass an examination both on the methods employed and the result obtained, at the end of the course. Before leaving the laboratory, the student must see that his desk is clean and neat; that all apparatus is dry; that the battery has been disconnected (it is not enough to leave the key open); that all apparatus is covered. Care must be taken not to injure stools or desks. Of course any apparatus which is injured by a student must be replaced or paid for.

Do not begin an experiment until you have read the directions in the notes, and have clearly in mind the object of the experiment.

EXPERIMENT I.

Extensibility and Elasticity of a Steel Spring.

Apparatus.—The structure of the drum kymograph, the method of fastening the paper on the drum, of blackening the paper, and of fixing the record, will be explained by the instructor.

Examine your kymograph with care and be sure that you understand how the clockwork is wound up; how to change the gearing so as to obtain the faster and slower speeds of the drum; how to arrange drum to be driven by the clockwork or to be rotated by hand; and how to raise and lower the drum. The instrument will be in order when you receive it and must be in order when you return it.

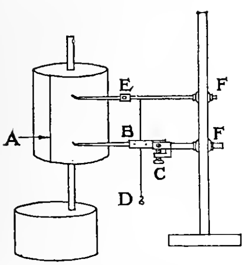


Fig. 1. Apparatus for recording extensibility and elasticity of a steel spring. A, joint of paper on drum; B, lever; C, supporting screw; D, pin hook for weight; E, steel spring; F, F, clamps.

Mount spring with pointer (E) and heavier muscle lever (B) on the longer iron stand, with supporting screw (C) down, as shown in diagram. The stand holding the recording instruments should always be placed to the *right* of the kymograph, so that these instruments shall point in the direction that the drum revolves. The clockwork turns the drum clockwise, and when it is turned by hand it should be rotated always in this direction. If the drum be rotated backward, the recording points are liable to be injured. All records should read from left to right. Decide at what part of the drum the record is to be made *before finally clamping the recording apparatus on the stand.* Fasten two pieces of thread to the writing lever at the hole second from the axis, and attach one of the threads to the spring 8 cm. from brass supporting rod, and the other to a pin hook as shown in diagram. Observe the following cautions:

1.—See that the axis of the writing lever is horizontal.

2.—See that the thread connecting the lever with the spring is vertical.

3.—See that the knots are securely fastened.

4.—See that every clamp is screwed firmly in place.

Now remove the drum from the kymograph, fasten a sheet of glazed "curve paper" smoothly around the drum, and blacken the surface evenly over the gas flame, rotating the drum constantly so as not to burn the paper. Replace the drum, place the kymograph so that the writing lever is tangent to drum surface, touching lightly. *Notice that lever writes an arc on a curved surface.* If barely touching when horizontal, it will leave the surface and fail to write as it moves up or down. The lever should press on the drum just enough to write for 2 or 3 cm. above and below the horizontal line falling through its axis. The position of the point with reference to drum and joint of paper (A) is indicated in the diagram.

EXPERIMENT.—Turn the drum by hand in a clockwise direction to draw a base line 8-10 cm. long. Turn it back (taking care not to injure writing points) to the starting point and mark the place by touching the lever lightly. Now turn drum clockwise ½ cm. and then carefully place a 10 gram weight on the pin hook. Turn same distance again and add another weight. Continue in this manner until 9 weights have been added, then turn the drum ½ cm. once more. The writing point has now recorded the curve of extensibility of the spring. To obtain curve of elasticity, turn drum ½ cm. in same direction and remove one weight, and continue in this manner until all the weights are off, then turn ½ cm. once more, and mark point by touching lever.

The vertical distances recorded on the drum should be of equal length. If they are not, try to account for the error. Since steel is perfectly elastic, the writing point should return to the base line. If it does not, try to account for the difference.

MOUNTING OF CURVES.

Using the two triangles and a needle, or other instrument with a sharp point, draw a rectangle about each record worth preservation. It is desirable to leave a generous margin about the curve. Cut out piece thus outlined, and mount on the cardboard by gluing the corners on with a little paste. If a knife be used to cut off the piece, cut upon a piece of cardboard. Do not cut on the table. To protect the curves, place over them the sheet of paper upon which the notes concerning the experiment have been written. Let the right hand end of the sheet overlap the cardboard slightly, and fasten it to the back of the cardboard with paste. Do not write on cover paper when it is over a curve.

THE STUDENT'S NOTES.

Write as plainly as possible on the *upper left hand corner* of the paper which covers the curves, your name and desk number, and the *number of each of the experiments* mounted on the card. Also head each mounted curve with the number of the experiment and the letter of the subheading to which it belongs, and label the corresponding notes on the cover paper in like manner.

The notes should contain an accurate statement, not of what the books say on the subject, but of the results actually obtained by you in performing the experiment. Do not describe the method of the experiment unless it is different from the directions in these notes, in which case let the explanation contain all the facts required to let another understand the exact conditions of the work. Mention all sources of error which are likely to arise from the method used. This is most important. An apparatus is a servant employed to make observations. You must know in what respects its report is to be trusted and where it is liable to deceive. It is worse than useless to employ apparatus in experiments or in physical examinations unless you know your apparatus thoroughly. If the results obtained differ from those which you know to be usually obtained in similar cases, try to explain why the difference occurs.

Look upon each experiment as a piece of original research, and do not be satisfied with simply carrying out directions. Learn to cultivate the power of independent observation and thought. You will be judged as much by the originality displayed in your reports as by the accuracy of your work. If you can learn to observe accurately and to record your observations concisely and at the same time in sufficient detail to make another understand the results of your experiments, you will be able to make a valuable physical examination and keep a reliable case book.

EXPERIMENT II.

Extensibility and Elasticity of Frog's Muscle.

APPARATUS.—Mount moist chamber on standard, and fasten threads to lever so that it will magnify the movement 6 times. Have all apparatus in readiness and the drum blackened before preparing the muscle.

METHOD OF KILLING FROG.

Kill a frog under the direction of a demonstrator. Straighten hind legs by letting hand glide over body, and wrap legs in dry cloth. Insert one blade of strong scissors into mouth as far back as angles of jaw, and with the other blade across the head *as far back as possible,* remove skull by a single cut of the scissors. The cut should fall at the back of the tympanic membranes, (See E, Fig. 9). In making the cut, hold frog, head down, over a plate. Cut off hind legs close to body. As there is a possibility that the brain may recover from the shock, complete its destruction by thrusting a blade of the scissors into the cranial cavity and breaking up the brain. There is no evidence that the rest of the nervous system is capable of feeling; nevertheless, as a matter of precaution, destroy the spinal cord and all remnants of the brain with a pithing needle. Be sure that all of the central nervous system has been destroyed, for even comparatively small parts in cold-blooded animals can recover from severe shock.

MUSCLE PREPARATION.

Remove the skin from the leg, and put leg on piece of filter paper moistened with physiological salt solution. Clean off the thigh muscles from femur without injuring tendon of the gastrocnemius muscle. Cut tendo-Achillis below ankle and separate gastrocnemius from tibia. Remember that you are not in the dissecting room, and that you are dealing with living tissues. Do not touch the muscle with the fingers, nor pinch it, nor injure it by pulling on it, etc. It can be handled by holding the tendon with forceps. Cut off tibia just below knee, insert and fasten femur in clamp in moist chamber, put pin hook through middle of tendo-Achillis, and in doing this avoid pulling on muscle. Place a piece of wet filter paper in the moist chamber.

a. EXPERIMENT.—Repeat the work of Experiment I, allowing an interval of *ten seconds* between the addition or removal of any two weights. The drum should be moved at the end of *10 seconds,* in order that any delayed effect of the change in load may be recorded in the proper place. After removing last weight and waiting 10 seconds, if the writing point has not returned to the base line, turn drum again and wait one minute, repeat until lever ceases to rise or base line is reached. Plot the curves of extensibility and elasticity of muscle. If several curves are taken with the same muscle, keep them all and label 1, 2, 3, etc. *Explain in your notes the differences observed.*

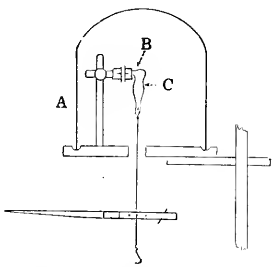


Fig. 2. Apparatus for recording extensibility and elasticity of frog's muscle. A, moist chamber; B, femur fastened in bone clamp; C, muscle.

b. *Plotting of Curves.*—The curves drawn by the writing point are inexact in two respects: the point does not move in a vertical line, and the drum may not be moved equal distances. To obtain exact curves of the extensibility and elasticity, proceed as follows. Take a piece of cross section paper and draw heavy lines for the two axes. Mark dots at equal distances along the horizontal axis (the abscissa) and number them 0-10-20, etc., to represent the weights used, writing *grams* at end of line. Place along the vertical axis (the ordinate) at equal distances the numbers 0-5-10-20, etc., to represent the number of millimeters through which the writing point moved, writing *mm,* at the head of the column. As the separate movements are small, it may be wise to let each millimeter of movement be represented by 2 or 5 millimeters of the paper. Measure with the aid of a magnifying glass, and the millimeter rule the exact height of each movement recorded. It is usually best to make the measurements all from the base line. The amount of the individual movements can be obtained by subtraction. Give these measurements in your notes, in order that they may be checked, and enter the results on the chart, by marking, for each observation, a dot at the point of intersection of the vertical line corresponding to the weight, and the horizontal line corresponding to the height of lift. Now surround each dot by a little circle and connect the circles by straight lines. Mount the plotted curve at the side of the original. How does extensibility differ from elasticity? How do the curves obtained from muscle differ from those obtained from a steel spring? How do the successive curves of elasticity obtained from the same muscle differ? Explain.

EXPERIMENT III.

Response of Muscle to Making and Breaking Induction Shocks of Various Strengths and Use of Short Circuit Key.

Apparatus.—Before preparing the muscle, arrange apparatus as indicated in the diagram, mounting the moist chamber and lever on the tall stand. Employ the light muscle lever in this experiment. When the weight is supported so as not to bring a strain on the muscle until it

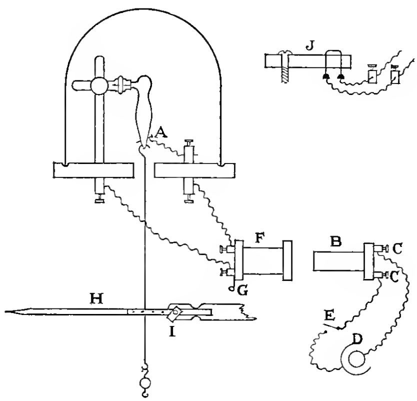


Fig. 3. Apparatus for recording contractions of frog's muscle, excited by induction shocks. A, pin electrode; B, primary coil; C, C, posts 1 and 2; D, dry cell; E, mercury key; F, secondary coil; G, short-circuiting key; H, light muscle lever; I, yoke of lever arranged to support it; J, scheme of mercury key in primary circuit.

contracts, we have what is known as an "after-loaded contraction." In this case the muscle is to be after-loaded. Connect the muscle with the sixth hole of the lever; see that the thread is vertical; rotate the yoke carrying the axis of the lever, until it supports the lever when the thread is tense, and tighten the screw that fastens the yoke to the rod. Now suspend ten grams from the lever. To obtain good results it is necessary to observe the following directions:

1.—Clamp mercury key to edge of table.

2.—Clean and brighten all wires at points of metallic contact.

3.—Connect wires of battery circuit (the primary circuit) to posts 1 and 2 of induction apparatus.

4.—Turn binding screws firmly down.

5.—Leave key in battery circuit open when not in use, to prevent waste of battery.

6.—See that surface of mercury in key is bright, and that platinum loop touches mercury in both cups when key is closed.

7.—Avoid closing key so forcibly as to jar mercury globules.

8.—See that thread is tense when lever is properly supported.

9.—When it is not the intention to stimulate the muscle, see that short-circuiting key is closed, to guard muscle against accidental closure of primary circuit.

Some Facts Regarding Induction Apparatus.

Recall the following facts concerning the induction apparatus. The wire of the primary coil, through which the battery current flows, has no metallic connection with the wire of the secondary coil, and consequently the battery current does not enter the secondary coil. The current which is used to excite the muscles is an induced current of very brief duration, which develops in the secondary coil at the instant that the battery current is thrown into, or is withdrawn from the primary coil. It is the disturbance of the magnetic field about the primary coil, that causes the induced currents in the secondary, and the induced currents are of very brief duration, lasting only until equilibrium has been established. The nearer the secondary approaches the primary coil, the more it comes under the influence of the magnetic field about it, and the stronger the induced currents become. Like movements of the secondary coil, result in a more and more rapid growth in the intensity of the induced currents as the primary coil is approached; a movement of a millimeter when the secondary is close to the primary increases the induced current as much as a movement of a centimeter or more when the coils are far apart. Rotation of the secondary coil on the pivot, because changing the angle at which the lines of magnetic force will cut the windings, also influences the development of the induced currents, and they become less the more the angle between the two coils approaches a right angle.

Why is the making, weaker than the breaking induction shock? When the battery current is made, an electro-motive force is set up in the primary coil, and this force induces a counter electro-motive force in that coil of opposite direction to that of the battery current. As a result, the disturbance in the magnetic field about the primary coil is slow to develop and comparatively slight, and the making induced current in the secondary coil gains its full intensity slowly and is feeble. When the battery current is broken, the electro-motive force induced in the primary coil has the same direction as that of the battery current, and consequently the breaking induced current in the secondary coil gains its full intensity very rapidly and is very strong.

a. *Response to Making and Breaking Shocks of Increasing Strength.*

EXPERIMENT.—Place muscle preparation in the moist chamber, insert pin electrode into the tendo-Achillis (not the muscle substance). The exciting current will pass through muscle from end to end. Place kymograph so that lever bears lightly on drum near the joint of the paper. Move secondary coil as far from primary as the construction of instrument permits, then turn it on the pivot until it is at right angles to the primary coil. Now open short circuit key and make and break the primary circuit by means of the mercury key: no contraction. The stimulus is sub-minimal. Gradually turn the coil to strengthen the induced current. making and breaking the circuit at each new position of coil. A position will be found, either while turning the coil or afterwards by sliding it towards the primary, at which a small contraction will result. Notice that the contraction occurs on breaking the circuit and that no corresponding making contraction is seen. Now give muscle a rest of ½ a minute and then try to put the secondary coil in such a position that the contraction will be so small as to be scarcely visible. Such a contraction is said to be minimal. These later trials should be made at intervals of not less than 10 seconds.

Now move the drum a few centimeters, and record first a minimal contraction, and then, ½ cm. apart, a series of breaking contractions obtained by stimulating with gradually increasing stimuli. In stimulating, make the circuit, wait 5 seconds, then break, and wait 10 seconds. If the stimuli are given too rapidly the irritability of the muscle will be raised. Soon a contraction will appear when the circuit is made, but smaller than the breaking contraction that goes with it. If the secondary coil has not been moved too rapidly this first making contraction will be nearly minimal. After a minimal making contraction has been obtained, continue stimulating and recording as before. After a time the breaking and making contractions will be maximal, i. e., will cease to grow with increasing strength of current, and if the work is continued, a second growth in height of contractions may be seen, and supra-maximal contractions be recorded. Mark on the record to indicate which contraction is a minimal break, a minimal make, a maximal break and a maximal make.

b. Use of Short Circuit Key.

Move drum a few centimeters, then slide secondary coil to a position which excites making contractions about half as high as the corresponding breaks, and record four making and four breaking contractions, stimulating with same time intervals as in part *a*, but with the strength of current unchanged. Move drum a short distance, close the short circuit key and stimulate: no contraction. Two paths are now open to the current, and the current is divided between them in inverse proportion to the resistances. The muscle, having much greater resistance than the metal of the short circuit key, gets so little current that the stimulus is subminimal. This method of dividing the current is technically known as "shunting."

Leaving coil in same position, record a series of four making contractions, cutting out breaks with short circuit key, then record a series of four breaks, cutting out the makes in the same manner. Indicate which are makes and which are breaks in the last group of records.

EXPERIMENT IV.

Relation of Amount of Load to Height of Lift and Quantity of Work Done.

APPARATUS.—The same apparatus is to be employed as in Experiment 3, except that the heavy muscle lever is to be used. Because of the heavy load to be carried, care must be taken to fasten securely all clamps, threads, and hooks. The muscle is to be after-loaded, and the supporting screw must be carefully adjusted so that the whole height of each contraction shall be recorded. Make note of the amount of magnification. Have 20 ten-gram weights ready for use.

a. EXPERIMENT.—Place muscle in moist chamber, and make electrical connections as in Experiment 3. Find strength of current required to produce maximal breaking contractions of unloaded muscle. In doing this avoid fatiguing muscle by too frequent excitations. For stimuli use maximal breaks at intervals of 15 seconds, and cut out the makes with short-circuiting key. Record on the drum at distances of ½ cm., the contractions obtained with 0, 10, 20, 30, etc. grams, and continue the addition of weights until the muscle can no longer lift the load. The muscle should be able to life 70 grammes. If more than one experiment is made with the same muscle, state the fact, since fatigue will modify the results. The "absolute power" of the muscle is measured by the weight which the muscle just fails to lift and which cannot stretch it when contracting.

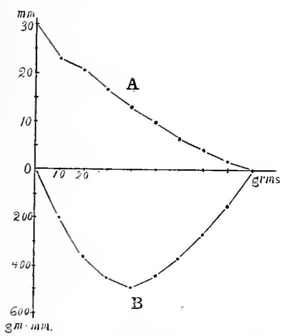


Fig. 4. Curve of lift and of work. A, curve of lift; B, curve of work.

b. Plotting of Curves.

State in tabular form on the cardboard, by the side of the original curve, the recorded height of lift, and the apparent work done by each of the contractions, (the work being the product of the height times the weight lifted), and the actual work, which is obtained by dividing the figures of the apparent work by the magnification of the lever.

To plot the curves of lift and work, take a piece of cross-section paper, about 10 cm. square, and lay off axes as shown in diagram. Plot above the abscissa line the curve of lift, showing the heights of the contractions,—the ordinates representing the distances through which the weight was moved and the abscissas the weights. Plot below the abscissa line the curve of work, the ordinates representing the work and the abscissas the weights. In plotting the curves, 1 mm. of cross section paper can be used to represent any desired value of the curve to be plotted. The curve can magnify or reduce the values actually obtained. For example, 1, 2, or 3 mm. on the cross-section paper can stand for 1 mm. of lift, and 5, 10 or 20 mm. on the paper can represent 100 grammillimeters. Be sure to state on the plotted curve the values of ordinates and abscissas, as shown in Fig. 4.

With what weight was the greatest amount of work done? What was the *actual* amount of work done with this weight? What was the "absolute power" of the muscle? Have the results any practical bearing?

EXPERIMENT V.

Fatigue of Human Muscle.

Apparatus.—Many interesting facts concerning the fatigue of human muscle and the conditions on which it depends have been ascertained by the use of the ergograph. The effects of fatigue have been studied by 1, letting the muscle bend a stiff spring, the movement of which is greatly magnified, i. e., by the isometric method; 2, by letting the muscle raise a weight, i. e., the isotonic method. Several forms of apparatus are in use in the laboratory, and each is accompanied by directions. In the following experiments the isotonic method will be used. Apparatus for the isometric method will be provided if desired.

Experiment.—Connect a time signal with the clock circuit and adjust it to write below the writing point of the ergograph. Be careful that the hand is securely fixed, so that the work shall be done only with the group of muscles which are supposed to be used, and that it is comfortable, so that painful sensations shall not interfere with the work. Throughout the work, watch the metronome, and raise the weight and lower the weight rhythmically, taking care to maintain the rhythm. Always try to raise the weight as much as possible. Unless a maximum effort is made each time, the experiment is worthless. If the abductor of the index finger is to be used, a weight of 500 to 1,000 grams may be employed, the amount varying with the strength of the individual and the apparatus. In case the flexors of the second finger (the sublimis, profundus, and lumbricales) are to be used, two to four kilos can be employed.

a. Effect of Slow Rate.

The muscles are to contract at the rate of once in two seconds. Adjust the metronome for the required rhythm, and see that it is wound up. Arrange the drum to run at the rate of 2 mm. per second. Start metronome; raise weight while the metronome pointer swings in one direction, and lower it quickly when it swings back. Make a few contractions to catch the rhythm; rest a minute; then, *being careful to maintain the rhythm throughout, and always raising the weight as high as possible,* record the contractions for two minutes.

b. Effect of Quick Rate.

Rest 3 minutes. Adjust metronome to beat seconds, then repeat the work, raising the weight during one-half second and lowering it quickly. Work until the weight can not be raised.

c. Effect of Rest.

Rest 3 minutes and repeat work.

d. Effect of Massage.

Rest 3 minutes, and during the rest, massage the muscles vigorously. Repeat the work.

In your notes state the length of time during which the weight could be raised and the character of the fatigue curve,—i. e., the way in which the height of contractions altered. The amount of work could be estimated if desired by adding the height of the separate contractions and multiplying by the weight lifted. Explain results.

EXPERIMENT VI.

Time Relations of Myogram.

The record of a single muscle contraction is called a myogram. Hitherto we have been concerned only with the height of the myogram, which can be best observed when recorded on a stationary drum. In order to study the time relations of the myogram, the record will have to be taken on a moving drum, and the rate of movement of the drum be determined with a tuning fork.

a. Influence of Rate of Drum on Form of Myogram.

There are today a great variety of methods for obtaining graphic records of physiological processes and the changes which they undergo under normal and pathological conditions. In many cases these records are taken on moving surfaces, and it is important that one should be able to estimate the influence of the rate of motion of the surface on the shape of the curve.

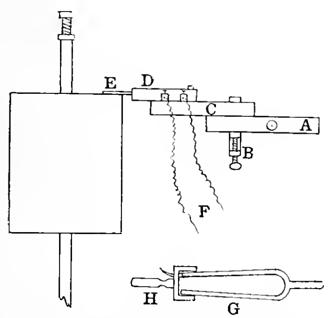


Fig. 5. Apparatus for automatically exciting muscle by letting the drum open the key. A, frog board; B, cabinet maker's clamp; C, mercury key; D, handle of key; E, key opener; F, wires to primary circuit; G, tuning fork; H, yoke.

Apparatus.—The apparatus for supporting the muscle and recording its contraction, and the electrical connections with the induction coil are to be the same in this, as in Experiment 3, the lighter muscle lever being used. In this experiment, however, the key in the primary circuit, instead of being opened by hand, is to be opened automatically by the drum when it is revolved. That this may be done, fasten a frog board by its iron rod to clamp on short stand. Place key in primary circuit on the board, so that it projects for two-thirds of its length beyond it, and clamp key to board by a cabinetmaker's clamp. Adjust board so that top of key is just above the level of the top of the drum. Clamp the key opener to the top of the drum, so that it projects a couple of cm. beyond it. Now move the key just near enough to enable the key opener to open it.

Experiment.—Blacken a drum; bring key into position to be opened when drum is turned; leave key open when the current is not wanted.

Prepare a gastrocnemius muscle; suspend it in moist chamber and connect it with lever; thrust pin of pin electrode through tendon; adjust support so that muscle shall be after-loaded *when thread is tense and the lever is horizontal.* Let short-circuiting key be closed when it is not desired to excite muscle; place secondary coil so that muscle shall give a maximal breaking contraction; short circuit all making shocks; rotate drum so that the part which opens key will point away from it. Now place stand so that the lever will write well upon the drum. Close key in primary circuit and then open short-circuiting key. Now open key in primary circuit by rotating drum by hand *very slowly.* A breaking contraction will be recorded. *Do not move the kymograph, or the stands holding key and lever.* Repeat the experiment four times, each time rotating the drum somewhat faster. Fix the record. State in notes in what respects the myograms obtained differ. Save the muscle to test the apparatus in part *b.*

b. Time Relations of Myogram.

Apparatus.—Use the same apparatus as in *a,* with the following additions: Mount on long stand beneath the muscle lever a tuning fork, to mark rate of movement of drum. Put on the wire spring, used in Experiment I, a celluloid pointer, and clamp the spring beneath the fork, to give a base line to be used in measuring the curves. See that the three writing points are in the same vertical line, using a drum-square for this purpose. Mark the position on the drum by moving each point. To be sure that these marks shall be recognized make a little cross over each of them. *Save the part of the curve showing the relative position of the points.*

This method should be employed in all experiments in which time relations are important.

EXPERIMENT.—The latent period, the duration of the period of rise and of the period of fall, are all longer for a fatigued than for a fresh muscle; it is therefore best to test apparatus with muscle used in part *a*. When you have learned to perform the experiment promptly prepare a fresh muscle. Ascertain the current just strong enough to give a maximal breaking contraction, and in doing this avoid exciting the muscle too often and call out as few contractions as possible. After the drum has been blackened, and the mercury key has been placed so that it will be opened when the drum revolves, see that the lever is horizontal when resting on its support with thread tense. Then move long stand so that fork and muscle lever will write lightly on drum. If now the drum is revolved, the mercury key will be opened when the muscle lever is at a certain point on the drum surface. To find what this point is, with short circuit key closed, close mercury key; then open short circuit key, and open mercury key by revolving the drum *very slowly*. The recorded myogram should be almost a single line. The contraction of the muscle will mark the point of drum which was opposite the end of the lever when the muscle was stimulated. Now, without changing position of key, drum, or lever, close short circuit key, revolve drum two-thirds the way round, put yoke on fork, close mercury key; then pull yoke off of fork and immediately open mercury key by revolving drum rapidly. Stop drum at the close of one revolution. If the muscle had contracted immediately the second curve would have begun to rise at the same point as the first. It does not, because the muscle has a latent period. The distance between the beginning of the two curves shows the length of this period, because the tuning fork curve enables us to know how long the drum took to traverse this distance.

c. Measurement of Records and Computation of Time Intervals.

To determine the latent period, it is first necessary to fix the exact points at which the two contractions began. Draw through the point of origin of the first recorded contraction the line *MN*, perpendicular to the base line. To fix the point at which the second contraction began, draw on the curve two fine parallel lines, one just above and one just below the line traced by the lever, as at *AB,* to aid the eye in fixing the point. Draw through it the line *OP* and estimate *MO*, the latent period, in thousandths of a second. One double vibration of the fork, measured from the crest of one vibration to that of the next, is one hundredth of a second. A good way of ascertaining the length of the latent period, is to estimate the value of one millimeter of drum surface in thousandths of a second, by dividing the time of one double vibration of the fork by the number of millimeters in the

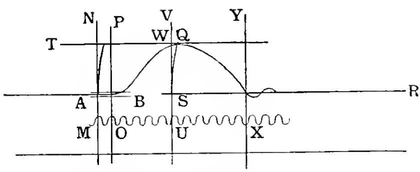


Fig. 6. Method of preparing myogram for determination of latent period.

wave which is recorded most nearly between *MO*, and multiplying this value by the number of millimeters in the recorded latent period.

To determine the period of contraction, draw *TQ* perpendicular to *MN* and tangent to the muscle curve at *Q*. With a radius equal to the length of the writing lever and a center on the base line traced by the muscle lever, as at *R,* revolve to *Q* to the base line at *S,* draw the perpendicular *UV* through *S,* and estimate the number of thousandths of a second between *OU*. To do this count the complete waves, and estimate in tenths the fractions of waves. The line *UV* must not be drawn through *Q*, because the distance *WQ* is due to the fact that the muscle lever draws an arc instead of a straight line. To determine the period of relaxation, draw *XY* through the point where the muscle curve strikes the base line at *X*.

State in notes length of latent period, contraction period, and relaxation period, in tabular form. Also mention the most likely sources of error.

EXPERIMENT VII.

Genesis of Tetanus.

Apparatus.—The apparatus is to be arranged as in Experiment 3, except that the mercury key is to be omitted, and the current of the battery circuit is to be made and broken as follows:

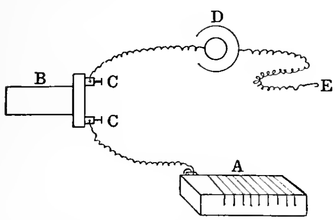


Fig. 7. Apparatus for studying summation of contractions. A, block of wood wound with aluminum wire; B, primary coil; C, C, posts 1 and 2; D, dry cell; E, bare end of insulated wire turned back on itself.

Fasten the block of wood on which the aluminum wire is wound, to the edge of the table by a cabinet-maker's clamp. Connect the binding post on block with post 1 of coil; connect post 2 of coil with one pole of dry cell; and fasten an insulated wire to the other pole. Now bend the free end of this wire back on itself, so that the end shall be smooth and rounded. See that the wire is bright. If this wire be touched to any part of the aluminum coil the primary circuit will be made, and if the wire is drawn across the coils, a series of making and breaking shocks will be given.

a. Summation of Two Contractions.

If two stimuli reach a muscle at a sufficiently short interval the second contraction process may begin before the first one is complete. What will be the result? In this, as in the preceding experiments, each student is to do the work independently.

Experiment.—Blacken drum and arrange for quick speed; make a muscle preparation and mount it in moist chamber, as in Experiment III; place drum so that lever will record well. Open short circuit key; with the drum still, excite the muscle by drawing free end of wire connected with battery across the last turn of aluminum wire on block (Fig. 7, *A*): choose a strength of induced current which will give a good breaking and no making contraction. Let muscle rest. Now start drum, and draw wire across windings *a* and *b*, at such rate as to cause two separate contractions; repeat several times, and more quickly each time, until the two contractions look like one. How do the records differ?

b. Incomplete Tetanus and Complete Tetanus.

Apparatus.—Use the same apparatus as in *a*, and in addition mount a time signal (chronograph) so that the writing point will write below and in same vertical line with the muscle lever. Connect the signal with the binding posts on the side of the desk. In the time circuit, there is a battery, and a clock which interrupts the circuit once a second. The signal should record seconds on the drum. The drum should run 4 cm. per second.

Experiment.—Make experiment as in *a*, only this time draw wire across all the windings of the aluminum coil. In doing this see that the hand is moved at an even rate across the coil. The experiment is a test not only of the behavior of the frog's muscle under varying rates of stimuli, but your capacity to move the hand constantly at different speeds, i. e., muscle coördination. *State in notes approximately the number of excitations per second required to tetanize.* Do not forget that an arc must be drawn. A complete tetanus is an apparently continuous contraction produced by a series of excitations. All voluntary contractions are tetani.

c. Complete Tetanus Obtained with Automatic Interrupter.

Apparatus.—The apparatus is the same as in Experiment III, excepting that the battery and key are connected with different posts of the primary coil.

Electrical Connections in Primary Circuit of Induction Apparatus.

Two kinds of coils are in use. Model A in which the secondary coil slides on metal rods, and Model B in which the secondary coil slides on the wooden base. The way in which the binding posts belonging to the primary circuit are connected with the primary coil and the automatic interrupter is different in these two forms of apparatus.

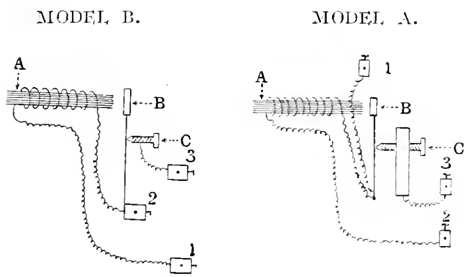


Fig. 8. Scheme of electrical connections of primary coil in two forms of induction apparatus. A, soft iron wires in primary coil; B, hammer; C, contact screw; 1, 2, 3, binding posts.

Model A—To obtain single making and breaking shocks use posts 1 and 2. To obtain tetanizing current use posts 1 and 3.

Model B—To obtain single making and breaking shocks use posts 1 and 2. To obtain tetanizing current use posts 2 and 3.

In each apparatus if single shocks are needed, the battery and key are connected with the posts to which the two ends of the wire of the primary coil are directly attached. If a long series of rapidly following shocks are needed, as for tetanus, the battery and key have to be so connected as to bring the automatic interrupter into the circuit. This is done in Model A by connecting the battery with posts 1 and 3. The current can then enter by post 3, pass to the contact screw, down the spring, then through the wire of the primary coil, and away by post 1. In Model B, posts 2 and 3 are used. The current enters by post 3, passes to contact screw, down the spring, through the coil, and away by post 2.

In each case, as the current flows through the coil it magnetizes iron wires inside it, and the hammer is attracted. The movement of the hammer breaks the contact between the spring and the contact screw, and the current ceases to flow; the soft iron wires lose their magnetism, the hammer is released, and the spring again makes contact with the contact-screw. Thus the primary current is being continually made and broken, and a series of rapidly following induction shocks develop in the secondary coil.

NOTICE.—In order that the automatic interrupter may work well, the contact-screw is screwed up until it barely touches the spring when at rest.

EXPERIMENT.—After the apparatus has been arranged, the automatic interrupter tested, and a fresh drum blackened, prepare a muscle and mount it in the moist chamber. Now adjust lever to drum; see that short-circuiting key is closed; close key in primary circuit; start kymograph clockwork (quick speed); open short-circuit key for a few seconds; the close short-circuit key; stop drum a few seconds later and open key in primary circuit. If the curve does not return to the base line promptly when the excitation ceases, it is because the after contraction, known as "Contracture," is present.

d. Fatigue Caused by Tetanus.

EXPERIMENT.—This experiment is to be made with the same muscle and in the same manner as *c*, excepting that the drum should revolve slowly and the tetanic excitation be permitted to act on the muscle until it is completely fatigued.

e. Fatigue of Continued Voluntary Contractions.

In the case of voluntary muscular contractions of the arm, as the final step of the brain processes which result in the effort, the cells in the motor arm area, anterior to the fissure of Rolando, become active and send stimuli to the anterior horn cells in the gray matter of the spinal cord, and they discharge nerve impulses at a rapid rhythm, which cause the muscles to be tetanized. By continued voluntary contraction fatigue shows itself in much the same manner as in the above experiment.

Test this by raising the left arm to the horizontal position, and trying to hold it there. Gradually the arm tends to fall and stronger efforts must be made to bring it back to, or hold it in the horizontal position. As fatigue comes on, painful sensations, not at first noticed, come from the muscle sense organs. It is not necessary to carry the experiment to complete fatigue. Describe the result of your experiment. State where the fatigue probably occurred, and your reasons.

EXPERIMENT VIII.

Rate of Tapping.

The apparatus permits a determination of the greatest speed with which it is possible to make a series of brief voluntary contractions (tetani) of a muscle.

Apparatus.—Adjust a drum to the pointer of a time signal and the recorder of the apparatus, which is held in contact with the surface by a delicate weighted thread. Connect the time signal to the clock, so as to record seconds. Carefully pull the cross-needle down as far as possible. Place the arm on the board and practice tapping the Morse key, being careful to use a wrist movement only, and saving time by moving the hand through very short distances. Each tap causes the cross-needle, operated by the clockwork, to rise a definite amount.

Experiment.—With cross-needle down, start the drum at a rate of 2 mm per second and begin tapping; keeping this up at a steady rate till the cross-needle reaches the upper stop. Try this for the right and left hand. Now figure the number of seconds required to tap 234 times (the number necessary to make a complete rise of the cross-needle). Determine the number of taps per second for each hand. Notice in the record the failure to tap when the rate became too rapid. What was the cause? Discuss the physiological value of the experiment.

EXPERIMENT IX.

Independent Irritability of Muscle.

Arrange the induction apparatus for tetanizing current, and connect a pair of platinum electrodes to the secondary circuit.

Experiment.—Kill a frog by pithing the brain in the presence of an instructor. (Method will be demonstrated.) *Have a pointed match ready,* and as soon as pithing needle is withdrawn plug the skull cavity through the foramen magnum, to prevent loss of blood and to insure destruction of the brain. If the brain has been destroyed, the frog will not raise its nose from the plate, and will not make spontaneous movements, although it will make reflex movements if it be excited. Slit the skin on the back of left thigh longitudinally, separate the semimembranosus from the ileofibularis muscle, and expose the sciatic nerve, (see Fig. 10, Dorsal View). Carefully separate a portion of the nerve from the surrounding tissues without injury to the nerve or the blood vessels. Pass a ligature under the nerve, carrying the ends around to the front of the thigh, and tie tightly, thus including all the structures of the limb except the nerve, (See Fig. 11). Cover exposed nerve with filter paper moistened with salt solution.

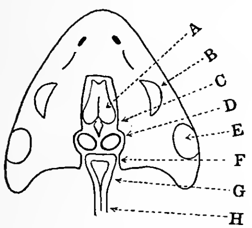


Fig. 9. Relation of brain to skull of frog. A, cerebral hemispheres; B, eyes; C, thalamencephalon; D, optic lobes; E, tympanic membrane; F, cerebellum; G, medulla oblongata; H, spinal cord.

Inject into the dorsal lymph sac about 1 cc. of a stock solution of curara. Use for this purpose a pipette with fine point and rubber bulb. To insert pipette, raise loose skin of back over forward part of dorsal lymph sack with forceps, and make *small* opening in skin with scissors. Lay the frog on a plate and cover it with moist filter paper. Observe that pinching the toes of either hind leg *slightly*, causes a contraction of the muscles of the leg thus irritated, and that a stronger stimulus causes a contraction of the muscles of both legs. Do not excite more strongly than is required to produce the effect.

As the drug takes effect, the ability of the right leg to respond to such irritation gradually becomes less, and after 20 or 30 mintes it ceases altogether, although the left leg will respond as before. Notice especially whether a crossed reflex movement occurs in the left leg after the right leg is paralyzed.

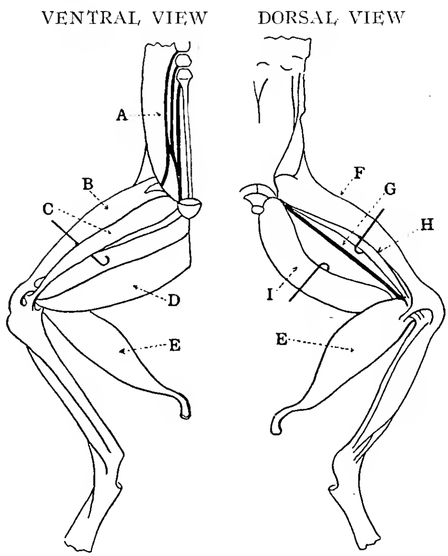


Fig. 10. Dissection of right leg of frog. A, sciatic plexus; B, cruralis; C, sartorius; D, gracilis magnus; E, gastrocnemius; F, glutaeus magnus; G, sciatic nerve; H, Ilio-fibularis; I, semimembranosus.

When all the body but the left leg has become completely paralyzed, open the abdominal cavity and remove the vicera, care being taken not to injure the nerves behind them. (see Fig. 10. Ventral View). Cut the body in two, leaving the last two vertebrae connected with the legs. Split these vertebrae lengthwise, and holding the fragments with forceps, dissect out the sciatic plexus supplying the hind legs. Do not take hold of nerves with forceps, and avoid stretching them. Stimulate the plexuses in turn with the tetanizing current. What is the result? Now apply the stimulus directly to the muscles of the legs. What is the result?

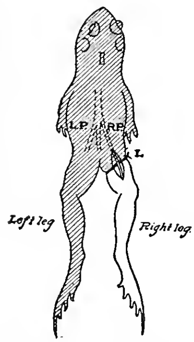


Fig. 11. Diagram to illustrate effect of curara. The shaded portion shows the parts affected by the drug. L, ligature surrounding the whole of leg, except the sciatic nerve; R, P, right sciatic plexus; L, P, left plexus.

Keep the preparation, to use in Experiment 10, which should immediately follow this one.

Answer the following questions in your notes, and state proofs:

How did the drug reach the leg?

Does curara poison nerve fibers?

Does it poison muscles?

What does it poison?

Can curara paralyze before it produces anaesthesia, that is, when the sensory nerve endings, fibers and central nervous mechanisms are capable of functioning?

When an electric current is sent through a non-curarized muscle, as in the preceding experiments, what two kinds of stimuli may act on the muscle?

EXPERIMENT X.

Isolated Conduction in Muscle.

Although the separate fibers of a striated muscle are in close contact, they are like the nerve fibres in a nerve trunk, independent mechanisms. If a fiber is excited, the condition of activity which is aroused runs the length of the fiber in either direction from the point of excitation, but does not spread to neighboring fibers. This fact can be demonstrated most readily on a curarized muscle, and by employing unipolar excitations.

Apparatus for Unipolar Excitation.—Arrange induction coil to give tetanic excitations. Connect one pole of the secondary coil by an insulated wire with the binding post on the sheet of copper. The other pole of the secondary coil may be left free, or, if a strong current is needed, be connected with a gas pipe and so with the earth.

Experiment.—Remove the sartorius muscle (see Ventral View, Fig. 10), from the curarized leg of the frog used in the Experiment IX. Lay the muscle on the copper plate. Start the automatic interrupter and lightly touch one edge of the muscle for a moment with the point of a needle or other metalic instrument with sharp point. The muscle will be seen to contract along the edge that is touched and to curl toward that side. If the other edge is touched, the muscle fibers will draw together on the other side. With a reading glass one can see that the only fibers to contract are those near the point touched. By this method of unipolar excitation the current does not flow in a circuit. The current enters the muscle wherever it is in contact with the copper plate (the indifferent pole), but being diffuse fails to excite it; it leaves the muscle, to charge up the body of the experimenter, at the point that is touched by the needle (the active pole), and the dense stream causes excitation at that point. The strict limitation of the contraction process to the fibers excited, shows that the excitation does not spread from fiber to fiber.

Why is it necessary to supply a curarized muscle in this experiment?

EXPERIMENT XI.

Contractions of Non-Striated Muscle.

Apparatus.—Set up apparatus like that used in Experiment III, and in addition mount two electric signals so as to write in the same vertical line as the lever. Connect one signal in the primary circuit, to mark the time of stimulation, and the other in the clock circuit to record seconds. Because of the resistance of the time signal, and the fact that smooth muscle reacts poorly to currents of such brief duration as induced currents, it will be necessary to use two dry cells in the primary circuit. No weight should be used on the lever.

Experiments.—Kill a frog, remove the stomach, cut off from stomach a ring 5 mm. wide, and hang this ring of non-striated muscle on a pin hook which has been fastened vertically in the clamp intended for femur. Suspend the light muscle lever from the ring by means of a pin hook. Stick the pin of the pin electrode through the lower border of the ring. Keep moist chamber closed and moisten muscle frequently, as it is so small that it is especially liable to be injured by drying.

a. Time Relations of Myogram.—The drum is to be revolved by the clockwork, and to have a rate of 2 mm. per second. See that writing points are in the same vertical line, and put part of curve showing this in your notes. Find the latent period, and the time of the rise of the curve. Remember that non-striated muscle is very readily excited by mechanical stimuli and that its power to keep in tonic contraction is much greater than that of striated muscle. If the ring is drawn together, wait for the muscle to relax before exciting it. Watch to see if relaxation is taking place.

b. Rate Required to Tetanize.—Set the drum turning slowly and find by experiment slowest rate of stimulation which will tetanize non-striated muscle. In order to tetanize, a second contraction should be called out a short time before the preceding contraction has reached its full height. If one knows the latent period and the contraction period, one can make a fair estimate of the required rate of excitation.

c. Spontaneous Contractions.—Set the drum to run at the rate of 1 mm. per second or slower, and record a series of spontaneous contractions. Let the time be recorded in seconds. Spontaneous contractions may occur from the first, and interfere with the determination of time relations. If such is the case, the only way to secure the results is to give the stimuli at such a time that one can be sure whether the following contraction is a response to the stimulus or a spontaneous contraction.

How does the latent period and the contraction period of this non-striated muscle compare with that of the gastrocnemius? What rates were needed to tetanize these muscles? For comparison state in the notes the values obtained in experiments VI and VII. What was the rate of the spontaneous contractions?

EXPERIMENT XII.

Frog's Heart—Its Structure; the Relative Time of Action of the Different Parts.

Apparatus.—Set up as shown in Figure 12, except for electric signal which will be used only in Experiments XIV and XV. Clamp horizontally on short stand, the nickled rod with hole for wire and binding screw in end (A), letting the free end of the rod project about 7 cm. beyond the stand. Place a clamp on the end of the rod, and fasten vertically in this clamp the rod (*B*) carrying the lighter muscle lever. Thus arranged the lever can be either raised or lowered, or can be rotated so as to bring the point against the drum. Loosen the screw fastening the yoke (*C*) of the

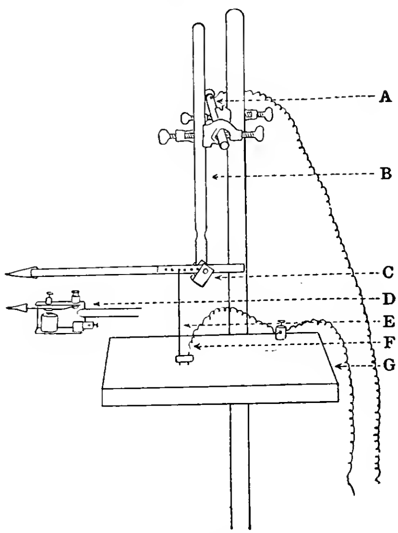


Fig. 12. Apparatus for recording the beat of a frog's heart. A, horizontal rod carrying binding screw for wire; B, vertical rod carrying lever; C, yoke supporting axis of lever; D, time signal; E, wire, connecting lever with button to rest on the heart; F, piece of flexible insulated wire, connecting short piece of wire, passing through button, with binding post on frog board; G, frog board.

lever to the rod, and turn the yoke until it supports the lever with the tip 2 cm. below the horizontal plane passing through its axis; then turn the screw home. Now bring the drum up to the lever, and see that when it is horizontal it has such a height that it can be made to write on any part of the drum by raising or lowering the drum. Clamp the frog board (*G*) to the stand below the lever. Connect the steel wire (*E*) of the heart electrode with the lever. The hole into which it must be inserted will depend on the size of the movements of the heart. The record of the movements should be not less than a centimeter in height. Fasten the piece of flexible insulated wire (*F*) to the binding post on the frog board. Observe that the two wires which project through the button may, when brought in contact with the heart, be used as electrodes.

OPERATION.—Choose an active frog; pith brain as described in Experiment IX; cut off the projecting end of the match; and put frog, back down, on the plate. Operate at once, before the effects of the shock have passed off. Make median skin incision from a centimeter above pubis to one-half centimeter below jaw. Raise ensiform cartilage with forceps, and with sharp scissors remove sternum, always keeping point of scissors well away from the pericardium and aortae. In cutting through the abdominal wall avoid the large vein. Now slide the heart lever up out of the way, and place the frog on the frog board so that its ventricle lies directly beneath the button on the prop of the lever. With the frog in this position, draw the fore legs widely apart so as to expose the heart beating within the pericardium, and pin these legs firmly to the frog board. Now pick up the pericardium over the bulbus arteriosus, and slit the pericardium throughout its length with sharp pointed scissors.

a. Gross Anatomy of the Heart.

Moisten the heart from time to time with normal salt solution; it must not be allowed to dry. Observe the position of the bulbus arteriosus (*H*) and the two aortic arches (*A*); the relation of the two auricles (*B*, *C*) to each other and to the ventricle (*E*), (the line of separation of the auricles lies behind the bulbus arteriosus); and the well marked auriculo-ventricular groove. Lift the ventricle with a camel's hair brush moistened with saline solution, and notice the place where the vena cava inferior opens into the sinus venosus (*F*); the white crescentic line where the sinus joins the auricle; also the frenum, a slender ligament which attaches the dorsal wall of the ventricle to the pericardium.

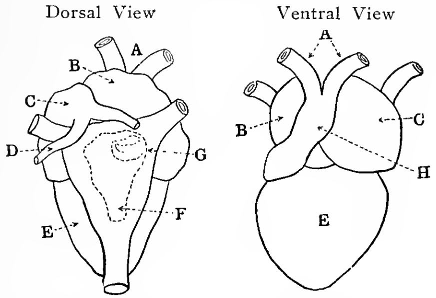


Fig. 13. The gross anatomy of frog's heart. (Ventral view after Cyon, dorsal view after Howes.) A, aortae; B, right auricle; C, left auricle; D, pulmonary vein; E, ventricle; F, sinus venosus; G, sino-auricular valves; H, bulbus arteriosus.

b. Origin and Course of the Wave of Contraction.

1.—Inspection.—Try to observe the place where the wave of contraction begins, and the order in which it spreads over the different chambers of the heart. See that when a part contracts and drives the blood out, it grows paler, while the part receiving the blood swells and flushes. The change of color begins somewhat later than the process causing it. Answer in your notes the following questions: What is the action of the auricles during the ventricular diastole, and during the ventricular systole? What changes are observed in the ventricle during auricular diastole, and during auricular systole?

2.—The Myocardiogram.—Adjust the button on the prop of the lever to the ventricle, with the prop vertical and the *lever horizontal*. Be careful that both of the wire points on the under surface of the button are in contact with the ventricle, and that the button does not touch the auricle so as to be moved directly by it. Once rightly adjusted, it should not be necessary to alter the position of the lever during the afternoon. The prop should be connected with the hole in the lever which will give a writing of one and a half to two centimeters in height. Record the beats with slow, medium and rapid speeds of the drum, studying the heart itself while the curves are being written. Mark on the record the part of the cardiac cycle which is responsible for each wave of the curve. Notice that the lever records at the same time changes in the position, form and volume of the ventricle. How and why does the beat of the auricle show in the curve? Which part of the curve was made by the ventricular systole? Does the lever fall or rise in the ventricular diastole? Explain.

EXPERIMENT XIII.

Effect of Temperature on Heart Rate.

a. Effect of Air.

Pith a frog, and expose the pericardium. Count the heart rate. Role up a tube of paper round a pencil, and using the tube, warm the heart by slowly breathing upon it, and observe the change in rate. After the new rate has become established, place the end of the tube close to the heart, but without touching it, and suck air over the heart. Note the rate of beat.

b. Effect of Solutions.

Let the heart take on the temperature of the room, and then after counting the rate, place the frog on his back in a shallow tray, and cover the heart with salt solution heated to 30° C. Note the rate. Replace the warm solution, by cold salt solution, 10° C., and when it has had time to cool the heart, again record the rate.

Put the figures which you obtained in your notes, and explain the effects observed. If the heart is beating well at the close of the experiment, dry it off and use it in the next experiment. The tray must be cleaned and dried before it is returned.

EXPERIMENT XIV.

Refractory Period and Compensatory Pause.

Apparatus.—The same apparatus for recording the contractions of the heart may be used as in Experiment XII. In addition arrange an induction coil to give single shocks, and connect a time signal in the primary circuit. Adjust the signal to write just below and in the same vertical line with the heart lever. One cell in the primary circuit, with the secondary coil pushed half way up, usually gives sufficient strength of current. Avoid using a current stronger than is required to call out an extra contraction, otherwise the current will spread to the muscles of the trunk. One of the wires of the secondary coil is to be fastened to the binding post on the frog board, and to be brought into communication with the ventricle by means of the fine insulated wire passing to one of the pins in the button which is to rest on the ventricle (see Fig. 12) ; the other wire is to be fastened in the horizontal rod supporting the heart lever, through which it communicates with the heart.

In order that the curve may be read with accuracy, three things are essential, viz:—*the length of the lever must be known, the relative position of the writing points must be marked on the drum, and a base line must be drawn with the lever horizontal.* If the mark which shows the position of the lever is a long arc, it can be used to determine whether the base line was properly drawn, and if it was not, to establish a correct base line. The relative position of the writing points must be recorded on each curve at the beginning or end of the experiment. A cross can be written over each of the marks to identify them.

Experiment.—Adjust lever to heart and place drum so that contractions will be recorded. Leaving drum in this position, turn yoke at axis so that it will support lever horizontally. Rotate drum to give base line, and at beginning of curve mark a large arc by raising lever, and mark position of time signal. Lower yoke and make experiment. Let the drum run at the rate of 20 mm. per second; and while the heart records its contractions, stimulate the ventricle with single breaking shocks every fifth or sixth beat, *the makes being short circuited,* to test the effect of exciting it at the following times—during the systole of the ventricle, and early and late in the diastole of the ventricle.

State in notes in which case the stimulus produces no effect (the "Refractory Period"); and when an extra contraction. State relative size of the contractions obtained in different parts of diastole. Notice that an extra contraction is followed by a pause, (the "Compensatory Pause"). Is the pause long enough to compensate for the extra contraction, so that the rhythm of the beat is not changed afterward? Explain these phenomena. Was the auricle excited by spread of current?

The curve of contraction is distorted by the fact that the lever records an arc. To determine the part of a contraction at which a stimulus was applied, it is necessary first to make sure that the lever was horizontal when the base line was drawn. If the line drawn was not correct, draw one at the proper height. Draw a vertical line through the point of excitation, as given by the time signal, to the base line which corresponds to the position of the heart lever when horizontal, and then having allowed for the relative position of the writing points, draw through the heart curve an arc, the axis of which is on this base line and the radius of which is equal to the length of the lever.

EXPERIMENT XV.

Response of the Resting Heart to Stimulation by Induction Shocks.

APPARATUS.—Use apparatus the same as in Experiment XIV and in addition mount a tuning fork on large stand above the electric signal. Prepare a frog, and expose heart, losing as little blood as possible.

EXPERIMENT.—Bring heart to rest by tying a ligature, the first Stannius ligature, about the juncture of the sinus with the auricles. To do this pass ligature under the aortic arches close to the auricles, then pass the ends around the heart posteriorly, so that the ligature lies at the base of the auricles, and tie a single knot loosely over the crescentic line where the sinus and the auricles join. *Make sure that the ligature is in the proper place,* then tighten and tie securely. The heart should stop beating. If it does not do so within a few seconds, tie a second ligature closer to the auricles.

a. Myogram of Heart Muscle.

As soon as the beat stops, place frog on board and adjust the lever to the heart. Establish the position of the writing points and draw a base line as described in Experiment XIV. Move coil far away, and find smallest stimulus that will cause a contraction, taking care that the current does not excite the muscles of the trunk. Record the curve of contraction and beneath it the tuning fork curve, and the moment of make and break of the primary circuit, as shown by the signal. Short circuit the make. Turn the drum by hand at rate of about 10 cms. per second, and excite by the break. Assume that the signal records the exact moment of excitation, and calculate from the record the time relations of the myogram, as in Experiment VI. *Save a part of the record which shows that the writing points are* *in the same vertical line, and state in notes length of lever in millimeters.* In what respect does the myogram obtained from the heart differ from that of striated muscle?

b. Bowditch's Staircase.

Stimulate about 15 times with a medium strength of current at intervals of 2 to 5 seconds, recording on drum moving 2 mm. per second. A gradually increasing height of contraction is usually given, which is called a staircase, and explained as a result of increased irritatibility due to frequent repetition of the stimulus.

c. All Contractions Maximal.

As soon as a sufficient number of myograms have been recorded, remove the fork, and stimulate about ten times with gradually increasing current at intervals of 30 *seconds*, recording contractions on drum about 1 cm. apart. There should be no increase in height of contraction due to increased stimulus. Any stimulus sufficient to cause heart muscle to contract, causes a maximal contraction. This is often spoken of as the law of "All or none." See that the muscles of the trunk do not contract.

d. Effect of Frequent Stimuli.

Connect wires of primary circuit with automatic interrupter and record the response of the heart to frequent stimuli, using first a weak and then a medium current. See that the muscles of the trunk do not contract. Drum should turn 5 mm. per second. Weak stimuli should cause separate beats and stronger stimuli, increase of tonus, indicated by a higher base line.

EXPERIMENT XVI.

Location of a Few Motor Points on the Human Arm.

The few motor points surrounded by a circle in the diagram (Fig. 17), are to be located on each arm. In doing this, the unipolar method of excitation is to be employed. To use this effectively, the more efficient pole of the induction coil will have to be used.

The More Efficient Pole of an Induction Coil. When the manner of winding and connecting wires with posts can be plainly seen, the direction of induced currents can be found easily, for the direction of the primary currents can be observed by inspection of the battery and its connections, and the induced current flows in the opposite direction to the battery current at the time of the make, and in the same direction at the time of the break. But in most coils the windings and connections are hidden, making it necessary to determine the point in question in some other way.

Connect a dry cell with a key and a pair of platinum electrodes as shown in Figure 14. Lay a small piece of filter paper on a clean plate, and slightly moisten it with only a few drops of a solution of starch and potassium iodide. Draw the ends of the electrodes slowly and lightly across the moistened paper, first with the circuit open and then with it closed. Observe the dark line given at the anode while the current is passing, and the absence of color at the cathode. The current decomposes the potassium iodide, and the iodine, being the acid ion, goes to the anode and there gives the color reaction with the starch.

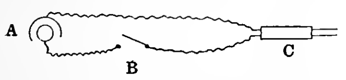


Fig. 14. Apparatus to detect direction of flow of current in a simple circuit. A, dry cell; B, mercury key; C, electrode.

Now connect the cell to the primary coil of induction apparatus, the anode with post 1 and cathode with post 2.

Connect the platinum electrodes to the posts of the secondary coil. Place the ends of the electrodes on the moistened paper and make the primary circuit, then slide the electrodes to a fresh place and break. A dark dot will be given at one pole on making and at the other on breaking, but no effect will be seen during the time the primary current is flowing. Remembering that the color reaction indicates the anode, we can determine the direction of the current in the secondary circuit when the primary is made and when it is broken.

Since the excitation developed at the cathode where the current leaves the tissue, is stronger than that developed at the anode where the current enters it, and since the break induction shock is stronger than the make, it follows that the

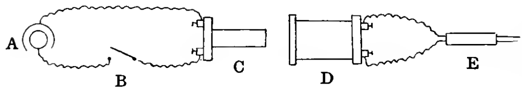


Fig. 15. Apparatus to detect direction of flow of current in secondary coil of an induction apparatus. A, dry cell; B, mercury key; C, primary coil; D, secondary coil; E, electrode.

more efficient pole of the secondary circuit is the one that is the cathode when the primary circuit is broken. Make a note of this point, stating whether the more efficient pole is the one to which the short circuit key is attached or the opposite one. Of course it must be remembered that this will be true only when the anode of the cell is connected with post one, as in the above test.

Preparation of Skin.—Since the epidermis when dry offers great resistance to the current, it is necessary to moisten it thoroughly. For this purpose use a warm solution of common salt and borax. The solution can be warmed in a granite dish, standing on a tripod over a gas flame. Apply the solution with a sponge or cloth to the parts to be stimulated for at least five minutes; or a pad soaked in the solution may be bound on. Unless the skin is thoroughly moistened, the stimuli are apt to be painful and inefficient. Do not spill the solution on tables or apparatus.

APPARATUS.—Connect two dry cells and a key to the primary coil of an induction apparatus; and connect a large copper plate (the indifferent electrode), to the less efficient pole of the secondary coil, and a small brass electrode (the active electrode), to the more efficient pole.

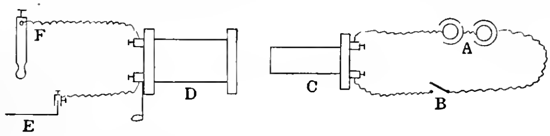


Fig. 16. Apparatus for unipolar excitation of human nerves. A, battery; B, mercury key; C, primary coil; D, secondary coil; E, copper plate used as indifferent electrode; F, exciting electrode.

EXPERIMENT.—Locate the motor points on the left arm first. By the motor point is meant the spot at which the motor nerve enters the muscle, or where a nerve is most accessible to the current. Fasten the copper plate by an elastic band on the back of the left hand, putting a wet

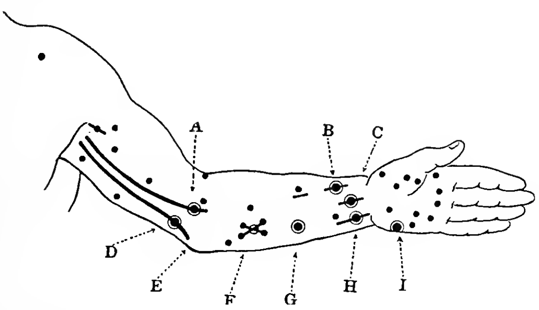


Fig. 17. Diagram of location of motor points on flexor side of arm. (After Erb.) A, median nerve in upper arm; B, flexor longus policis; C, median nerve at wrist; D, ulnar nerve in upper arm; E, ulnar nerve in groove between the internal condyle of the humerus and the olecranon process; F, flexor profundus digitorum; G, flexor sublimis digitorum; H, ulnar nerve at wrist; I, abductor minimi digiti.

gauze pad between to prevent the metal from touching the skin. Let your companion press the active electrode firmly upon the skin at the point to be stimulated, and make and break the circuit, first with the secondary coil moved far away and then with it closer to the primary, until a position of the coil is found that gives a moderate breaking contraction. As soon as a suitable stimulus is found, try to establish the motor points corresponding to those marked with a circle in the diagram. Find for each point the position of the electrode at which the best motor response is given. The stimulating electrode must be kept well moistened. If a good contraction cannot be obtained without the sensation being painful, it indicates either that the epidermis is not sufficiently moistened or that the right position for stimulation has not been found.

Consult an anatomy and locate the motor points on the left arm of each student. Mark the points on the skin. Demonstrate to instructor, and make a diagram showing the position of the points which you found.

EXPERIMENT XVII.

Response of Human Muscle to Separate Induction Shocks and to a Tetanizing Current.

Wet the left arm over the motor point for the flexor longus pollicis, bind on a wet pad, and then arrange the apparatus. See that the hands are dry in handling the apparatus.

APPARATUS.—This consists of an arm rest and recording instruments, and the stimulating outfit used in Experiment XVI. The arm rest is to be placed on the table before which the subject is to stand, with the recording apparatus to the left, and the stimulating outfit to the right, with key and coil within easy reach of his hand. The arm is to

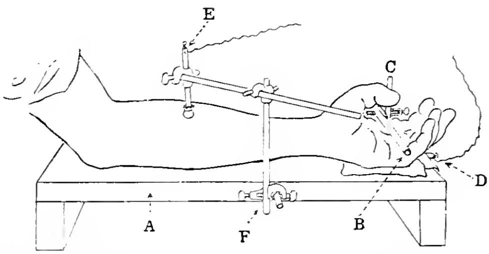


Fig. 18. Arm rest for support of hand and electrodes. A, arm rest; B, horizontal rod fixing hand; C, vertical rod on arm rest; D, copper plate, the indifferent pole, on which is a gauze pad; E, exciting electrode; F, vertical rod, clamped to horizontal rod on the arm rest.

lie in supination on the arm rest, and the hand is to be fixed by a horizontal rod (*B*) which presses lightly on the palm, and is clamped to the vertical rod (*C*) on the arm rest.

The movement of the thumb is to be transmitted by a thread, which is fastened by a loop to the thumb and passes round a pulley (see Fig. 19) to a muscle lever, which is connected by another thread to a rubber band supported on an L rod, clamped to the same stand as the levér and above it. The thread from the thumb is fastened to the second, and that from the rubber band to the third hole in the lever. When the flexor longus pollicis contracts, the lever will be drawn down, and when it relaxes the rubber band will pull the lever upwards. A time signal is to be placed in the primary circuit of the induction apparatus so as to record makes and breaks, and an indifferent and a stimulating electode connected with the posts of the secondary coil. The copper plate (Fig. 18, D), which is to act as the indifferent pole, is to lie on the arm rest in such a position that the back of the hand will press on a wet pad placed over the plate. Care must be taken that the pad does not come in contact with the vertical rod on the arm rest and that the hand does not touch the bare copper of the plate. The active pole (E) instead of being held in the hand, is to be fastened above the arm in a clamp on a horizontal rod, which in turn is clamped to a vertical rod (F), which is supported by a clamp fastened to the horizontal rod at the side of the arm rest. This arrangement permits the exciting electrode to be fastened at any desired point on the arm.

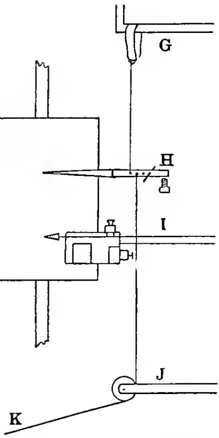


Fig. 19. Apparatus for recording movement of thumb. G, rubber band supported by L rod; H, recording lever; I, time signal; J, pully; K, thread to thumb.

a. Making and Breaking Induction Shocks of Various Strengths.

EXPERIMENT.—Put the wet pad on the indifferent electrode; then place the arm on the arm rest, so that the back of the hand rests on the pad; and fix the hand by fastening the horizontal rod across the palm. Adjust the active electrode over the motor point of the flexor longus pollicis muscle. Connect the thread to the thumb, and move the arm rest so that the thread shall have the proper position with respect to the pulley, and the elastic band be slightly stretched. Place drum in position. The lever should point slightly upward, so that when drawn down it will keep in contact with the drum. The subject handles the key and coil while his associate has charge of the kymograph, and turns the drum by hand. To stimulate, close to the key, wait 2 or 3 seconds, then open and wait 10 seconds. The student attending to the kymograph should keep track of the time with his watch and tell the subject when to stimulate. Begin with the coil placed so as to give no effect, and move it up a short distance after each time the circuit is broken. The signal marks the time of stimulation, and thus shows what stimuli fail to give contractions. In case insufficient current is obtained, cut out the time signal. Unless the current causes too much discomfort, continue until both making and breaking contractions of fair size are recorded. During the experiment the arm should be completely relaxed. Voluntary movements should be avoided as far as possible, and should be noted when they occur.

b. Tetanizing Current.

APPARATUS.—Connect battery, key, and signal with the automatic interrupter of the induction coil.

EXPERIMENT.—Moisten electrodes. Choose strength of current sufficient to cause a tetanic contraction. Start drum at fast speed and obtain a record.

EXPERIMENT XVIII.

Galvani's Experiment.

Arrange apparatus as shown in the diagram, making sure that the zinc rod and brass hook are bright and clean.

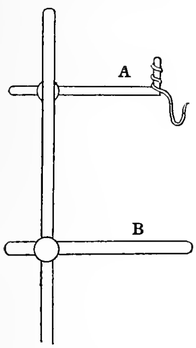


Fig. 20. Apparatus for Galvani's experiment. A, brass hook, supported on L rod; B, zinc rod.

Kill a frog, open the abdomen, and remove the viscera from the posterior part, taking care not to injure the nerves. Cut the body in two transversely, ½ cm. above the point of exit of the nerves from the spinal column. Remove the skin from the lower part of the body, cut a small slit through the back between the nerve plexuses and the urostyle, and hang the preparation by this slit upon the brass hook. Adjust the zinc rod so that upon giving the preparation a slight swing the outside of the thigh near the knee will strike it. Set the preparation swinging. Upon each touch of the leg against the zinc rod a contraction should occur, throwing the preparation away, and this should be repeated every time the swing brings the leg against the zinc.

We have here two unlike metals moistened by a liquid which is practically continuous through the tissues of the preparation; in other words, we have the essentials of what is called a Galvanic battery. This experiment is of considerable historical interest, for it was the observation of the contraction of frogs' muscles in a similar case, that led Galvani to make his famous studies of what he supposed to be animal electricity, and which was followed later by the invention of the first battery by Volta.

We see here that a battery current, like an induced current, is able to excite. In the next few experiments the effects of the direct battery current upon nerve and muscle will be observed. Save the preparation for the next experiment if made the same day.

No notes required.

EXPERIMENT XIX.

Polarization of Electrodes.

a. Polarizable Electrodes.

APPARATUS.—Fasten two short wires to the posts inside a moist chamber and place the free, bare ends so that a nerve can be laid across them, i. e., arrange these wires to be used as polarizable electrodes. Connect the binding posts on the bottom of the moist chamber with two dry cells and a key. Make the connections so that the current shall flow from the carbon (+ pole) to the electrode which will be nearer the muscle. This will then be the anode, and the current an ascending current, one which will pass up the nerve, and leave it by the negative pole, the cathode, and so flow back to the battery.

EXPERIMENT.—Make a nerve-muscle preparation from the frog used in the preceding experiment. The method of making preparation will be demonstrated. Never take hold of the nerve with the forceps, and avoid stretching it. Place the preparation in the moist chamber, and let the nerve rest across the two copper wires. Avoid stretching the nerve and protect it from drying, or its irritability will be altered. Bring the writing point of the lever against a drum, and arrange the kymograph to turn the drum 2 mm. per second. Start the kymograph, and let it run continuously until the end of the experiment. Close the key and let the current flow through the nerve for sixty seconds. Mark on the drum the point at which the key is closed, *C*, and the point at which it is opened, *O*, whether a contraction occurs or not.

Then disconnect the wires from the battery, and connect both of the wires from the binding posts on the moist chamber with the key. Immediately begin closing and opening the key regularly, once a second. If contractions result, continue until they cease. *Notice whether the contractions are given on closing or on opening the key, or both, and mark them accordingly, C and O,* since it is now the polarization current which is closed and opened.

Notice carefully, throughout the experiment any change in the character of the contraction following closing and opening the circuit. The contractions observed after the battery has been disconnected are caused by a current going in the opposite direction from the battery current, i. e., a descending current. This current results from electrolysis which has taken place at the points of contact of the nerve with the wires. The condition set up at these points by the passage of the battery current is analagous to that taking place in a storage battery, when it is charged, and the wires are said to be polarized. In order to avoid such disturbing currents it is necessary, whenever the direct current is used as a stimulus, to employ non-polarizable electrodes.

b. Non-Polarizable Electrodes.

APPARATUS.—The non-polarizable electrodes used in this course, consist of two boot-like pieces of porous baked clay, hollowed at the top to hold a solution of zinc sulphate, in which two small pieces of zinc are immersed. The boots of the non-polarizable electrodes should have stood for some time in physiological salt solution, so that they are thoroughly saturated with it at the time they are employed. When they are to be used, dry the glazed tops thoroughly; put the metal clips on the tops of the boots; fasten the clips on a glass rod; and fix the rod in a clamp on the support which holds the muscle clamp, in the moist chamber. (See Fig. 21.)

Dry the wires just used as electrodes, and connect them to the zincs; with a dropper put about half a cubic centimeter of zinc sulphate into the boots, being careful not to spill any of it on the outside of the electrodes. Then insert the zincs into the tops of the boots.

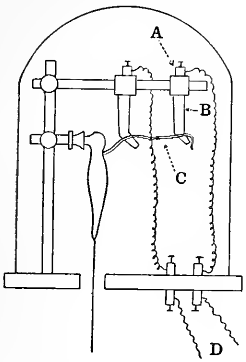


Fig. 21. Method of arranging non-polarizable boot electrodes in moist chamber. A, zinc; B, porcelain boot; C, nerve; D, wires to key.

EXPERIMENT.—Lay the nerve across the tips of the boots and repeat the experiment made before. If the electrodes are non-polarizable, closing and opening the battery circuit should give the same effect as before, but there should be no response to the movements of the key after the battery has been removed from the circuit.

On completing the day's work, the non-polarizable electrodes must be thoroughly washed and returned to the normal salt solution.

Pflüger's Law.

The polarization current which is set up, is strongest at first and gradually fades away; consequently in the course of an experiment, the student often sees the effects of the opening and closing of strong, medium, and weak currents. These effects, which differ with the direction in which the current flows through the nerve, have been classed under what is known as Pflüger's law. To recall this law one has only to remember the following facts:

1. The closing excitation develops in the nerve in the region of the cathode, and the opening excitation near the

anode, the irritability rising at the cathode when the current is closed, and at the anode when the current is opened (See Fig. 22).

2. The closing excitation is the stronger, the rise of irritability at the cathode when the current is closed, being greater than the rise at the anode when the current is opened.

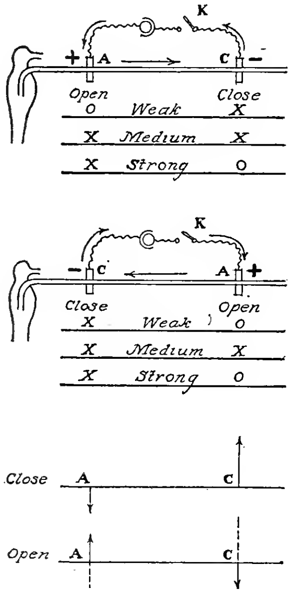


Fig. 22. Pflüger's Law. The two upper diagrams show the effect of ascending, and descending, weak, medium, and strong direct battery currents on the excitability and conductivity of a nerve. A, positive pole, the anode; C, negative pole, the cathode; K, key; X, stimulus effective; O, stimulus ineffective. The two lower diagrams indicate the irritability at the anode and cathode, when the key is closed and the current is flowing through the nerve, and the after effect following the opening of the key.

3. By strong currents the conductivity like the irritability of the nerve is lessened at the anode during the flow of the current, and at the cathode at the instant that the current ceases.

4. With an ascending current the anode is nearer the muscle, and with a descending current the cathode is nearer the muscle.

EXPERIMENT XX.

Response of Nerve Upon Closing and Opening the Direct Battery Circuit with Currents of Various Strengths.

APPARATUS.—Use the ordinary apparatus for recording muscle contractions. Introduce a rheocord into the circuit of a battery of two cells, making connections as indicated in Fig. 23. Mount a pair of non-polarizable electrodes, in the moist chamber, connecting the wires so that the current

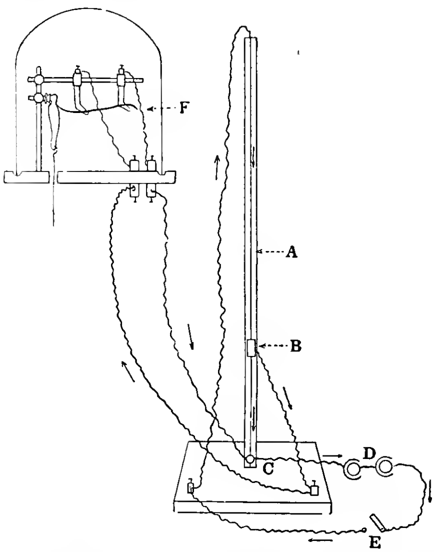


Fig. 23. Method of using rheocord. A, German silver wire; B, slider; C, double binding post at lower end of German silver wire; D, battery; E, key; F, nerve bridging the boot electrodes, the current being ascending.

will ascend the nerve. Observe that the current passes down the fine German silver wire of the rheocord to the slider (B) and there divides, part going to the nerve and part going through the lower part of wire. At the double post (C) at bottom of the wire, the two streams of the current unite again and pass together to the battery. Observe that the current traversing the nerve must increase as the slider is moved upward, because the resistance in the wire below the point (B) where the circuit divides is increased.

EXPERIMENT.—Since the direct current rapidly changes the irritability of a nerve, the following *Cautions* must be observed:

1.—Do not apply the current at all except when you wish a record.

2.—Do not let the current flow longer than is absolutely necessary.

3.—Obtain the record by comparatively few stimulations.

4.—Do not excite oftener than once in 15 seconds.

Move the slider to the bottom, then close and open the key. There should be no response. Move slider up 2 or 3 cm. and repeat. Continue in this manner, and mark on the curve the positions of the slider at which minimal and maximal, closing and opening contractions were obtained. Record as in Experiment III. Did the closing or opening contraction appear first? Did Wundt's closing or Ritter's opening tetanus show? If your preparation reacts well, and if you like, you may observe the facts tabulated as Pflüger's law (see Exper. XIX); this is not required, however.

EXPERIMENT XXI.

Stimulation of Human Nerves by a Direct Current.

APPARATUS.—The electric current, which is to be used, is supplied from a dynamo giving 60 volts.

Key G, Fig. 24, controls the flow of the current to the rheostat. In the rheostat it is shunted, the current passing through the resistance from P to N, and a portion of it being led off through the metal slider H to the post PP, which gives the branch of current to the arm circuit. The resistance in the rheostat is equivalent to the German silver wire of the rheocord used in Experiment XX.

Note that as the slider is moved clockwise, the resistance between the slider and post N increases and hence more current will go to the arm.

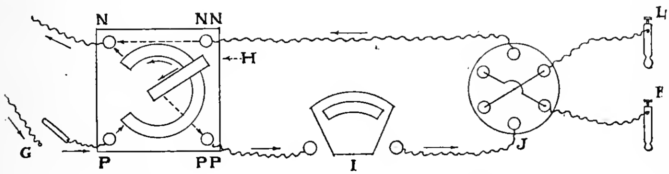


Fig. 24. Apparatus for stimulation of human nerves by a direct current. G, key; P, post where current enters, and N, where it leaves rheostat; PP, post connected with slider, from which current goes to milammeter; H, slider; I, milammeter; J, commutator for reversing current; K, L, electrodes; NN, pole on rheostat connected with N and receiving current returning from commutator.

In flowing to the arm, the current passes through the milammeter I, and then to the commutator J, through which it is carried to one or the other of the arm electrodes, according to the direction in which the bridge is rocked. If the bridge is rocked towards the electrodes, K becomes the positive electrode, the anode, and L the cathode; if it be rocked away from the electrodes, the current goes through the crossed wires, and L becomes the anode and K the cathode. In both cases the current returns from the cathode by way of the commutator to the pole NN of the rheostat, and thence to the pole N and so away.

EXPERIMENT.—When ready for this experiment report to instructor. Two stimulating electrodes are used, one being applied to each arm, over either the median or the ulnar nerve near the wrist. Choosing the nerve which in the preceding experiment gave the best results, and using your own induction coil, ascertain again the exact points on the two arms giving the best motor response. Mark these. Wet the places on the two arms again thoroughly by binding a wet pad, moistened with warm salt solution, on each, and while the skin is becoming saturated, study the apparatus. *See that hands are dry when apparatus is handled.* Bring slider against *flat side of checking post,* and see that the key is open. Then place the arms on the arm supports (see Fig. 18) and pressing the electrodes firmly over the motor points, make the electrodes fast.

In making the experiment the subject sits quietly, watches for the first appearance of sensation or contraction resulting from the stimuli, and reports at which pole it occurs. The other student, who is the experimenter, handles the key and rheostat, reads the milammeter, and records the results in a table of the following form, stating the number of milliamperes required to produce the effect sought. The red scale of the milammeter is the one to be observed.

TABLE OF STRENGTHS OF CURRENT REQUIRED TO PRODUCE EFFECT.

Physical Anode on.................................hand

	SENSATION.	CONTRACTION.
Cathode closing ..	....	....
Anode closing ...	....	....
Anode opening ..	....	....
Cathode opening .	....	....

When all is ready the experimenter closes and opens key. There should be no movement of milammeter needle and no effect at electrodes. He then advances the slider a short distance, closes the key, saying "close," then *as soon as the milammeter reading can be made,* opens the key and says "open." Experimenter must watch milammeter, leaving subject to report effects. If the current is allowed to flow too long, there are changes in irritability which destroy the value of the results. Advance slider again and stimulate again. Continue in this way, trying to find the least current that will give the effects mentioned in the table. Of course the experiment must stop when the stimulus causes too much discomfort COC (cathode opening contraction), is usually not obtained for this reason. No graphic record is taken. When table is completed, return slider to place of starting, rock the commutator, to reverse the current, then stimulate with various strengths of current

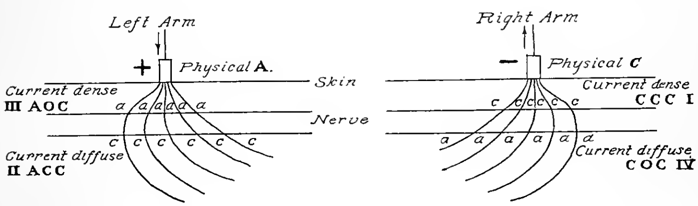


Fig. 25. Diagram of paths taken by direct current applied to human skin over nerve, and of place where current takes effect. +, positive electrode, the physical anode, on left arm; —, negative electrode, the physical cathode, on right arm; a, a, a, physiological anodes; c, c, c, physiological cathodes; I, CCC, closing excitation where current is dense; II, ACC, closing excitation where current is diffuse; III, AOC, opening excitation where current is dense; IV, COC, opening excitation where current is diffuse.

as before. Observe that the order of appearance of CCC, ACC, AOC, COC, are the same as before, but that they appear at the opposite hand. Do not take time to read milammeter in the second test. Table is to be made out for each student, and each reports results obtained by the experiment on himself.

To understand the results it is necessary to recall the following facts, as illustrated in Fig. 25:

The first letter of the ACC and AOC, refers to the positive electrode, the physical anode (see large A), and the first letter of CCC and COC, refers to the negative electrode, the physical cathode, (see large C).

The second letter, C or O, refers to the closing or the opening of the circuit. On closing the circuit, the stimulus is developed at the point that the current leaves the nerve, that is at the physiological cathode, (see small c, c. c) and on opening the circuit, the stimulus develops where the current enters the nerve, at the physiological anode (see small a, a, a).

In experiment XX, you saw that the closing contractions came with weaker currents than the opening, and the same should be seen in this experiment, CCC and ACC should be obtained with weaker currents than COC and AOC. There are two places where closing stimuli might develop, at the physiological cathodes (c, c, c), under the physical anode (A) and at the physiological cathodes (c, c, c), under the physical cathode (C). Since the current would be denser where it left the nerve under C than where it left it under A, CCC should come with a weaker current than ACC. For a similar reason AOC should come with a weaker current than COC.

EXPERIMENT XXII.

Currents of Rest and Currents of Action.

a. Current of Rest detected by Rheoscopic Frog Preparation.

APPARATUS.—Mount on short stand a brass L rod, and fasten a muscle clamp, with the jaws horizontal, to the short arm of the rod. Connect a dry cell and a key with an induction apparatus so as to give tetanizing excitations, and connect a pair of electrodes with the secondary coil.

EXPERIMENT.—Prepare (*A*) a nerve-muscle preparation, (*B*) a nerve-leg preparation (a "rheoscopic frog" preparation, which consists of a leg intact from knee down, and the sciatic nerve), and (*C*) a piece of thigh muscle having one uninjured surface and one surface cut squarely across the fibres. To prevent drying, put between layers of filter paper moistened with physiological salt solution. Place knee joint of *B* in clamp with leg pointing upward and nerve hanging below. Avoid clamping the nerve. Place *C* on a glass slide; make a fresh cross section on *C;* then holding glass slide in hand, bring *C* up beneath *B* in such a way that the nerve of *B* shall fall suddenly across cut surface and normal surface of *C*. *B* should contract, because the injured part of the muscle *C* is undergoing katabolic change and is consequently negative as compared with the normal surface. The nerve closes the circuit and is stimulated by the so-called "Current of rest," the "Demarcation current."

b. Current of Action detected by Rheoscopic Frog Preparation.

Mount the glass side in holder on L rod, and the rod on a stand. Place *A* upon the slide, and clamp the L rod so that the nerve of *B* lies lengthwise upon the muscle of *A*.

Stimulate nerve of *A* with tetanizing current of medium strength. Both muscles should be tetanized.

To find if currents spreading from electrodes have caused *B* to contract, ligature nerve of *A* tightly at its middle, with a moist ligature, and then stimulate above ligature. No contraction of *A* or *B* occurs. A moist ligature would not block an electric current, but by breaking the continuity of the nerve fibers, it effectually blocks a nerve impulse. It follows that *B* must have been stimulated by the "Current of action" the "Negative variation Current," of the muscle *A*. When *A* contracts, a wave of contraction passes over it, and at a given instant, some parts are undergoing greater catabolic change than others, and hence are electrically negative as compared with the less active parts. The nerve completes the circuit and is stimulated.

EXPERIMENT XXIII.

The Reflex Frog.

The value of this experiment is great if it be properly interpreted. Through it we have the best physiological evidence of the method of spread of reflex processes in the spinal cord. When studying the movements which result from excitation, one should try to recall the finer anatomy of the spinal cord, the longitudinal paths of conduction, the method of communication between the posterior and anterior roots, and the way impulses pass from side to side of the cord.

a. Time of Recovery from Shock.

Pith a frog's brain and plug cavity of skull with as little loss of blood as possible. (see Exper. IX). Note the time at which this is done. Place the frog on a plate, back upwards, and with the legs stretched out at full length. Note the time required for recovery from the shock, as shown by the drawing up of the legs. Now cover with moist paper and leave for half an hour. At the end of this time observe the frog's position. If cerebrum and cerebellum have been completely destroyed, *it will lie with nose against plate;* if turned on back it will not turn over; if thrown in water it will not try to swim; if stimulated it will move legs but not jump; the power to perform the most highly coördinated movements is absent.

b. Spread of Reflexes.

Clamp nickled L rod on stand, and put frog-hook on short arm of L. Suspend the frog from hook passed through nose. Gently irritate flank with a needle and observe local twitching of muscles; excite more strongly and notice spread of reflexes to limbs. Pinch a toe gently and then more strongly (do not crush) and observe and note the order in which the different parts of the leg and of the body respond to the excitation.

c. Are Reflexes Purposeful?

Place beneath frog a battery jar two thirds full of water, so that by lifting the jar the body can be washed. *Caution.*—In this and the following tests requiring the use of acid, be sure to wash it off after each test. Put a bit of paper two mm. square, wet in 10% acetic acid on right flank, left flank, median line of lower back, and on various parts of leg, and state in your notes the results. Hold right foot lightly and put paper on the right flank. Reflex should appear in right leg, and later in the left leg. The word purposeful in the question heading this section is not used in the sense of well adapted to the needs of the animal, but directed by volition to accomplish a definite object. In short, do the movements of the frog justify the view that the spinal cord is the seat of intelligence?

d. Reflex Time.

Immerse tip of longest toe in 0.1% H_2SO_4 up to a definite mark, noting number of seconds between immersion and withdrawal. Repeat five times with each foot and report average for each. Immerse to the same mark each time, as the distance affected influences the result. Wash off the acid after each test. Where is the time probably lost? Does the experiment favor the "neuron theory," or the theory of a continuous nervous network?

e. Spasm of Muscles versus Coöodinated Movements.

APPARATUS.—Arrange induction coil to give tetanizing excitations. Connect a pair of electrodes with the secondary coil.

EXPERIMENT.—Remove frog from hook. Open abdomen by cutting away whole of anterior wall; remove vicera without injuring the sciatic plexuses behind them. Cut through the *middle* of the sciatic plexus on one side, and free the nerves so that they can be laid across a pair of electrodes. Put frog on hook. Apply electrodes first to the peripheral, and after, to the central cut ends of the nerves of the plexus, taking care to use the *weakest effective tetanizing current and to avoid touching the electrodes to anything except the nerves.* Explain how the resulting movements differ.

EXPERIMENT XXIV.

Reaction Time to Sound.

Apparatus.—Blacken drum and fasten it at highest point on kymograph. Arrange to turn it by hand. Fasten the heavier muscle lever, with supporting screw down, on long stand at such height that it will write 2 cm. from bottom of drum. Put L rod on stand above lever; put elastic band on rod; and connect band with lever by a thread put through second hole, so that band will be slightly stretched. Fasten one end of a thread to the strip of wood provided, by passing thread through hole nearest the end and back through other hole, and tying it so that thread will not slip. Fasten other end of thread to third hole in lever, leaving thread of such length that the end of the piece of wood to which thread is fastened will be so near the table that when it is pressed on by finger the lever will move about 4 mm. Bring writing point of lever to drum. Mount fork on short stand, and place this stand so that fork will write the time one centimeter below lever and in same vertical line.

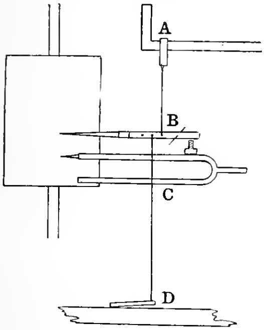


Fig. 26. Apparatus for recording reaction time for sound. A, rubber band; B, lever; C, tuning fork; D, strip of wood, which is to be pressed by finger against table.

Experiment.—The subject is to put finger on strip of wood and depress it so that the lever is pulled down and the wood rests on table; (see that the thread is vertical). He is to remove finger as soon as he can after hearing sound of fork. He must not react to sound of the moving drum, and to give quick response must have in mind the sound of fork. The experimenter must put yoke on fork; tell subject to close eyes; say "ready," and sometimes about a second later, at other times 2 or 3 seconds later, whirl the drum; then pull yoke off fork and stop drum as soon as subject is seen to respond. Be sure the drum is well under way before pulling off the yoke.

Rehearse the experiment two or three times without the pointers touching the drum. Then move drum up to pointers and see that they write well. *Mark the relative position of the pointers* on the drum by moving them. This is to be done before each test. Take 10 reaction times with each student as subject.

Reading of Curves.—Using two triangles draw a perpendicular from point where lever began to move, through the corresponding tuning-fork curve. Allowing for position of the writing points, count the number of waves, starting with the crest of the first and estimating in tenths the value of any fraction of a wave at the end. State time in hundredths of a second. Give in notes result of the separate observations and the average of 10 observations. Throw out only such observations as were known to be faulty at the time they were made. Account for variations.

Ordinary reaction time to sound is 0.15 second; to a touch on the skin, 0.145 second; and to an electric flash 0.195 second.

EXPERIMENT XXV.

Cutaneous Sensations and Muscle Sense.

Five types of sensation can be obtained from the sense organs which lie close to the surface of the human skin, viz.: cold, warmth. pressure, tickle, and pain. Each of these is caused by the excitation of special spots on the skin, and presumably special types of nerve endings. The pressure and tickle spots appear to be excited only by mechanical stimuli; the spots for cold and warmth are not so excited, the warmth spots responding to heat, and not to cold, and the cold spots to cold, and not to heat. The pain spots are excited apparently most readily by some form of pressure, but also respond to intense heat and cold.

It is strange that the same form of mechanical excitation, that caused by the pressure of the point of a small instrument, can awaken three different types of sensation. The quality of these sensations, if they are at all strong is so different, however, that they are unmistakable. The irritability of the tickle points is very variable. When it is slight and the stimulus is weak, the sensation is to be distinguished from pressure, in that it is more vivid, fixes the attention more readily, and lasts longer; when the irritability is greater, the tickle sensation is very different from the dull, short lived, pressure sensation. The peculiar burning, or tingling quality, lasting for a long time and often increasing in intensity after the irritant has been removed, is suggestive of pain rather than pressure. It excites an almost irresistable desire to rub or scratch the place, and is inhibited by strong deep pressure on the skin. The inhibition is probably due to fatigue. When the surface of the skin is at all dry, even slight pressures cause depression of a considerable amount of surface, and frequently excite both pressure and tickle spots at the same time, giving mixed effects. Touch is probably a mixture of faint tickle and pressure sensations. Apparently the sense organs for tickle lie slightly more superficial than those for pressure, and the organs for pain deeper, so tickle can be awakened by the most delicate pressures, a sensation of pressure by slightly stronger pressures, and pain by still stronger pressures. Pressure spots are closely related to the hair follicles, lying to the windward side of the hairs, and are easily excited by movements of the hairs. Tickle, too, can often be produced by very delicate movements of hairs, but if the hairs be repeatedly moved, the tickle sensation often gives place to pressure, because when the irritability of the tickle sense organs is slight, they fatigue more rapidly than the pressure organs. Both sensations can be obtained from parts of the skin where there are no hairs. Pain spots are by far the most numerous, the tickle spots come, perhaps, next in order, then follow pressure, cold and warmth spots. The number of the different spots to be found in a given area of skin differs greatly in different parts of the body. The tickle sense organs are probably our chief defense against insects, the bites of which have been found to innoculate animals with many forms of disease.

Experiment.

a. Cold and Warmth Spots.

Mark with red ink on some part of the skin, free from hairs, and convenient for study, as the volar surface of the forearm, or the radial side of the back of the hand, a square, 2 x 2 cm. and divide this into four, and then into 16 squares, by drawing fine lines. Determine on yourself the cold and warmth spots in the large square, by gently sliding the rounded point of a metal rod forward and back across the surface, in such a way as to cover it completely. In seeking the cold spots, use a cold dry rod; and in trying to find the warmth spots, use a dry rod that has been heated in water that feels hot to the hand. As the rods cool quite quickly, let one be heating while the other is being used. Mark the position of the spots found, by fine blue and red *crosses,* the ink being applied by a fine pointed stick. See if the cold spots respond to heat, and the warmth spots to cold. Do they react to pressure?

b. Tickle and Pressure Spots.

Examine the skin for tickle spots in an area 1 cm. square, by sliding across it the little glass ball on the point of a fine needle carried in the frame which will be provided. When a tickle spot has been approximately located, determine its position more exactly by reversing the frame and lightly touching the skin with the head of the needle. The pressure spots can be similarly located by using a slightly heavier needle. If the skin be dry at the time, exact localization is impossible because too large an area will be depressed. Softening the skin with warm water and then with vaseline is of assistance. The irritability of the tickle spots varies greatly, not only with different individuals but by the same person at different times. Mark the points found with fine red and blue *dots*. Is tickle obtained from the pressure spots, and vice versa?

c. Pain Spots.

The pain spots are so numerous that their positions cannot be marked except by very fine points, and by working under a magnifying glass. Locate a number of them near together, and see whether there are places on the skin between them where pain is not felt. Use the point of a fine needle; lightly press on the skin without puncturing it.

Before writing up your notes, check up a number of your results, to see whether the spots can be found a second time, at the place where they were first located. A map is to be drawn showing the position of the spots which were located.

d. Muscle Sense.

Under this term are grouped the sensations supplied by the different nerves from the muscles, tendons and joint surfaces. Although these sensations are ordinarily unnoticed they are the indispensable guides for all coördinated acts, being assisted by sensations from the skin.

Experiment.—1. Close the eyes; slightly separate one upper arm from the body; flex the elbow to slightly more than a right angle; partly separate the fingers. Now, without looking, place the other arm and hand in the same position. See how nearly the positions correspond. Repeat, and closely observe the sensations which you experience.

2. Close the eyes; raise both arms at the same time, and try to touch corresponding points on the two sides of the nose at the same time, with the fore fingers.

3. Place the left hand on the right; press down hard on the right hand, at the same time that the right hand resists the pressure. Notice all the points where you experience sensations.

Report the results of the above experiments in your notes.

EXPERIMENT XXVI.

The Knee-Jerk as Modified by Reenforcing and Inhibiting Influences.

If a blow be struck on the ligamentum patellae when the lower leg is in a position that puts the ligament under slight

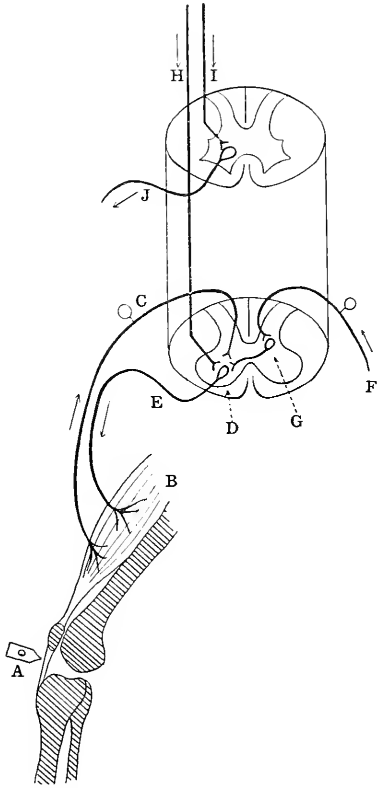


Fig. 27. Diagram of nervous paths followed by the nerve impulses causing the knee-jerk and its reenforcements. A, hammer placed to strike ligamentum patellae; B, quadriceps muscle; C, posterior spinal nerve root; D, motor cell in anterior horn of gray matter of lumbar cord; E, anterior spinal nerve root; F, sensory nerve from other leg; G, commisural cell; H, descending path from leg arca in cerebral cortex; I, descending path from arm area in cerebral cortex; J, motor nerve to arm.

tension, a twitch is transmitted to the vastus internus and crureus divisions of the quadriceps extensor muscle. The result is a brief contraction of this muscle and a sudden forward swing of the leg.

Two explanations of the contraction of the quadriceps are offered; viz: (1) The knee-jerk is a reflex act (See Fig. 27). The twitch acts as a mechanical stimulus to the sensory nerve ends in the muscle and its tendon; the resulting impulse passes to the spinal cord through the posterior spinal nerve roots, and excites anterior horn cells in the leg areas of the third and fourth lumbar segments of the cord; and these cells discharge motor impulses to the quadriceps muscle and cause it to give a sudden, brief contraction. The response of these cells to the sensory stimulus may be either reënforced or inhibited by other impulses reaching them a short time before the impulses from the leg. (2) The knee-jerk is the result of the direct mechanical stimulation of the muscle, itself. The greater the tension the better the muscle responds to the blow on the tendon. The anterior horn cells are always, during waking hours, sending tonus impulses to the muscles which keep them under more or less tension, and these impulses are increased by reënforcing and decreased by inhibiting influences. It will be here assumed that the first explanation is correct.

Apparatus and Position of Subject.—The subject is to lie on his left side with his head on a pillow, his thigh on a support, and his foot in a swing (see Fig. 28). The position must be perfectly comfortable, so that he could go to sleep. Adjust the support (A) *under the thigh so that the lower leg will swing freely.* The subject must be in such a position that the cord suspending the swing is vertical when the leg is at rest; and throughout the work he must lie quietly and relaxed with eyes closed except when told do otherwise. Connect the back of the swing by a thread passing round pulley (B) to a cross shaped writing needle (C), so that the rubber band (D) supporting the latter is under a slight tension and the needle free to move. The rubber band must be given a few twists, so that by its torsion it will keep the writing point against the drum. Adjust the hammer (E) so that when it hangs vertically, the middle of the striking face will just touch the skin over the middle of the ligamentum patellae, and so that the blow will be struck at *right angles* to the ligament. Ordinary clothing will not interfere with results. *Make this adjustment with great care,* then clamp the rod supporting the hammer.

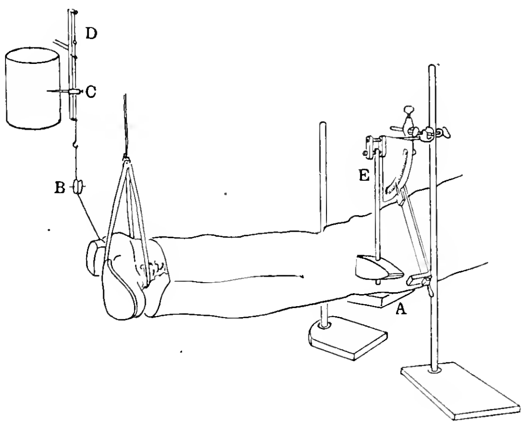


Fig. 28. Method of supporting thigh and foot and of recording the swing of the lower leg in the knee-jerk experiment. A, support under thigh; B, pulley; C, cross shaped writing needle; D, rubber band, twisted so as to keep point of needle against drum; E, knee-jerk hammer.

EXPERIMENT.—Four students work together, each taking his turn as subject, experimenter, assistant, and clerk. The experimenter uses the hammer; the assistant sits near the head of the subject and applies the sensory or psychic stimuli when signaled by the experimenter; the clerk looks after the drum, and keeps record of any reënforcing or inhibiting stimuli, marking on the drum, 1, 2, 3, etc., to correspond to his notes. During the entire experiment the subject must be completely relaxed and the room perfectly quiet. Success depends entirely on the contrast between repose and action of the central nervous system. If those who make the experiment are not quiet and annoy or excite the subject, except when a special effect is desired, the whole experiment fails.

a. Record of Normal Knee-Jerk.

Find the position of the hammer that will give a knee-jerk, the record of which is about 2 cm. high. Make note of position of arm holding hammer. Start drum at 2 or 3 mm. per second and record a series of 20 normal knee-jerks, giving the blows rythmically at such a rate that the foot has time to come to rest after each jerk. Observe that even when the subject is relaxed and the room quiet, the knee-jerks vary in height, in other words, that the irritability of the reflex mechanism is changing.

It not infrequently happens, at first, with an irritable subject, that the writing point does not return to the base-line, because of increased tonus of the extensors of the thigh. As he becomes accustomed to the experiment and quiets down, the tonus generally decreases and the knee-jerk lessens.

b. Motor Reënforcement.

When the jerks become about the same height, *while continuing to strike the knee rythmically,* tell the subject to clench his hand at the instant the command is given. Note whether speaking to him causes larger knee-jerks, i. e., a psychic reënforcement; then give order to clench the hand, and release the hammer just after the order is given, i. e., allow for reaction time of subject, and cause hammer to strike knee about 0.1 sec. after his hand is clenched. Bowditch and Warren found that if the blow on the knee occurs at the instant the hand is clenched or within 0.4 secs. after the clench, the knee-jerk is greater than normal, i. e. reënforced; if the blow is struck between 0.4 and 1.7 secs. after the clench, the knee-jerk is lessened, i. e. inhibited. If the blow comes still later, the clench has no effect. The explanation of the effect of the clench, is that when the motor-cells of the arm area of the cerebral cortex are called into action, the motor cells of the leg area of the cerebral cortex are excited through association fibers, and impulses from the cells of the leg area of the cortex spread to the anterior horn cells of the leg area of the cord, and increase their irritability for a short time. If, however, the nerve impulse from the leg reaches the anterior horn cells as late as from 0.4—1.7 secs. after the clench, it finds them in a condition of decreased irritability, an after fatigue effect, and the knee-jerk is inhibited instead of reënforced. Record another series of normal knee-jerks, and see if the time of the blow with respect to the clench alters the result. Sudden discharge of voluntary impulses to any other muscles, e. g. clenching the jaw, or even winking, will also cause a reënforcement or inhibition.

c. Reëforcement by Sensory Stimuli.

Pulling hair, tickling face with a camel's hair brush, an unexpected sound or odor, an excitation of the mucous membrane of the throat, of a type to cause unintentional, as well as intentional swallowing, in short, any sensory impulse of a type to cause reflex contraction of voluntary muscles, will cause a reënforcement. In such cases the secondary impulse acts to alter the irritability of the anterior horn cells (see Fig. 27), and so effect the way they will react to the sensory impulses caused by the blow.

To show this, record ten or more normal knee-jerks by a series of rythmical strokes, and when the jerks are of about equal height, test several sensory effects, marking on drum the times that each of the stimuli is given.

d. Psychic Reënforcement.

With subject as quiet as possible, eyes closed, room perfectly still, record a series of 10 or more normal jerks, and then, while continuing to strike the blows rhythmically, test the effect (1) of speaking to subject; (2) of asking him to multiply two numbers given him; (3) of asking him to think of some stirring poem, etc. The clerk should note all these occurrences with care, and also the effect of sounds produced in neighboring rooms or out of doors, the entrance of any one into the room, and all external influences that are able to excite the subject in the least degree. The susceptibility to such influences varies greatly with the subject. The student who was the subject of the experiment is to have the record.

EXPERIMENT XXVII.

Conditions Governing Blood Pressure and Velocity of Flow. Use of the Artificial Circulation Apparatus.

In this apparatus the auricle is not contractile, and the ventricle is filled in part by gravity and in part by suction from the bulb, which has a much greater suction power than a true ventricle. The pulmonary circulation does not appear.

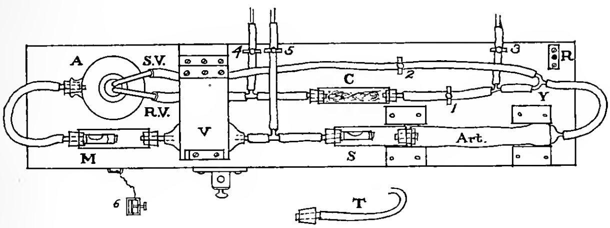


Fig. 29. Floor plan of artificial circulation apparatus. A, bottle representing left auricle, with two tubes, representing veins, entering top, and tube communicating with valve at bottom; M, mitral valve, consisting of an aluminum tube, closed at the end, and having a hole in the side, which is covered by a tube of rubber dam, which has at one side an opening for escape of fluid, (when the valve is competent the rubber tube is adjusted so that it covers the hole in the aluminum tube, and when it is made incompetent the rubber tube is turned round so that it only partly covers the hole in the aluminum tube). V, hinged board actuated by cam, not shown in diagram, and compressing the rubber bulb which represents the left ventricle; S, aortic semilunar valve; Art, large artery connecting by Y tube with two small arteries; 1, screw clamp, representing muscles in walls of renal artery; 2, clamp, representing muscles in walls of arteries of skin; C, tube containing glass wool, representing resistance in renal capillaries; RV, renal vein; SV, skin veins; 3, clamp controlling mercury manometer recording pressure in renal artery; 4, clamp, controlling mercury manometer recording pressure in renal vein; 5, clamp controlling tube leading to membrane-manometer, recording pressure in ventricle; 6, clamp by which tube leading to mitral or aortic valve can be partly closed off to produce the resistance of stenosis; R, support for vertical rod, to which is to be clamped the receiving tambour, which is to be applied to the large artery, so that its pulsations may be recorded; T, stiff walled tube which is to connect valve chamber S, with Y tube, when the effect of a stiff walled artery is to be studied.

Become thoroughly familiar with the apparatus before proceeding with the experiment. Adjust the machine as follows:

See that the clamps 3, 4 and 5, controlling the connections with the manometers, are closed, and the clamps 1 and 2, controlling the small arteries, are open; then fill the tubes with water by pumping rhythmically. If there is not sufficient water in the reservoir, have the assistant replenish it with *distilled water*. When filling the tubes, hold the right hand end of the apparatus up at an angle of 45°, until the air is out of the tubes nearest the bulb, and then tip up the other end, and expel the air from the rest of the tubes.

Compress the bulb only by means of the board placed above it. The rod supporting the cam can be moved up or down. When a small amount of compression is desired, let the end of the rod rest on the little block of wood beneath; when more compression is needed, swing the block to one side and lower the rod.

The following cautions must be observed.

The air should be driven out of the apparatus.

The arterial manometer should be watched, to see that the mercury is not driven down round the bottom of the U.

The clamps controlling at least one of the arteries should be kept partly open; see that during the pumping water flows into the reservoir.

Be careful not to bend the rods carrying the pointers of the mercury manometer.

Mercury should not be allowed to collect above the manometer floats.

Dry the apparatus and table before leaving, and raise the rod so that the board shall not rest on the bulb.

Whenever the stopper is to be taken out of a valve chamber, clamp the tube between the bottle and the mitral valve.

ADJUSTMENT OF APPARATUS.

Connect the arterial and venous system of the apparatus with the larger and smaller manometers, respectively, and open the clamps wide. Mount a time signal to write at the bottom of the curve, about half a centimeter below the venous manometer. Adjust the pointers on the floats so that the venous manometer will write about a centimeter below the arterial; the three writing points should be in the same vertical line. Be very careful not to bend the delicate rods carrying the pointers.

Adjust the apparatus to what may be called *"normal" conditions.*

a. By sliding the piece of wood under the rod on which the cam operates, thus limiting the compression of the bulb, and the amount of fluid pumped.

b. By screwing down clamp 2 on the tube not connected with the capillaries.

c. By gradually tightening the other arterial clamp 1, until the flow into the bottle is constant and the venous manometer barely oscillates, and the arterial manometer records a diastolic pressure of about 25 mm. (i. e., the pointer keeps about 12½ mm. above the base line at the close of diastole) when the rate of pumping is once in two seconds.

Pump rhythmically at the rate of once in two seconds, and observe:—

1. The ventricle is filled mainly by the suction created during diastole, and partly by the force of gravity. (In the body suction plays only a small part, the ventricle being filled by the returning blood and by the contraction of the auricle.)

2. The force of the ventricular contraction is converted partly into energy of flow, i. e., kinetic energy, as seen by the entrance of the fluid into the bottle; and partly into energy of pressure, i. e., potential energy, as seen by the stretching of the wall of the large artery, and the rise of the mercury in the manometer.

3. The pressure falls during diastole, because the potential, or pressure, energy is converted into energy of flow, as shown by the venous flow, the narrowing of the large artery, and the fall of the mercury in the arterial manometer.

4. The pressure in the veins is low, because of the small resistance ahead, and the fact that a large part of the energy is expended in overcoming the resistance in the small arteries.

5. The pressure in the veins is quite constant, because it is kept up during systole by the contraction of the ventricle, and during diastole by the elastic recoil of the arterial walls acting against the resistance in the small arteries and capillaries. Notice that if the resistance is lessened by opening clamp 1 on the artery connected with the capillaries (causing vaso-dilation), the flow becomes rhythmic, and that as this clamp is screwed down (vaso-constriction produced), the venous flow becomes constant again, and the venous manometer ceases to oscillate. Adjust the arterial clamp so that the venous manometer bearly oscillates, and make the following experiments:

EXPERIMENTS. PART I.

a. Effect of Inertia of Mercury.

Adjust the drum to the pointers, and revolve it to draw base lines. Pump for twenty seconds at a regular rate of once in two seconds, watching the venous flow and the arterial manometer, and when the rhythm has been acquired, and the mercury has reached the new level, continuing at the same rate, start the drum and take a record. The venous pressure remains almost constant and low; the arterial pressure rises in systole, and during diastole gives several oscillations. due to the inertia of the mercury.

Now gradually screw down the clamp 3 on the tube communicating with the arterial manometer until these secondary oscillations disappear. Leave the machine adjusted in this way in the following experiments. This method is used to minimize the changes due to inertia, and gives a record approaching more nearly the mean pressure.

b. Effect of Rate.

Pump at the rate of once in two seconds and when the arterial pressure has reached the new level, start the drum and record five or six pressure waves and stop drum. Repeat at the rate of once a second, and again, at a rate of once in two seconds. Next decrease rate to once in three seconds, and record five waves.

c. Effect of Increased Output.

Pump at a rate of once in two seconds, and when the pressure has reached the new level, start the drum and record five waves. Now increase the output by lowering the rod on which the cam works, and repeat, recording five waves.

d. Effect of Resistance.

Pump with "*normal output*," at the rate of once in two seconds; when the pressure level is reached, record five waves and stop the drum; keep on pumping, but loosen the screw of clamp 1, representing the peripheral arterioles, and when the new pressure level is reached, start the drum and record five waves; stop the drum, but keep on pumping; now screw down the clamp until the venous flow is almost obliterated, and when the new pressure level is reached, start the drum and record five waves.

e. Effect of Resistance in Two Systems of Arteries on Distribution.

The main artery divides into two branches; the one having the capillaries and controlled by clamp 1, can be considered the renal artery, and the other controlled by clamp 2, the arteries of the skin. Dilation of the skin vessels will lower the general arterial pressure, and the pressure in the renal artery will fall, and the flow through the kidney will lessen. Increasing the vaso-constriction in the skin will produce the opposite effect.

Test this out on the model, by pumping at the rate of once in two seconds, when clamp 1 is adjusted to "normal conditions, and clamp 2 is closed; then while continuing to pump, and while watching the flow from the renal vein, gradually open clamp 2, (produce vaso-dilation in the skin vessels); then screw down clamp 2, (cause vaso-contriction in the skin). Repeat the experiment with the drum running, and record the changes in pressure in the renal artery.

f. Some Clinical Applications.

By varying the rate of pumping, the volume pumped, and the peripheral resistance, one can imitate a number of interesting phenomena.

1. *Effect of Vagus Inhibition.* By vagus inhibition the heart is stopped, then occasional beats are seen, then, when the inhibition ceases, the heart beats gradually faster until a rate somewhat higher than normal is reached (to compensate for the low pressure), and then returns to its normal rate. To test these effects, adjust machine to normal conditions, pump at rate of once in two seconds, let drum run, and after about ten seconds produce the inhibition effects by altering the rate of pumping

2. *Action of Depressor Nerve.* This nerve starts at the root of the aorta, where it is excited by a pressure higher than normal. It acts to inhibit the vaso-constrictor center in the medulla and possibly to excite the vaso-dilator center, and so causes vaso-dilation. The action can be readily imitated by pumping at a regular rate, and after the normal pressure is obtained, lessening the peripheral resistance in the small arteries gradually, (clamp 2 can be used to advantage), and then restoring the pressure by gradually tightening the clamp.

3. *Traube-Hering Waves.* These waves are caused by rythmic action of the vaso-constrictor center.

4. *Nitrite of Amyl.* This drug acts on the muscles of the walls of the arteries, causing them to dilate. As the dilation occurs the heart beat quickens to compensate for the fall of blood pressure. During the pumping produce a gradual fall of pressure, and then attempt to restore the pressure by quickening the rate of the heart.

5. *Hardening of Wall of Artery (arterial sclerosis).* Obtain a "normal" record of five or six pressure waves. Stop the drum, substitute for the elastic, an inelastic, stiff walled rubber tube (T) supplied in the basin. Leaving the other adjustments as before, pumping at the same rate, again record five or six waves. Observe the character of the

flow into the bottle. *Caution.* There will be a big fling of the mercury and the manometer must be watched to see that the mercury is not thrown out.

Notes. State in the notes the effect of increased heart rate, increased output, increased peripheral resistance, and a hardening of the arterial wall, on the mean, systolic, diastolic and pulse pressures recorded by the arterial manometer. State effect of these factors on the venous pressure, on the size of the venous pressure oscillations, and the venous flow. State how the blood flow through an organ is influenced by vaso-motor changes in a distant organ. The results may be given to advantage in tabular form, an increase being noted by + and a decrease by —.

	Heart has Increased		Vaso-constriction		Artery
	Rate	Output	Local	Distant	Hardened
Arterial pressure					
Mean					
Systolic					
Diastolic					
Pulse					
Venous pressure					
Venous oscillations					
Venous flow					

EXPERIMENT XXVII—SECOND DAY.

PART II.

The method of air transmission devised by Marey, is employed to record a great variety of physiological movements. By this method, two little drums covered with rubber membrane are connected together by tubing. A plate of metal resting on the membrane of one of the drums, (the recording tambour), is connected with a light lever, and when air enters or is driven out of the other drum (the receiving tambour), by movements imparted to the membrane covering it, the lever rises or falls. There is a T-tube at one part of the tubing connecting the drums, and this supplies a side opening by which air can enter or escape when the tambours are not in use. This opening is controlled by a pinch-cock. The level of the lever can be adjusted by placing the support of its axis at a suitable angle.

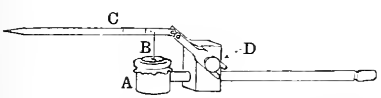


Fig. 30. Recording tambour. A, tambour; B, aluminum plate, with ball-and-socket joint for pin acting on lever; C, lever with celluloid writing point; D, support of lever.

Caution. Do not apply the pinch-cock, excepting when the tambours are to be used. See that the lever of the recording tambour is horizontal just before a record is to be taken, and never let the membrane of the recording tambour be greatly stretched.

Adjustment of Apparatus to Record the Pulse and Intraventricular Pressure.

Adjust a receiving tambour to the wall of the artery, and connect it with the large recording tambour. Connect the tube from the ventricle with the small recording tambour. Arrange the writing points, to write in the same vertical line with the float of the arterial manometer. Adjust the rod limiting the pressure of the cam on the bulb so as to give a small output from the ventricle, then pump in the manner directed, at the rate of once in two seconds. Only a very small pulse is given with clamp 1, representing small arteries, *wide open*. Gradually increase the peripheral resistance, and observe the resulting distention of large artery and pulsation of tambour. Several beats may be required to fill the artery before the tambour will record, and then the record should be 8-10 mm. high. Record on the drum, simultaneously, the pulse, the intra-ventricular pressure, the arterial and venous pressures, and the time. The pulse given by the apparatus does not give a true picture of the human pulse; for example the dicrotic and the predicrotic and postdicrotic waves are not shown. One can use the machine, however, to study the effect of a number of conditions on the height of the pulse oscillations, and on the rate of fall of the pulse wave.

a. Effect of Rate.

With the machine adjusted for normal conditions, pump for thirty seconds, at the rate of once in two seconds; start the drum, adjusted to run four mm. per second, and record five or six waves. Stop drum. Pump at the rate of once a second; once in two seconds; once in three seconds, consecutively, getting records in each case, stopping the drum between records.

b. Effect of Volume Output.

Record five normal waves. Stop drum. Increase output by lowering rod and keeping the same rate, record five more waves.

c. Effect of Peripheral Resistance.

Open the clamp (1) representing the peripheral resistance in the arterioles. Pump at the rate of once in two seconds, and record five waves. (Low resistance pulse). Stop drum, continue pumping, and gradually increase the peripheral resistance by tightening the clamp until a stream barely flows into the bottle. Record five waves. *Caution*—Watch arterial manometer.

Notes.—Explain effect of rate and volume output on shape and size of pulse. Why does increasing peripheral resistance, for example, cause pulse waves to first grow larger and then smaller? Explain the effect on the rate of fall of the pulse wave. Explain difference in ventricular and aortic pressure curves.

PART III.

Effect of Lesions of Heart Valves.

Failure of a valve to close its orifice perfectly is called *insufficiency*. Abnormal narrowing of its aperture is called *stenosis*. These defects in heart-valves are usually accompanied by dilation of the cavities, which discharge through the valves, and hypertrophy of the heart muscle, which is known as *compensation*. These three conditions can be imitated in a way in this machine as follows: *Insufficiency*, by rendering a valve incompetent, by adjusting the rubber tube so that it only partially covers the opening in the aluminum tube; *stenosis*, by applying clamp 6 to the tube leading to a valve chamber; and *compensation*, by increasing the compression of the bulb, thus permitting a greater outflow at a stroke.

It must be borne in mind that these lesions in the living subject are accompanied by other changes, so that the results are of value only as indicating fundamental relations, which are here separated from complications usually present. In the model compensatory changes can occur only in the left ventricle, and the compensatory effects produced by changes in the auricle and in the right side of the heart cannot be studied.

With the apparatus adjusted for normal conditions, being sure that there is a *slight* venous pulse, and pumping at the rate of once in two seconds, record, first, five or six normal beats; stop the drum, create the lesion desired, and after pumping a number of times, start the drum and record five or six lesion curves. Again stop the drum, cause the compensation, and after pumping a short time, again record five or six waves. This compares in a row, normal curves, effect of cardiac lesions, and effect of compensation.

Repeat for each valvular lesion in the following order:

a. Mitral Stenosis.
b. Aortic Stenosis.
c. Mitral Insufficiency.
d. Aortic Insufficiency.

Notes.—*Explain the results in each case, and state in which cases the compensation made the curve more nearly normal, and why. Also state changes in form of pulse.*

Use the following form in reporting the effects of the valvular lesions studied.

LESION	PRESSURE Increased or Decreased	COMPENSATION Effective or Ineffective
Mitral Stenosis	Systolic............ Diastolic........... Pulse............... Intraventricular.... Venous.............	....

EXPERIMENT XXVIII.

Circulation and Respiration of the Mammal.

Experiments on these subjects will fill two afternoons, the apparatus and general methods being the same for both days. The students will work in groups of four, and the part of the work to be done by each student is shown in the following schedule. The number of the student as given in the schedule will be assigned by lot.

SCHEDULE OF WORK.

Experiment 28	STUDENT 1	STUDENT 2	STUDENT 3	STUDENT 4
Right carotid and vagus	Operate	Assist	Etherize	Apparatus
Left carotid and vagus	Apparatus	Operate	Assist	Etherize
Sciatic	Etherize	Apparatus	Operate	Assist
Tracheotomy and open chest	Assist	Etherize	Apparatus	Operate
SECOND DAY Experiment 29				
Right carotid and depressor	Assist	Etherize	Apparatus	Operate
Left carotid and depressor	Etherize	Apparatus	Operate	Assist
Tracheotomy and open chest	Apparatus	Operate	Assist	Etherize
Phrenic and peristalis	Operate	Assist	Make nerve leg prepart'n	Apparatus

Success in the experiments, requires that the apparatus shall be thoroughly understood before the work is begun. Students assigned to this work will be given an opportunity to study the apparatus, and be quizzed on these notes, the latter part of the preceding afternoon.

Apparatus.—The arrangement of the apparatus is to be seen in Fig. 31. The following list of apparatus and instruments will be required, and everything must be at hand before the work is begun. The cannulae are to be kept in parafine oil, and will be issued by the Instructor.

APPARATUS TO BE FURNISHED BY LABORATORY.

Animal-board with head-holder.	Electrodes.
Manometer outfit.	Bulldog forceps.
Artificial respiration outfit.	Kymograph for long paper
Basin for sodium chloride.	Ligatures, fine.
Battery jar.	Ligatures, coarse.
Bottle of ether.	Water manometer.
Bulb and cannulae for artery.	Two pinch cocks.
Cabinet-makers' clamp.	Plate.
Two Cannulae for trachea.	Pneumograph.
Burette clamp.	Rod, nickled.
Three clamps for stand.	Rubber tube with glass T.
Screw clamp for trachea.	Scalpel.
Three screw clamps.	Shears.
Etherizing cone.	Sponge.
Four cords for animal board.	Small stand.
Two cords with hooks.	Support for kymograph.
Two cloth covers.	Recording tambour.
Director.	Two towels.
Dish for sodium sulphate.	Silk thread and weight.
Dropper.	Time signal.

APPARATUS TO BE FURNISHED BY THE FOUR STUDENTS ASSIGNED TO THE WORK.

One dry cell.	Fine and strong forceps.
Induction coil.	Mercury key.
Drum square.	Wires.

DIRECTIONS TO STUDENTS CARING FOR APPARATUS.

First close cock 1 and all clamps, then raise pressure to 110 mm. (55 on scale), in bottle (I) containing anticoagulation fluid, by using pump. Pump very carefully, or the mercury will be forced out of the manometer. Next raise bulb K until it and its tube are vertical; open clamp 4, then gradually open clamp 3, and let fluid rise in tube and fill bulb; finally close clamps 3 and 4. Put bulb in dish so that any drip will be caught. Open cock 1, and then gradually

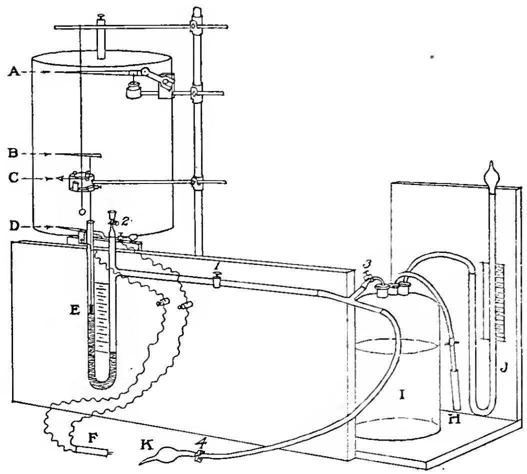


Fig. 31. Scheme of apparatus for studying the blood pressure of a mammal. A, tambour lever; B, pointer of a manometer float; C, time signal; D, short-circuit key; E, mercury float; F, electrodes; H, bicycle pump; I, anticoagulation fluid pressure bottle; J, manometer communicating with pressure bottle; K, bulb and cannula; 1, cock; 2, 3, 4, clamps.

open clamp 3 and fill the tubes connected with the manometer. When the fluid has risen as far as clamp 2, close clamp 3 and then clamp 2 and cock 1. It may be necessary to introduce a wire into the right side of the manometer after taking off clamp 2, in order to remove the air from that portion of the manometer. If in the process of filling, air bubbles are seen in the tubes, they may be removed by raising the manometer end of the system and tapping on the tubes. Clamp 3 should be closed or only slightly open while this is being done. Notice that the mercury in the two arms of the manometer is not at the same level. This is due to the weight of the anticoagulation fluid on one side of the U. Now place bulb K slightly above level of mercury in manometer; open cock 1 and clamp 4, and lower bulb until the mercury of the recording manometer has the same level in the two arms; close clock 1 and clamp 4. Place point of time signal (C) just behind and on a level with the pointer of the manometer float (B). The time record will in this position give a base line from which all pressures are to be read.

Connect the clock circuit with the binding posts at the back of the board connected with the time signal. Place the induction apparatus behind the manometer outfit, and put a dry cell and a key in the primary circuit, connecting them so as to give a tetanizing current. Connect secondary coil with the binding posts at the back of the board connected with the short-circuit key (D) on top of manometer board. Fasten a pair of electrodes (F) to the binding posts on the front of the board. Start vibrator, open short-circuit key, and test current with the tongue. A current of medium strength will suffice. Using drum square, see that writing points of recording tambour (A), manometer (B), and key (D) write in the same vertical line.

By means of pump, raise the pressure in the bottle containing anticoagulation fluid until the mercury in the manometer connected with the bottle stands at 100 mm., pumping with care. Open cock 1, and then gradually open clamp 3, until the mercury in the recording manometer rises to 50 mm. Close 1 and 3. The true pressure is twice the amount recorded, for the mercury falls on one side of the tube as it rises on the other. The object of raising the pressure, is to limit the amount of blood which will leave the artery when it is connected with the manometer.

The apparatus must be ready to use the instant that the operation is completed. See that three loops of paper for kymograph have been blackened, and place one on the drums. Mark the position of the writing points on the paper.

During the taking of the records you must start and stop the drum; must mark the position of the writing points on the drum before each test; must give the stimulations by depressing the short circuit key; see that the drum runs for at least 15 seconds before and 15 seconds after each test; put a letter a, b, c, etc., indicating the experiment, just over the record of the short circuit key, for each test; and must label each loop of paper with your name, before giving it to the assistant to fix. At the close of the experiment, you must clean all stimulating and recording apparatus, and account for each piece to the Instructor.

DIRECTIONS TO ASSISTANT.

It is the business of the assistant to see that the instruments and ligatures are in order, and are at the hand of the operator throughout the operation and the experiment. Cannulae will be supplied by the Instructor when required. While the animal is being etherized, fill the animal board with water at 45° C; heat some salt solution in a basin provided for the purpose, put a sponge in it, and place it on the operating table. During the operation, be ready to sponge the wound, to pass needed instruments to the operator, and to tie the ligatures when required. Do not be officious. Remember that you are the assistant of the operator. At the close of the experiment you must return all instruments, cannulae, etc., in good order to the Instructor, and see that the animal board, head holder, and artificial respiration apparatus are clean.

ANESTHESIA.

Anesthesia may be divided into three stages: I, Incomplete; II, Complete; and III, Danger period. These stages show the following peculiarities, which must be kept in mind when administering ether. (For anesthesia in man, see Cushney's Pharmacology.)

STAGE I. *a.* Struggling because of dislike of the drug, and later because of excitation of Nervous Systems; respiration irregular from irritation of mucous membrane, often with pauses and gasps; salivation for the same reason; pupil dilated. *b.* Consciousness beginning to be lost, and toward end, lessening of reflexes.

STAGE II. Quiet; respiration regular and deep, ("snoring respiration"); pupil contracted; reflexes lost; complete unconsciousness.

STAGE III. The danger period. Respiration slow and shallow, often long pauses; pulse slow and feeble; pupil dilating quickly; absence of all reflexes.

Rabbits differ from men, dogs, and cats, in that convulsive respirations immediately precede death in the third stage.

These effects may be tabulated as follows:

STAGES ANESTHESIA.

	INCOMPLETE	COMPLETE	DANGER POINT
Respiration Depth	Medium	Deep	Shallow
Rate	Rapid	Slow	Slow
Regularity	Irregular often long pauses	Regular	Gasps or long pauses, or convulsive
Reflexes	Present	Absent	Absent
Pupil	Dilated	Contracted	Dilating

The Behavior of the Pupil may be explained as follows: The size of pupil is controlled by two muscles, the sphincter pupillae and the dilator muscle. Each of these antagonists is during waking hours in more or less tonus. Contraction of the pupil might be caused by excitation of the sphincter or inhibition of the dilator muscle; dilation might be caused by excitation of the dilator muscle or inhibition of the sphincter; or both of these processes might occur simultaneously ("reciprocal innervation").

During waking periods, the tone of the sphincter tends to be inhibited by sensory stimuli, and the pupil tends to dilate.

Light falling on the retina causes reflex excitation of the sphincter, and perhaps inhibition of the dilator, and the pupil tends to contract.

Emotional excitement tends to cause marked dilation of the pupil, by excitation of the dilator, as well as inhibition of the sphincter, and this is to be seen *when the ether is first applied.*

In sleep the eyes are rolled upward and outward, and the pupils constrict because of lessening tone of the dilator and greater tone of the sphincter, and this is to be seen in *complete anesthesia.*

In the danger stage, the centers controlling the sphincter cease to act and the pupil dilates.

Directions to Anesthetizer.

See that there is no gas flame in the same part of the room. Ether vapor travels far and is exceedingly inflammable.

Let the student who is to operate, hold the four legs of the rabbit between the fingers of the left hand, and hold the ears between the second and third fingers, and the nose between the thumb and index finger of the right hand. He should take care not to use unnecessary force. There is no need of hurting the animal.

The anesthetizer puts some ether on the gauze of the cone, and places the cone over the animal's mouth and nose. It is well to place a towel beneath the head, and bring it up to the sides of the cone. Ether vapor is heavy and falls, hence the towel prevents waste and facilitates use. Do not "force the ether," i. e., let the animal have plenty of air to breathe. Remember that etherization is not asphyxiation. The man giving the ether *must think of nothing else.* If the animal dies through his fault, he must pay for another, (50 cents). Watch especially the respiration, and when in doubt, pinch foot, to see if leg reflex is present; also note the corneal reflex, which consists in a closing of the lid when the cornea is lightly touched. When well under, the animal should breathe regularly and quietly. If the respiration becomes irregular, with pauses, and the reflexes are present, the animal is "coming out" and needs more ether. If the respiration stops, or becomes convulsive, immediately test the reflexes, and if the reflexes are absent stop the ether; start artificial respiration, by rhythmically compressing the chest laterally; and call instructor. The amount of ether should be lessened when the third stage is reached, and only a little given at intervals, to keep the animal asleep. In case coarse râles caused by collection of mucus are heard, swab out the throat with absorbent cotton on large forceps.

DIRECTIONS TO OPERATOR.

When the animal is sufficiently under to have stopped struggling, fasten it on animal-board, by placing a noose about each leg above the hock, and tying the cords to the cleats on the sides of the animal-board. Put head in head-holder. The instructor will show the method of application.

As soon as the animal's head has been placed in the head-holder, remove the hair from front of throat for a space an inch wide, and from top of thyroid cartilage to sternum. Put the hair in a battery jar.

A rolled towel placed beneath the neck may help operator by putting parts under tension. Sponge off the loose hairs, and as soon as the reflexes have ceased, make a median incision with scalpel through skin, from top of thyroid cartilage to near top of sternum. Avoid veins at lower part of incision. Cut through the platysma muscle in the median line. Tie off any large vessels that have been cut, and have assistant sponge off blood with warm salt solution. Separate sterno-mastoid from sterno-hyoid; this brings the sheath of carotid artery into view. Close to the artery are the veins and nerves. From this time on it will probably be better to tear away the fascia longitudinally with the blunt end of a director or similar instrument,

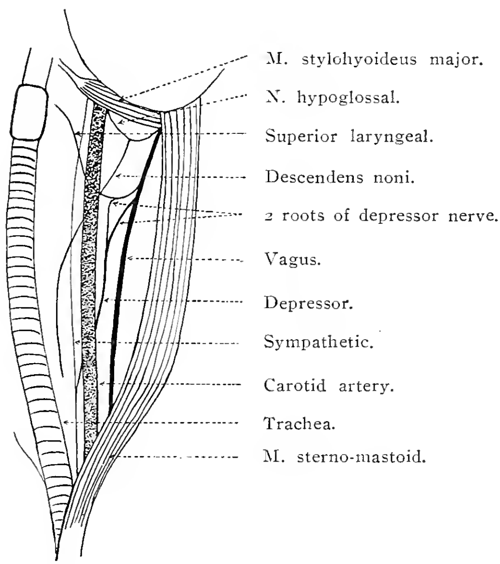


Fig. 32. Dissection of nerves of left side of neck of rabbit. The trachea has been pulled to the right and the nerves to the left.

rather than use a knife. The descendens noni lies superficially; the vagus lies behind the carotid; to the inside of the vagus are the sympathetic and depressor nerves. Isolate the vagus, the largest of these, for a distance of an inch or more and pass a thread under it, tying the ends together so that the nerve can be lifted by the loop. Avoid pinching, stretching, or otherwise injuring the nerve.

Prepare the *upper part* of carotid for insertion of cannula, by *carefully separating it from its sheath* for a distance of at least an inch. Pass two ligatures under it, and tie one of them tightly at the upper end of the exposed part of the artery; place the other so that it can be used at short notice to tie the cannula in place. Apply a pair of bull-dog forceps to lower part of artery to shut off blood. There are two methods of inserting a cannula, viz: 1. Grasp with fine pointed forceps as small a part of the arterial wall as you can hold securely, and with fine pointed scissors make a diagonal slit in the direction of the heart and through about half the width of the artery. Still holding the flap, insert the cannula supplied by the Instructor, and let the assistant tie it in firmly with the ligature which has been placed there for the purpose. 2. Place the index finger of the left hand beneath the artery; with sharp, fine pointed scissors make a cut in the wall of the artery; and without withdrawing the finger insert the cannula. It is of advantage to put the cannula into the upper part of the artery, so that the lower part can be used in case the cannula has to be put in a second time.

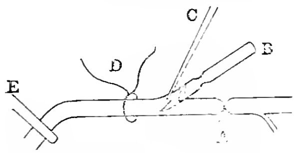


Fig. 33. Method of inserting cannula into carotid artery. A, ligature tied to the distal side of the place where the cannula is to be inserted; B, cannula; C, forceps; D, loop of ligature placed around artery, to the proximal side of point where cannula is to be inserted; E, bull-dog forceps.

Fill cannula with anticoagulation fluid, by means of a fine pipette, *the instant* the cannula is tied in. Now without losing time place the animal-board so that the cannula can be readily connected with the bulb on the manometer outfit. Make sure that the cannula, bulb and connecting tube, are full of anti-coagulation fluid, and then connect them. Fasten the tube of the bulb in a burette clamp, in the position which will bring the least possible strain on the artery. Apply the pneumograph and connect with tambour.

a. Measure of the Blood Pressure in the Carotid.

As soon as the cannula has been fastened to bulb, remove bull-dog forceps, and make sure that there is no leak between the cannula and the artery. The blood should be seen to enter the cannula and diffuse into the fluid in the bulb. If all is right, gradually open stop-cock 1. The manometer float should rise, and the height of arterial pressure be recorded. Start the drum and take four records, stopping the drum and marking the position of the writing points between them. Notice that curve shows larger waves of pressure due to respiration, and upon these, smaller waves caused by heart beats. The small waves do not show the amount of blood expelled by heart, but the effect of corresponding pressure changes in the artery, on the mercury in the manometer.

b. Excitation of the Peripheral End of the Right Vagus.

The operator now ties two ligatures around the vagus near each other and close to the center of the isolated portion of the nerve, and then cuts the nerve between them. Remember to mark position of writing points before each test. Place peripheral end of vagus on the electrodes, taking care that they touch nothing else. Close key of primary circuit; see that vibrator works well. Record a curve of normal pressure for 15 seconds and then let the apparatus man open short-circuit key. If weak, the current should slow the heart, and if strong, should stop it. Strengthen current if necessary. Excite for only 10 seconds, then close short circuit and watch recovery 15 seconds. Repeat the experiment 4 times, to provide a record for each student, and give an interval of half a minute between the succeeding tests.

c. Excitation of Central End of the Vagus.

Now while taking record of blood pressure and respiration, excite central end of vagus with weak current. Afferent fibers are excited, (sensory of the air passages and "respiratory pressor and depressor" of the lung), resulting in the following:—

1.—Excitation of respiratory center, causing change in amount and frequency of respiration.

2.—Excitation of vaso-motor center, tending to produce a rise, but occassionally a fall of blood pressure.

3.—Excitation of vagus center, which frequently slows the heart through a crossed reflex, and causes a fall of pressure in spite of vaso-constriction which may occur.

4.—If current is too strong, and the anesthesia incomplete, there may be reflex excitation of motor centers, causing convulsive movements which may mask the other effects and cause a rise of blood pressure.

Now let the operator tie off the right carotid below cannula, and remove canula from artery. Let assistant hold a dish under the cannula and then disconnect bulb from manometer tube; wash bulb and cannula out thoroughly; connect bulb again with manometer tube; return cannula to the instructor. Handle bulb and cannula with care, as they are fragile and hard to replace. Sponge up all fluid spilled and put apparatus in order for next experiment. Disconnect and remove pneumograph.

d. Excitation of Peripheral End of Left Vagus.

The student who is to operate, takes the animal-board to the operating table and proceeds to prepare the artery and nerve of the left side, the other students doing the work assigned in the schedule. When the operation is finished, test and record blood pressure, when the left vagus is excited.

e. Excitation of Sciatic Nerve.

The sciatic nerve lies beneath the vastus externus on the middle of the external surface of the thigh. Remove hair over region; cut skin longitudinally for 2 inches; cut through vastus externus and expose the nerve. Animal *must be well under the ether* before the nerve is handled, and especially on stimulating. Pass a ligature under nerve and tie ends together. When ready to excite, ligate peripheral end of part exposed and cut peripherally to ligature; place nerve across electrodes, which must not touch anything else, then apply current. See rise of blood pressure due to reflex vaso-constriction, or, as not infrequently occurs, a fall due to reflex vaso-dilation. If current is too strong or animal not well under, convulsive movements will be produced which will mask the effect desired.

f. Blood Pressure during Asphyxia.

Expose the trachea and place *low down* upon it a clamp used for rubber tubing, so that the trachea can be closed off quickly. Start drum at rate of one or two mm. per second, then clamp off trachea, marking the instant this is done by means of short circuit key. Observe the following stages:

1.—DYSPNEA. Blood pressure rises gradually. Deep and prolonged respirations, with short expirations, soon affect the blood pressure in a marked manner.

2.—CONVULSIONS. Each convulsion is accompanied by a rise of blood pressure.

3.—Weakening and slowing of heart beats; respirations feebler and fewer; finally both heart beats and respirations stop.

g. Elasticity of Lung Tissue.

Make incision in trachea; insert cannula; and connect with a water manometer, noting the level of the fluid. Open the chest and note the new level to which the water in the tube rises when air enters the chest and the lungs collapse. The air which leaves the lung when the chest is opened is the "residual" air, (see diagram, Experiment XLI). To open chest, first make an incision with the knife over the entire length of the sternum: grasp ensiform cartilage with strong forceps; push point of strong shears through chest wall at end of ensiform cartilage and cut sternum lengthwise, in the median line, to within 2 cm. of its upper end. Keep point of shears close to sternum, to avoid cutting lungs or other organs. Pull the cut edges of the sternum apart and see the collapsed lungs. Remove the lungs; put them in water, and notice that they float. This is because of the "miminal air" which is imprisoned by the collapsed bronchi. The fact that the lungs float, provided that there are no gases due to decomposition, is considered a proof that the animal has breathed.

NOTES.

In mounting the curves, be careful to preserve the part of each record which shows the relation of writing points, and the portion showing 15 seconds before, and 15 seconds after the period of stimulation. Draw three pairs of long vertical lines from the time curve through the pressure and respiration curves, so as to enclose periods of 6 seconds before, during, and just after cessation of stimulation.

To find the blood pressure, measure from the base line, given by the time signal, to the blood pressure curve, using the middle of the pulse beats for the mean pressure, and multiply by two. For heart rate, count the pulse beats in the 6 seconds between the verticals and multiply by 10. In a similar manner determine the number of respirations per minute. Write the figures obtained, on the cardboard above the mounted curve, at points corresponding to the observations.

Give brief statements of the results obtained under each of the subheadings of the experiment, stating the cause of the changes in arterial pressure, pulse, and respiration produced by the excitations.

EXPERIMENT XXIX

Circulation and Respiration of the Mammal, Continued.

a. Excitation of Right Depressor Nerve.

The depressor is an afferent nerve from the root of the aorta, and hence excitation of the peripheral end has no effect. Excitation of central end has little effect on the cardiac centers, but causes dilation of peripheral vessels by inhibition of the vaso-constrictor center.

Expose the carotid as in Experiment XXVIII. To find the depressor, remember that vagus lies behind the artery and the depressor and the sympathetic to the inner side. High up the vagus gives off a transverse branch, the superior laryngeal, (see diagram, Experiment XXVIII) to the larynx. The depressor arises as a very slender nerve by two branches from this, or one from this and one from the vagus. Find the place of division, then trace the nerve down for 2 cm. or more, tie a thread about it and cut peripherally to thread. Handle nerve with utmost care and see that it does not dry.

Now isolate carotid and insert cannula; connect with manometer; apply pneumograph; record normal curves of blood pressure and respiration. Excite central end of depressor while drum is running. Excite only long enough to produce an evident effect, and let drum run till recovery is well under way. Take four records, waiting in each case until recovery is complete. Is the rate of heart changed?

b. Excitation of Left Depressor Nerve.

Prepare depressor and carotid of other side and repeat above experiment.

c. Tracheotomy and Artificial Respiration.

Remove cork of bottle in outfit for artificial respiration, put about 2 cm. of ether in the bottom, and replace the cork. Make an incision in the trachea, insert the cannula, and tie it firmly in place with a strong ligature. Now give the ether by holding the cone above the tracheal cannula. While this is being done, the apparatus man should prepare artificial respiration apparatus and test the amount of ether it gives. Regulate supply of ether by means of clamps on tubes connecting with ether bottle.

To open the chest, first make an incision with knife over entire length of sternum, grasp ensiform cartilage with strong forceps; push point of shears through chest wall at end of cartilage and cut sternum lengthwise, in the median line to within 2 cm. of its upper end. Keep point of shears close to sternum to avoid cutting lungs or other organs. Special care is necessary at the upper part, or blood vessels will be cut.

As soon as the chest is opened, with clamp on side tube open, connect tracheal cannula with ether bottle, and start bellows, pumping at rate of once a second. Screw up clamp on side tube until the lungs are seen to expand and relax well.

Observe the effect of artificial respiration on the curve of blood pressure. The respiratory waves of the curve are now reversed, the curve falling soon after the air begins to enter the lungs, and rising soon after beginning of expiration, due to elastic recoil of lung. Does your curve corroborate this statement? If not, why?

d. The Current of Action of the Heart.

Draw chest walls apart with the hooks provided. Open the pericardium widely, taking care not to cut the heart in doing so. Now hold the bone of a nerve-leg preparation in forceps, with nerve hanging down; let the nerve lie upon the beating ventricle lengthwise; the muscle should contract with each beat. If it does not, lift it and try again.

e. Observation of Exposed Heart during Vagus Excitation.

Observe the effect of excitation of the peripheral end of a vagus nerve on the rate and strength of beat of the exposed heart. Test with weak, medium, and strong currents.

f. Tension of Ventricle during Systole and Diastole.

Take the ventricle gently between the thumb and fingers, and feel it harden with each systole.

g. Observation of the Changes in Heart during Death from Asphyxia.

Open chest widely so as to obtain a good view. Stop artificial respiration and observe the effects of asphyxia on the rhythm of auricles and ventricles as the heart dies. Make notes of the order in which the strength of beat of auricles and ventricles changes. Notice any irregularities, and which auricle or ventricle gives out first. What part of heart is most distended at death?

h. Innervation of Diaphragm by the Phrenic Nerves.

These nerves are easily found, running down lateral and posterior sides of pericardium. Excite one, then the other, observing contraction of diaphragm from upper side. Open the abdominal cavity by one incision in median line; observe relations of organs; push viscera down and excite phrenic while looking at under side of diaphragm. *Notice* that contraction of diaphragm depresses the floor of the chest; thus increasing chest cavity and lessening abdominal cavity.

i. Peristalsis of Intestines.

Observe any peristaltic movements that may occur because of exposure to air and loss of blood. See direction of waves. Watch for anti-peristalsis. Try effect of mechanical and electrical stimulation of stomach and intestines. Excite bladder electrically.

NOTES.

Write up the notes as directed in the preceding experiment.

EXPERIMENT XXX.

The Carotid Pulse in Man.

The Form of the Pulse Wave, and Effect of Arterial Pressure.

The pulse is a wave of pressure which is transmitted along the arterial system when the heart drives blood into the aorta. Each systole raises the pressure suddenly, giving what is called the systolic pressure, and during the following diastole the pressure falls, until, just before the next systole, the diastolic pressure is reached. The amount that the pressure changes, that is the difference between the systolic and diastolic pressures is known as the pulse pressure, while the pressure midway between the systolic and diastolic is for ordinary purposes spoken of as the mean pressure, although on account of the distribution of the pressure values from systole to systole, it is not the true mean.

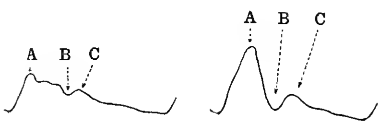


Fig. 34. Sphygmograms of two pulse beats, one taken when the pressure was quite high and the other when it was quite low. A, crest of primary wave; B, dicrotic notch; C, dicrotic wave.

Under ordinary conditions the caliber of an artery cannot be seen to change when the pulse wave travels through it; nevertheless, if the vessel be slightly compressed by the finger, the pressure change can be felt, and if the finger has been trained, not only the extent but character of the pulse wave, and the amount of the systolic and the diastolic pressure can be more or less accurately estimated. If a suitable instrument, a sphymograph, be applied to the skin over the artery a record of the pulse pressure changes may be obtained. The instrument will not measure the pressure, and the record fails to give an absolutely correct picture of the course of the pressure oscillations, because they are modified by the intervening tissues and by the incapacity of an instrument to follow with exactness all the rapidly alternating phases of the pressure changes. Nevertheless, the most marked changes in the pressure are well pictured both with respect to time and extent, and the records give information which in certain conditions are not only of scientific interest but of decided clinical value.

The form of the pulse curves varies greatly with the instrument used and the artery from which the pulse is recorded. A typical pulse curve is usually described as consisting of a rapid primary up-stroke, the anacrotic limb, and a prolonged fall, the catacrotic limb, on which a number of oscillations are to be seen, (see Fig. 34). One of these oscillations, which shows one-third the way along the curve, is always to be seen. It consists of a more or less deep notch, the dicrotic notch, and is followed by a definite wave, the dicrotic wave. The dicrotic notch is of especial importance because the descending limb of the notch marks the closure of the aortic valve. The notch therefore divides the curve into a systolic portion, during which the left ventricle is in communication with the aorta, and a diastolic portion, during which the arteries are shut off from the heart. The systolic portion gives indication, therefore, of the way the ventricle imparts pressure to the blood in the artery and the resistance which it encounters, and the diastolic, of the conditions in the arteries, themselves, which determine the rate of fall and oscillations of the pressure. Occasionally a wave or shoulder is observed on the ascending limb, an anacrotic wave, which usually implies that there is some unusual resistance offered to the flow of the blood from the ventricle. Almost always a wave is to be seen on the descending limb preceeding the dicrotic notch, and called the predicrotic wave. This in many cases at least is an instrumental error, due to the fact that the recording lever has been thrown too far, and has made a depression on the curve when it recoiled. Waves may also be seen following the dicrotic notch, post dicrotic waves, which are generally supposed to be reflected waves from various points along the walls of the arteries. Not infrequently there is a slight wave to be seen just at the close of the diastolic period; this wave, coming at the time that the auricle is completing the filling of the ventricle, suggests that the sudden swelling of the ventricle may have imparted a slight push to the root of the aorta.

The dicrotic notch is of additional importance, because the height of the notch above the base-line gives an indication of the rate of fall of diastolic pressure. When the pressure is maintained during diastole, the post-dicrotic portion of the tracing falls in nearly a straight line and the dicrotic notch is high; when the pressure falls off rapidly during diastole, the post-dicrotic portion falls in a curve which is markedly convex toward the abscissa, and, especially if the mean pressure is low, the dicrotic notch is deep.

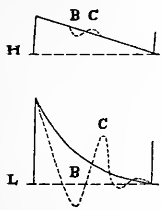


Fig. 35. Diagram of a high pressure pulse (H), and of a low pressure pulse (L). B, dicrotic notch; C, dicrotic wave.

In Fig. 35 the unbroken lines give the "skeleton" of the pulse, that is, show the general course of the wave of pressure, and the broken lines indicate how secondary waves may be superposed on this. When the pressure is high, the waves are generally few and small, and when it is low, they are often many and large.

Apparatus.—Mount a recording tambour on a stand and connect it with an open tambour designed for carotid artery, leaving side tube open. *See that the lever of the tambour is horizontal.* Apply the open tambour to the skin of the neck over the artery, and fasten it in place with the U-shaped spring, placing the ball of the spring in the socket on the back of the tambour and placing the block against the opposite side of the neck. Then test the working of the outfit by pinching the side tube. With each heart beat there should be an excursion of the lever of at least 5 mm. Adjust position of tambour on neck, and pressure of spring to give the largest pulsation, then bring writing point very lightly against drum. Start drum at 5 mm. per second, close side branch with spring clip and record the curve of the pulse. Unless the friction of writing point upon drum is made as slight as possible, small waves of the pulse curve will be obscured. Mark on the curves to indicate the primary wave and the dicrotic notch. Usually the lever is thrown too high, and as it falls depresses the rubber membrane and records a notch which might be mistaken for the dicrotic notch. The second notch is generally the dicrotic, and is followed by a wave larger than that which would be given by the recoil of the membrane. This is the dicrotic wave. Do pre-dicrotic or post-dicrotic waves occur in the record? Take records with four widely different speeds of drum, and observe the effect on the form of the curve.

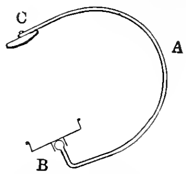


Fig. 36. Tambour and neck spring used to study the human carotid pulse. A, spring; B, ball-and-socket joint, on back of open tambour; C, block.

a. The Pulse Rate.

Mount a time signal to write below the pulse curve, connect it with the *clock* circuit, start drum at 5 mm. per second, and record the curves of time and pulse. Draw perpendiculars at intervals of ten seconds cutting the pulse curve, and determine the rate of the pulse per minute.

b. Duration of Systole and Diastole.

Mount a fork in place of the time signal; *see that lever is horizontal when the side tube is open;* and record curves of pulse and fork with the fastest speed of drum given by clockwork. Then, without moving drum, remove clip from side tube, and record a base line for the pulse curve. When the curves have been fixed, draw arcs with dividers from beginning of primary wave and from bottom of dicrotic notch to the base line, using a radius equal to the length of the writing lever and centers on the base line. Draw perpendiculars from the points where the arcs cut the base line, through the fork curve. If one triangle is placed horizontally beneath the fork curve and held firmly in place, the other can be slid along it, and the verticals be drawn rapidly and exactly. Count up the fork waves between the perpendiculars, and thus determine the duration of systole and diastole. In counting the vibrations of the fork, it is best to make a little mark over every fifth vibration. This can be done rapidly if one learns to see four vibrations at a glance and marks the fifth. Make this determination for five consecutive pulse beats and state the average in your notes.

c. Effect of Exercise.

Go through the form of taking a normal record, as in *a*, to make sure that the neck tambour is properly adjusted, and that the recording tambour is writing well. Then, without moving the drum or either tambour, detach the rubber tube where it joins the glass T. Take a quick run down stairs and back, *connect up the tambour as soon as possible,* and record the accelerated pulse. Determine duration of systole and diastole, and calculate the heart rate.

Which changes more in the quickening of the pulse due to work, the systolic or the diastolic portion? Are any other changes in the pulse curve to be observed? If so, describe them.

EXPERIMENT XXXI.

The Radial Pulse Studied by the Tambour Method.

Connect a recording tambour with a tambour designed for radial artery, leaving side branch of tube open. Arrange arm rest and tambour as shown in the diagram. Mark the point on left wrist where strongest pulse is felt. Subject seats himself comfortably in chair, holding one end of arm rest in lap, while other end is placed on table or stool so as to tilt it at a suitable angle for the arm to rest easily. Place arm on rest with marked point toward tambour; fasten thumb with loop of cloth, using holes in back board; apply button of tambour to marked spot, and adjust tambour so that rod bearing button is in line with tube of tambour and perpendicular to surface of wrist. Vary the pressure on artery by sliding tube of tambour in clamp until largest pulsation is given. An excursion of 3-5 mm. with each heart beat should be secured, but a smaller movement will suffice where this cannot be obtained. The arm must be relaxed and perfectly quiet.

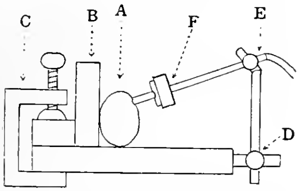


Fig. 37. Method of applying tambour to wrist, to obtain sphygmogram from the radial artery. A, cross section of wrist; B, back board of arm support; C, cabinet maker's clamp; D, clamp fastening L rod to the horizontal rod of arm rest; E, clamp fastening tube of tambour to short arm of L rod; F, tambour with disk, and prop to rest on artery.

a. Form of Radial Pulse.

Record the radial pulse on a drum and observe whether the same waves appear as in the carotid pulse.

b. Postponement of the Radial Pulse.

Arrange to write carotid and radial pulse and fork curve in same vertical line. Make sure that the levers of the tambours are horizontal. Mark *relative position of* *points,* then record the three curves with fastest speed given by kymograph. Without disturbing apparatus, remove clips from side tubes and, with the levers horizontal, record base lines for the two pulse curves.

Fix the tracing, and then, with centers on the base lines and the lengths of the levers as radii, draw arcs from beginnings of corresponding primary waves to their respective base lines; then correcting for positions of points, draw perpendiculars through fork curve and find duration of postponement of radial pulse as compared with carotid pulse. Take average of five consecutive beats.

EXPERIMENT XXXII.

The Radial Pulse as Recorded by the Jacquet Sphygmograph.

This is probably the most useful instrument for examination of the pulse that we have. It is fragile, and must be handled with care and returned in good condition. The strap *A* is buckled about the left wrist, with the end *B* toward the hand. The instrument slips into groove *C* of

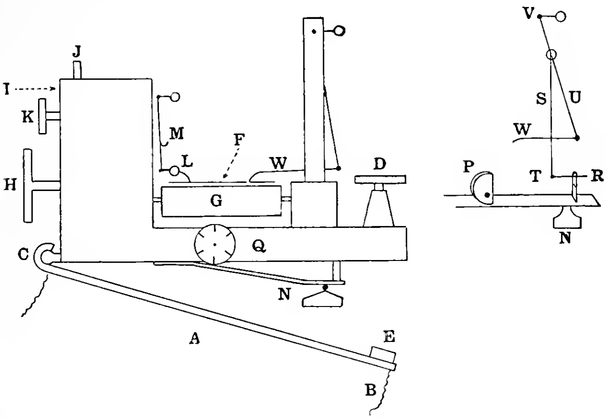


Fig. 38. Scheme of Jacquet's sphygmograph.

base, and thumb-screw *D* is turned into socket *E*. The paper, shown in cross section at *F*, runs between the roller *G* and two small wheels above it. Clock for moving paper is wound by means of large thumb-nut *H*, started and stopped by lever at *I*, and lever *J* gives a change of speed. Clockwork for time marker *L*, is wound by means of thumb-nut *K*, and gives fifths of a second. *M* is a clasp for holding *L* up out of harm when not in use. Cam wheel *P*, turned by thumb-nut *Q*, varies the tension of the spring, by which button *N* is pressed on the artery. Movements of *N* are transmitted through rod *R,* to lever *S,* turning on axis *T,* thence to lever *U,* turning on axis *V,* and finally to marker W. Position of writing point on the paper and the pressure of button on the artery, are regulated by thumb-screw D.

To obtain the proper pressure on the artery it is necessary, therefore, to use both thumb-nut Q and thumb-screw *D.*

CAUTIONS.

(1) Be careful not to injure the time marker. Raise and lower it with the fine point of a knife or pencil. It must *always* be lifted into clasp before removing the paper.

(2) Avoid bending the writing pointer when inserting the paper.

(3) Do not wind the clockwork too tight.

(4) Instrument must be held level to record time accurately.

a. Normal Curves and Effect of Position of Body.

Place several strips of paper around a drum, and blacken as usual, cutting the strips loose as needed. Place end of a strip between roller and wheels, start clockwork, and run the paper in, to the extent of 2 cm.

Having adjusted instrument so as to give the largest pulsation, proceed to make records while sitting and standing quietly, using slow speed of paper. In this and all subsequent tests, take care not to move arm or hand when the record is being written. Report the rate per minute as recorded for six seconds.

b. Effect of Compressing Brachial Artery.

While the tracing is being taken, compress the brachial artery with hand.

c. Effect of Deglutition.

Start the paper at the slow speed record a few beats, then, while record continues, take several swallows of water in quick succession, marking on the record the *exact time* when the swallowing begins and ends. Determine the rate before, during, and after swallowing. The change in rate is explained as due to alteration of vagus influence. The swallowing center is in the medulla oblongata not far from the vagus inhibitory center, and nervous impulses overflowing from the former affect the latter.

d. Effect of Inhalation of Amyl Nitrite.

Take the record on two strips of paper pasted together, and use the slow speed. Record normal pulse for 20 beats, then begin to inhale amyl nitrite that will be supplied by the instructor. Associate should mark on record the *exact time* of inhalation. Continue record to end of paper. This drug acts chiefly, when taken in small amounts, on the muscles in the walls of the small vessels, causing a dilation. Fall of blood pressure and increased dicrotism of the pulse results. The heart tends to compensate for the fall of pressure by increasing its rate. The change in the level of the writing, frequently seen, cannot be taken as evidence of the diminished arterial pressure, because it may be due to a movement of the wrist. The writing point must be placed high before the inhalation occurs, or it will run off the lower edge of the paper. *Do not repeat.* Mark on curve the place where the effect was the greatest, remembering that a deep dicrotic notch is an indication of low blood pressure. State in the notes what change took place in the heart rate.

e. Valsalva's Experiment.

Record 20 normal beats, then take a deep breath, and, with mouth and nostrils closed, make a strong expiratory effort for eight or ten seconds, then breathe freely. *Mark time of each stage on record.*. Report effect on rate and shape of pulse curve. The latter is especially interesting. The expiratory effort drives the blood out of the chest into the arteries, and prevents entrance of venous blood into the chest by compressing veins and right heart.

f. Müller's Experiment.

Record 20 beats, then exhale as completely as possible, and with mouth and nostrils closed make a strong inspiratory effort for five seconds, then breathe freely. Mark on record and report as before. The forced inspiration tends to keep the heart and large vessels dilated, tends to prevent blood from leaving chest, and causes a rush of blood into the chest by way of the veins.

EXPERIMENT XXXIII.

Capillary Circulation in the Web of the Foot of a Frog.

Choose a frog having little pigment in the skin of the foot. Destroy the brain by a pithing needle, and plug the skull cavity with a pointed match. Be sure to have the match ready to insert at the instant the pithing needle is withdrawn, so that the least possible blood shall be lost. Inject 1 cc. of curara into the dorsal lymph space. When the reflexes have begun to weaken, wrap the frog in moist cloth, place on special stage, face down, and spread the web over the opening, keeping in place by ligatures tied to the three longest toes, and fastened by binding posts on the stage. Avoid stretching web too tightly, and keep it moist, not wet. Place stage on microscope stage.

Examine first with a low power. If the blood is not seen to circulate through the smaller vessels, the web has probably been stretched too tightly, or has been allowed to dry. Decide which of the vessels are arteries, capillaries and veins, observing where the blood flows from large to small and from small to large vessels, where the blood stream is most rapid and where it pulsates. Do not let preconceived notions cause you to think that you see what you do not really see. As far as possible demonstrate the following phenomena to an instructor:

I. Examine a small artery, and observe:—
   a Pulsating stream.
   b. Rapid axial stream; lighter, peripheral layer,—the "inert layer."
   c. Eddies of the stream at a bifurcation.

II. Examine a small vein and observe:
   a. Constant stream (sometimes pulsating if the shock from the pithing has not been recovered from, and there is vaso-dilation).
   b. Slower current, and less marked "inert layer" than in artery.

III. Examine capillaries, and observe:
- a. Frequent anastomoses.
- b. Condition and behavior of corpuscles.
  - A. Red corpuscles (erythrocytes).
    1. Shape, transparency, color.
    2. The number that can pass abreast in a capillary.
    3. Position of long axis with respect to current.
    4. Elasticity, and change in shape when compressed, or when turning a corner.
    5. Passage through a capillary apparently smaller than cell.
  - B. White corpuscles (leucocytes).
    1. Shape and color.
    2. Peripheral arrangement.

IV. *Vaso-motor Action.*

Expose sciatic nerve, *using the utmost care not to injure the blood vessels.* Cut high up, and dividing branches, raise from wound and lay on a piece of moist filter paper placed over the skin. (There is an acid secretion on the skin which will injure the nerve.) Of course the nerve must be handled as little as possible and never be compressed. If the frog is well under the curara, excite nerve with induction current at the same time that a suitable part of the web is being examined with a low power. The vessels should be seen to grow smaller and the circulation should be consequently slowed or stopped.

V. *Diapedesis, i. e., Migration through Wall of Capillary.*

(This is optional.) This is not often seen to occur under normal conditions, but the phenomenon is of frequent occurrence when an irritant causes local inflamation. This can be best studied in the mesentery, a slight burn from a hot glass rod being a suitable irritant.

Examine with low power the effect upon the circulation of the part. Then choosing a capillary whose walls can be seen distinctly, watch carefully a leucocyte resting against the wall, and observe its change of shape as it passes through the wall. Make drawing illustrating the method of progression. Red corpuscles do not pass through, unless the walls have been greatly injured, since they do not possess amoeboid power.

VI. *The Capillaries of the Human Skin Will Be Demonstrated.*

EXPERIMENT XXXIV.

Cilia.

Cilia play an important rôle, by supplying the motor power to many forms of separate cells, and in moving substances along over the surfaces of mucous membranes lining many of the passages and tubes of the body. The character of the movement of the cilia is different in the case of different cells; in general four different kinds of movement are described, viz., hook form, pendular, wave-like, funnel form. The movement of the little protoplasmic process is generally regarded to be a result of contractility, the contraction being rapid and the recovery being somewhat slower; opinions differ, however, as in the case of muscles, with regard to the internal forces and method of action of the cell. The contractions follow each other too rapidly to be followed by the eye; Engelmann estimated the rate of vibration of the cilia of the mucous membrane of the esophagus of the frog to be twelve per second. As the cell begins to die, however, the movements slow and the phenomenon can be studied. Like all forms of protoplasm, the cilia-bearing cells have conductivity, and this may persist after contraction has ceased. The waves of activity take a definite course across a ciliated mucous membrane, and when watched under a microscope, call to mind the effect of wind blowing across a field of grain. The harmonious action of the cells of a membrane to move substances over the surface, suggests the passage of a peristaltic wave along the intestine. In spite of their microscopic size, the combined action of the cilia enables them to accomplish considerable work, and it has been estimated that one square cm. can move a load of 330 grams. The rate of action is influenced by temperature; weak acids at first excite, and later slow and destroy action; slight alkalinity favors activity.

EXPERIMENT. Pith the brain and the spinal cord of a frog; cut through the middle of the lower jaw, and extend the incision down the esophagus to the stomach; divide this, and carefully dissect off the esophagus, pharynx, and part of the mucous membrane of the mouth; pin the edges to a sheet of cork, so as to obtain a level field with the inner surface uppermost. Rinse with normal salt solution.

a. Work of Cilia.

By means of pins fasten two threads across the membrane, one cm. apart, and a short distance above it. Put a small piece of cork on the membrane and see in which direction it will be carried along, toward or away from mouth end. Cut some small flat pieces of lead, and find what is the greatest weight which can be moved by a given surface of membrane. Tilt the cork plate and see if the weights will be carried up hill.

b. Effect of Temperature.

Test the rate at which the small piece of cork will be moved when the membrane is at room temperature, when it is cooled and when it is warmed. (The temperature can be changed by placing sheet of cork with the membrane, in the dish which will be provided, and by flowing over the membrane normal salt solutions which are ice-cold, warmed to 25° C, and to 50° C.)

c. Microscopic Examination of Cilia.

Remove a few cells from the membrane by gently scraping it; put them in a drop of salt solution on a slide, and study the movements of the cilia under a microscope. Report the results of the above experiments in your notes.

EXPERIMENT XXXV.

Measurement of Systolic and Diastolic Pressure in Human Arteries.

The blood pressure is a measure of the potential energy available for overcoming the resistance offered by the walls of the vessels to the flow of the blood. The arterial pressure at a given point depends on the amount of blood being pumped by the heart, the condition of the arterial walls, and the resistance to the passage of the blood through the small arteries, capillaries, and veins of the body as a whole, and of the artery where the pressure is to be measured. Since a high pressure means excessive work for the heart, and since a low pressure means too little blood is being pumped, or that the vessels are abnormally dilated, it is evident that a measure of the blood pressure is of great clinical importance. In practice, it is assumed that the pressure of the blood in the brachial can be taken as a measure of the condition of the general blood pressure.

It is necessary to consider three forms of blood pressure. During every systole, the heart drives blood into the arteries, and at some time during the systole the maximal pressure for that beat is reached, and this would be the *systolic pressure for that cycle*. During the diastole of the ventricle, the blood flows out of the peripheral end of the arteries into the capillaries, and just at the close of the diastole the minimal pressure for that beat is reached, and this would be called the *diastolic pressure for that cycle. The pulse pressure for a given cycle* is that which is added to the diastolic pressure by the systolic injection of blood into the arteries. The systolic pressure for any beat is, therefore, the sum of the diastolic and pulse pressures for that beat.

In as much as the general arterial pressure is changing from moment to moment, showing respiratory and Traube-Hering waves, the individual pulse beats must be thought of as superposed on these waves. The *general systolic pres-*

sure would be the highest pressure reached during any beat on the crest of the highest blood pressure wave, and the *general diastolic pressure,* the lowest pressure reached during any beat in the trough of the lowest blood pressure wave. The *general pulse pressure* would have to be considered as the average of the pulse pressures of the separate beats occurring during the time that the pressure was being studied, and should be called the *"average pulse pressure."*

The lateral expansion of the wall of an artery by the blood pressure is resisted by the elastic forces of the wall. If the diastolic pressure is low, the wall is lax, and can be distended by the pressure added by each systole, and will contract during the next diastole. In this case, slight oscillations of the wall may occur. If the diastolic pressure is high, or even normal, the wall will be kept so much stretched all the time, that the added pressure of a systole will not distend it much, and the pulse oscillations of the wall will not be large enough to be detected by the eye. Nevertheless, there will be oscillations of pressure which can be felt by the finger pressing on the artery, or by a suitable apparatus.

Apparatus.—A sphygmomanometer is an instrument devised to measure more accurately than the finger, the systolic and diastolic pressures. Quite a variety of forms of this apparatus are now used in practice. The one employed in the laboratory, is a modification of the Erlanger apparatus. (see Fig. 39). It consists of a wide rubber bag which is placed on the inside of the upper arm over the site of the brachial artery, and is held in place by an inelastic leather cuff; a tube from the bag communicates with an air-pump, to blow it up, and raise the pressure which is to compress the artery; a manometer to register the amount of pressure; a fine leak, to let the pressure fall gradually; a larger leak to let the air out quickly. The air system is also connected with a distensible rubber bulb, enclosed in a flask, and the air in this flask communicates with a delicate, magnifying tambour; the arrangement is such that the pulsations of the air in the bag over the artery are imparted to the bulb in the flask, and through this to the surrounding air, and by means of this to the tambour.

Method of Measuring the Systolic and Diastolic Pressure.—The usual method is to compress the artery, by forcing air into the bag until the manometer registers a pressure of 140 mm., or more, of mercury, one sufficient to stop the

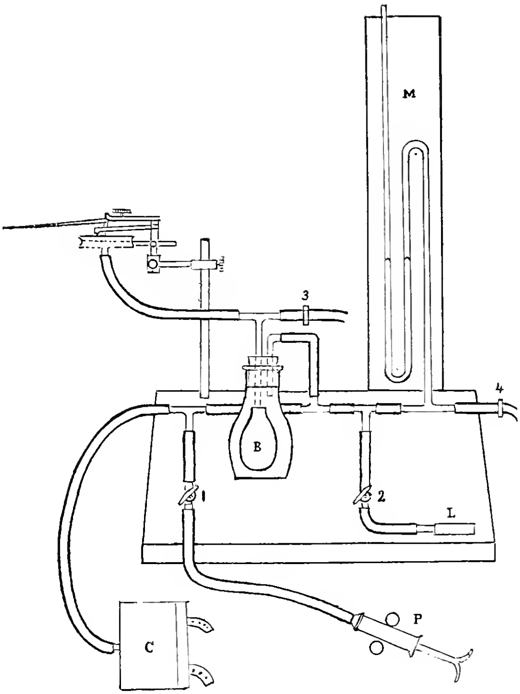


Fig. 39. A laboratory form of sphygmomanometer. C, arm bag; P, pump; M, mercury manometer; L, small leak; I, cock to shut off pump; 2, cock to shut off adjustable leak; 4, clamp at large outlet; B, bulb expanding and contracting as pressure changes; T, magnifying tambour recording pulse oscillations of bulb; 3, clamp controlling outlet of tambour

flow of blood through the artery, and then to let the air escape from the system through a fine leak; at the same time the pressures shown by the manometer are watched, and the pulse movements of the tambour are recorded. Several different criteria have been adopted as indicating when the systolic and diastolic pressures have been reached.

I. *Systolic Pressure.* The pressure at which the blood breaks through beneath the bag, is considered the systolic pressure. But all the criteria indicating that the blood has forced its way beneath the bag, give inconstant results at the critical point, because the pressure of the blood is undergoing respiratory variations, and with every rise of blood pressure, the pulse wave breaks through, and during the succeeding fall, fails to pass. The Traube-Hering waves of blood pressure exert a similar influence, and add to the difficulty of determining the systolic pressure with exactness. Nevertheless the pressure can be usually measured with sufficient accuracy for practical needs.

a. Tactile Criterion. Shortly after the pulse breaks through, it may be felt by the finger at the wrist.

b. Auscultatory Criterion. Soon after the pulse begins to pass the bag, one can hear with a stethoscope placed on the skin over the artery just distal to the bag, a series of low tones caused by the pulse wave acting on the collapsed artery. At first, faint, clear tones, or even clicks, are heard; these are followed by faint murmurs, or a roughening of the sound; then a louder, clear sound may be heard again; and finally softer sounds which fade away. Periodic variations in the arterial pressure may cause the first of these sounds to disappear and to reappear, also the rate at which the pressure falls in the bag may influence the duration and quality of the sounds. The systolic pressure should be read when the first sound is heard, and diastolic pressure at the point where all sounds suddenly become less.

c. Criterion of a Sudden Rise of Pulse Record. When the air is forced into the bag, the pressure in the bag acts with the elastic force of the arterial wall to overcome the pressure of the blood in the artery. As the walls of the artery are forced together, the elasticity of the wall of the artery plays less and less part, and finally the pressure in the bag alone opposes the pressure of the blood in the vessel. If the pressure is raised sufficiently to overcome the highest pressure in the artery, and prevents the blood from entering the part of the vessel under the bag, the bag pressure would be greater than systolic, (see I, Fig. 40) and in this case there would be no pulse oscillations of pressure in the air in the bag, except very small pulsations, caused by the end of the compressed artery beating against the side of the bag.

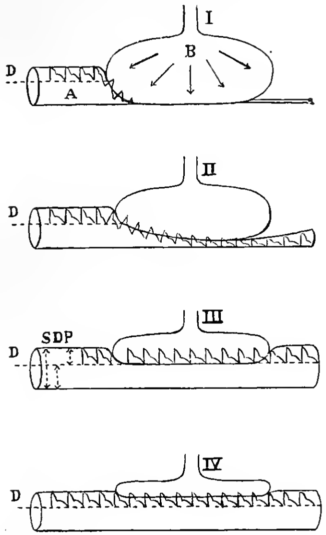


Fig. 40. Diagram showing how varying pressures in the bag, by acting against the systolic, diastolic, and pulse pressures, alter the tension of the wall of the artery, and consequently the pulse oscillations of the air in the bag and the tambour record. A, artery; B, bag; D, diastolic pressure; S, systolic pressure; P, pulse pressure; I, pressure in bag is more than systolic; II, pressure in bag is less than systolic, and more than diastolic; III, pressure in bag is diastolic; IV, pressure in bag is less than diastolic.

If now the pressure is lowered very gradually, the blood will begin to work into the artery beneath the bag, (see II, Fig. 40). Von Recklinghausen pointed out that if the pressure in the bag falls moderately rapidly, there usually comes quite a sudden rise in the height of the recorded pulse beats, at the instant that the blood forces its way into the part of the artery under the bag, and when this occurs it would seem to be a good indication of the systolic pressure.

d. . .Criterion of Separation of the Ascending and Descending Limbs of the Pulse Curve. Another piece of evidence is to be found in the shape of the pulse obtained with the tambour. Erlanger states that if the record be taken on a drum moving not too slowly, at the moment that the pulse beats begin to work under the bag, the up and down strokes are to be seen to separate, and that this separation is to be taken as the criterion for the systolic pressure.

II. *Diastolic Presure.*

a. The Ausculatory Criterion. The sudden lessening of the sounds heard over the artery, distal to compression of the bag. as the pressure in the bag falls.

b. The Largest Pulsation Criterion. As the pressure in the bag is lessened. the recorded pulsations of the air in the bag grow in height, till a certain maximum is reached, and then begin to decrease. How is this to be explained? After the blood has worked into the artery beneath the bag, the amount that the wall of the artery is stretched by the pressure of the blood during systole and diastole, depends on the amount of the pressure in the bag plus the elastic resistance of the wall of the artery, on the one hand, and on the amount of pressure in the blood during systole and during diastole, on the other. As the pressure in the bag falls, the arterial wall gradually losing this support, is stretched more and more, and has to sustain more of the blood pressure. As the pressure in the bag continues to lessen, a point is reached when the pulsations recorded by the tambour are greatest. (See I, II, III, Fig. 40.) At this point the pressure in the bag is just able to overcome the pressure in the artery at the time the pressure is diastolic, but not able to overcome the systolic pressure, therefore, the air pressure in the bag oscillates between the diastolic pressure and the pressure caused by the distension of the artery during systole. *The pressure, at which the greatest pulsations are seen, is considered the diastolic pressure.*

As the pressure in the bag falls further, the elasticity of the wall of the artery is called on more and more to resist the diastolic pressure, and the air in the bag is subjected less and less to the systolic presure. (See IV, Fig. 40.) For a considerable time, however, the pressure in the bag aided by the elasticity of the wall of the artery can equal the diastolic pressure, and the pulsations of the tambour can show the diastolic part of the curve, although the wall of the artery resisting the systolic pressure more and more, the air in the bag is affected less by this, and the tambour tracing shows less and less of the systolic part of the curve.

As the pressure in the bag falls still lower, the elastic wall has to support the blood pressure still more, and the pressure in the bag and the movements of the tambour fail more and more to follow the diastolic part of the curve, and finally the arterial wall alone acting against the pressure in the artery during diastole, no movement of the tambour will be seen.

EXPERIMENT.

I. *Systolic Pressure, as Determined by a Pulse at the Wrist (Tactile Criterion).*

First become familiar with the apparatus, (see Fig. 39), and its method of operation. The leak tube *L* has been adjusted so that the mercury in the manometer will fall at such a rate that the pressures can be easily read for every 5 mm on the scale, *i. e.*, for every 10 mm fall of pressure.

a. Subject seated. Open clamp 3, (this is to be always open except when records from the tambour are required). The subject should be seated and quiet, the left arm being flexed at a right-angle, and the forearm being supported by a sling. Strap the bag over the site of the left brachial artery and see that it is wholly covered by the leather cuff. Examine the pulse in the wrist, so as to be sure of the point where it is felt most strongly. Open the cock I (on the tube connecting with the pump) and close cock 2, (on leak tube) and close clamp 4, (on outlet tube). Raise pressure in bag by pumping until mercury in manometer stands at 140 mm., i. e., 70 mm. on the scale. Then close cock 1, and open cock 2. With finger on wrist, watch the fall of the mercury and note the exact point at which the first pulse beat is detected. Five good readings are required.

b. Subject standing.

Determine the systolic pressure with the arm in same position as in *a*. Be ready to take the reading as soon as the subject gets up, and continue to take readings at regular, short intervals. Five good readings required.

c. Effect of Exercise.

The subject is to run rapidly down and up stairs. The cuff is to be detached from the instrument, and is to be worn during the run. The readings are to be taken as soon after the run as is compatible with accuracy. Five readings should be taken at regular short intervals.

Notes.

The figures obtained in the three cases and their averages are to be recorded in the notes, together with explanations of the differences observed.

II. *Systolic and Diastolic Pressures by the Auscultatory Method.*

The experiment is to be made when the subject is in the sitting position, and in the same way as in *a* of the preceding section, except that, instead of the pulse at the wrist being taken, the sound given out by the artery below the cuff as the pulse beats enter it, is to be listened for. A stethoscope is to be used to hear the sounds (use your own if possible; if forced to use another, see that the ear pieces are well cleaned.) The first sound heard, is a clear sound, often a distinct click; later, the sounds are roughened, or are more like murmurs, with perhaps some clear sounds interspersed; and finally clear sounds are again heard and these gradually fade away. Five tests are to be made. Let several minutes elapse between the tests, to permit the effects of congestion to pass off.

a. Systolic Pressure.

The manometer is to read at the instant that the first pulse beat is heard. This marks the *systolic pressure.*

b. Diastolic Pressure.

A second reading is to be taken at the moment the sounds are fading away. This marks the *diastolic pressure.*

III. *Systolic and Diastolic Pressures by the Tambour Method.*

Arrange a time signal to write in the same vertical line and beneath the lever of the tambour, and connect the signal in the circuit with a Morse key and a dry cell. The subject is to sit quietly. The apparatus is to be used as before, except that the outlet from the tambour, cock 3, (see Fig. 39) is to be closed, so that the pulsations of the air about the bulb in the bottle will be communicated to the tambour. Record on a drum, running about 5 mm per second, a curve of the movements of the tambour. Start with a pressure about 20 mm above the systolic pressure found in the tests of the preceding sections. While the record is being taken, and the pressure is falling, tap on the key, so as to mark every 5 mm fall of the mercury in the manometer, and give a double tap at the 100 and at the 50 mm points.

a. Systolic Pressure.

Mark on the curve after it is shellaced the point when the pulsations suddenly begin to increase in height, (von Recklinghausen's criterion). Also mark the point when the up and down strokes begin to separate (Erlanger's criterion).

b. Diastolic Pressure.

Mark the place where the pulsations are greatest, or rather where they first begin to lessen in height.

EXPERIMENT XXXVI.

Conditions Changing the Volume of Hand.

The size of the arm or the finger, like that of most of the organs of the body, is continually changing. It is influenced by all conditions altering the general arterial pressure, and by local changes in the blood-vessels and lymphatics of the part itself. If the arm or a finger be enclosed in an air-tight chamber, and the chamber be connected with a sufficiently delicate recording apparatus, the changes in volume can be written on a kymograph drum. The record will show pulse waves superposed on respiration waves, and these often will be seen to be superposed on Traube-Hering waves.

Changes in the blood pressure, caused by vaso-constriction or dilation in other parts of the body, especially in the abdominal organs, or vaso-constriction or dilation of the part itself, will also change the height of the curve. Thus psychic activity of an emotional type, will cause constriction of the vessels of the arm and a fall of the curve; cold applied to other hand, through the effect of a crossed reflex on the vessels of the part, will cause vaso-constriction and a lessened volume.

APPARATUS.—This consists of a glass receptacle in which the arm or finger is placed, the space between the end of the tube and the member being closed off by a rubber sleeve. In the case of the finger the best results are to be obtained by connecting the chamber with a delicate piston recorder. In the case of the arm, a recorder capable of accommodating larger volumes of air has to be employed. Directions for the use of the apparatus will accompany it.

Caution.

The tube leading to the recorder *should be kept closed*, and the tube which communicates with the outside air *should be kept open*, except when the experiment is to be made.

The syringe, which connects with a side branch of the main tube can be used for fine adjustments of the air volume in the chamber.

Since the chamber is filled with air, it is very sensitive to temperature changes, and when the part is first introduced, the outlet tube must be left open until the system has adjusted to write below the recorder, and be connected with a dry cell and a key, so that the time of changes of conditaken on the new temperature. A time signal should be tions likely to influence the subject may be registered. The pain caused by a tetanizing current applied to the skin by a dry wire brush will be employed, and the brush should be connected with the secondary coil, ready for use.

Experiment.—Good results are to be obtained *only when the hand is warm*, for if the vessels are constricted, only very slight or no changes in the volume will be observed. The subject is to sit at ease and the left arm or the second finger of the left hand is to be used. See that the *side tube is open and that the clamp protecting the recorder is closed*. A sleeve having been chosen, which will make the opening between arm or the finger and the chamber airtight, but without constricting the vessels, place the part in the chamber. Let the subject sit quietly while the air is taking on the new temperature. After five minutes, open the clamp to the recorder, and then provisionally close the outlet by pinching the tube. The record should show pulse beats and respiration effects. To obtain the best results, the friction of the pointer on the drum must be reduced to a minimum. In case the record is rising rapidly again open the escape tube, and wait for the temperature to become adjusted. The drum should move at about the rate of 2 mm per second. When a normal *quiet* record has been taken, the effect of the following influences may be tried:

a. Tickling.

Brush the face lightly with the corner of a strip of paper, and record the time, by pressing on the key during the period of stimulation. The corners of the mouth are especially ticklish. The subject must avoid movements.

b. Pain.

Connect the primary coil of the induction apparatus in the circuit with the electric signal, dry cell, and key. Let the experimenter test the strength of the current to be employed by applying the brush to the skin of the back of his own hand, and increasing the strength of current until it is decidedly unpleasant. Now the secondary coil should be pushed back a short distance, the brush applied to the back of the hand of the subject, and a strength of current found which is as much as he wishes to stand. Wait about three minutes: then try the effect when the drum is running and a good normal record is being taken. The subject must try to avoid making any movements at the time. Remove coil from signal circuit and restore signal key.

c. Psychic Excitation.

When "quiet" records are being taken, the effect of psychic activity may be studied by letting the subject try to multiply 47 by 82, for example, and give the answer as quickly as possible. Record on the drum the instant that the problem is stated, by pressing on the signal key and keep it down until the instant that the answer is given.

d. Cold:—

Half fill a glass jar with ice cold water. Place jar on floor below suspended right hand of subject. After the hand has been in this position for two or three minutes examine the veins and make note of the color of the hand. When a "quiet" record is being taken, let a third student raise the jar, so that the hand of the subject will be immersed. The subject himself should make no movement. Record on the drum the instant that the jar is raised, and continue to press on the recording key until the jar is lowered. The muscles of the walls of the vessels are non-striated and slow to act. Three or more seconds are necessary for the first change to appear. Examine the hand again, making note of the color of the hand and amount of constriction of the veins.

EXPERIMENT XXXVII.

Venous Pressure in Man.

Under normal conditions, the pressure of the blood in the veins at the level of the upper border of the heart is very low. According to v. Recklinghausen, when a person is in the recumbent position, the level of the large veins at the point of entrance into the heart can be considered to be 7-11 cm dorsal to the sternum. If a normal man is lying down and places one hand on the bed and the other on the thigh, it will be found, after the few minutes required for adjustment, that the veins of the hand on the bed are somewhat distended, and those of the hand on the thigh are empty. If this is observed, the pressure can be regarded as normal. In case the veins of the hand on the thigh are distended, the pressure is above the normal.

Gaertner's method of measuring the venous pressure requires no apparatus and is sufficiently accurate. In order that the blood may flow to the right heart, the pressure must, at least, be equal to that of the blood in the veins at the level of the upper border of the heart. This point, in the upright position, can be considered to be at the height of the second intercostal space, (See Fig. 42).

The pressure of the blood in the veins of the hand at a given point would depend on the amount of energy left in the blood after it had passed the capillaries, and the resistance which it would encounter on its way to the heart. This latter factor would be composed of the resistance of the blood pressure in the veins at the heart, (which it is proposed to measure), plus the weight of the column of blood which would have to be lifted, plus the resistance offered by the walls of the veins. Neglecting this last factor, which we can not measure, the pressure of the veins in the hand, minus the weight of the column of blood from the hand up to the heart level, if the hand was lower, or plus this weight, if it was higher than the level of the heart, would give the venous blood pressure at the heart.

Experiment.—Let the subject sit erect in a comfortable position, and with his left arm on the lowered arm rest. Determine the height of the upper border of the heart, by adjusting the lower border of the horizontal meter stick to the level of the second intercostal space. Raise the arm rest to about 10 cm below this level, and wait two minutes; then, moving short distances and waiting two minutes between each test ascertain the height at which the largest veins collapse. Measure this height, and state in the notes the difference between this and the heart height, and report the figures obtained and the pressure of the venous blood at the heart in mm Hg. Blood is 5% heavier than water. Mercury has 13.6 times the weight of water. Note the temperature of the room, the time of day, and any other conditions that might influence the result.

EXPERIMENT XXXVIII.

The Pulse in the Large Veins of Man.

The pulse detected in the large veins of the neck is of great clinical interest because it gives information with respect to the action of the right auricle and ventricle, just as the arterial pulse gives information concerning the left ventricle. Before trying to obtain a record of the pulse, study the diagram in Fig. 41, so as to know the form of the curve to be sought, and its relation to the carotid pulse, and to the systole and diastole of the right auricle and ventricle.

Apparatus.—The venous pulse is recorded by an open tambour, or one closed by a thin, loose, rubber membrane, connected with a delicate, magnifying, recording tambour; the carotid pulse is recorded as in Experiment XXX. From the start, both of the recording tambours must be adjusted so that their levers are *horizontal,* i. e., with the writing points on a level with the axes. The length of each lever is to be measured, after it has been applied to the drum in the position in which it is to write. Place a fork so as to write below the two levers.

Experiment.—Let the subject lie on his back, and seek the venous pulse by applying the receiving tambour to various points over the veins of the neck, avoiding only the region over the carotids. Try first over the external jugular. Occasionally a good pulse is got by deep pressure in the supra-sternal notch. The position of the head is important, and often various positions must be tried before one suitable to the subject will be found. The muscles of the neck should be relaxed, and conditions favorable to a large flow of venous blood, such as a warm room, are desirable. The best result is usually obtained by a low heart rate. When a pulse, at least 5 mm high, and evidently different from that to be expected from a carotid, has been obtained, apply a tambour over the opposite carotid and record simultaneously the venous and arterial tracings, and the vibrations of

DESCRIPTION OF FIGURE 41.

Diagram showing relations of changes in size of the right auricle and ventricle, to the venous pulse, carotid pulse, time of heart sounds, and time of closure of valves. I, venous pulse curve; II, carotid pulse curve; III, changes in size of auricle and venticle; x—x, resting position of floor of auricle; IV, duration of systole of auricle and ventricle; A.S., auricular systole; V.S., ventricular systole; A.D., auricular diastole; V.D., ventricular diastole; V, time of heart sounds, first, second, and third; VI, time of opening and closing of valves; *tc* and *mc,* tricuspid and mitral close; *ao* and *po*, aortic and pulmonary open; *ac* and *pc,* aortic and pulmonary close; *to* and *mo,* tricuspid and mitral open; A, *pos,* first positive wave of venous pulse, caused by auricular systole; A, *neg,* first negative wave, caused by auricular diastole; S, *pos,* second positive wave, caused by protrusion of tricuspid valve into auricle, at beginning of ventricular systole; S, *neg,* second negative wave, caused by descent of floor of auricle; O, first onflow wave, caused by accumulation of blood in the veins; V, *pos*, third positive wave, caused by return of floor of auricle at beginning of ventricular diastole: V, *neg*, third negative wave, caused by filling of ventricle; *h*, second onflow wave, caused by accumulation of blood in the veins.

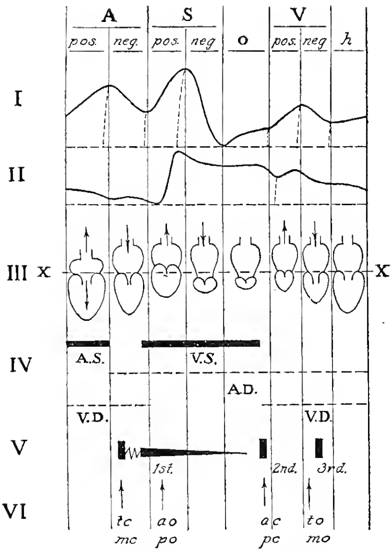


Fig. 41. Diagram showing relations of changes in size of the right auricle and ventricle, to the venous pulse, carotid pulse, time of heart sounds, and time of closure of valves.

the fork. At the instant that the tracing is to be taken, let the subject cease to breathe at the end of a *quiet expiration.* He must merely avoid taking the next breath, and not strain. Do not fail by each test, to mark on the drum *the exact position of the writing points,* by recording large arcs. Also *record base lines* by revolving the drum when the side tubes are open and the levers horizontal.

Analysis of Curves.

First make sure that each of the levers was horizontal when the base lines were written, by applying dividers, adjusted to the length of the lever, to the base line, and seeing whether it will describe the arc as written. Do not deface the arc in the process. Then draw a vertical line, just tangent to one of the arcs, to ascertain the relative position of the writing points. Now draw an arc from the beginning of each of the positive and negative waves of the venous pulse curve, and from the beginning of the rise of the primary wave and from the bottom of the dicrotic notch of the carotid pulse to the respective base lines. Perpendiculars may now be drawn down to the fork curve, from the points the time relations of which are to be compared.

For laboratory purposes, at least, it is best to use the above method, but many physicians find it simpler, when the relative position of two points on two curves is to be studied, instead of drawing perpendiculars, to measure with dividers the distance between the point where the arc from one of them intersects its base line, and the starting point arc, and then to lay off this distance on the other base line, from the starting point arc drawn by the other lever. In any case arcs must be drawn from the parts of the curves to be considered, to the respective base lines.

Notes.—State whether in your record the S wave began to rise at the same time as the primary carotid wave, and if not, why. What was the relation of the V wave to the descending limb of the dicrotic notch? Explain. Determine the time interval between the beginning of the rise of the A and the S waves. This is approximately the time taken for the conduction of the impulse through the auricle to the ventricle.

EXPERIMENT XXXIX.

The Normal Sounds of the Heart.

The normal heart sounds may be heard with the unaided ear, but the stethoscope is commonly used. It consists es-

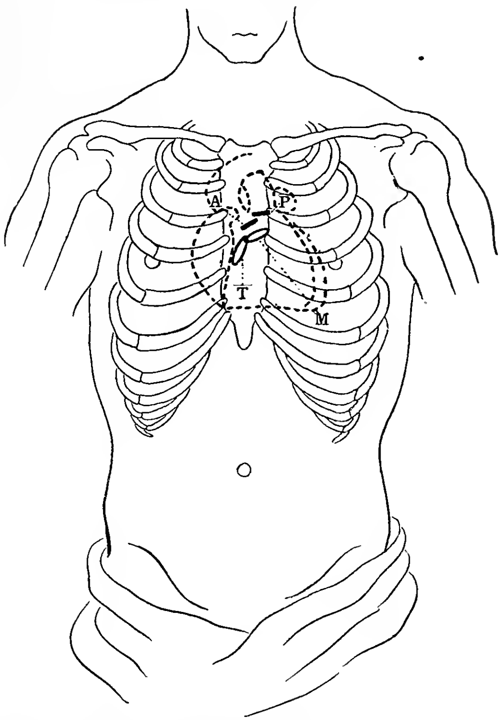


Fig. 42. Diagram showing position of heart in chest, position of valves as projected on the wall of the chest, and the parts of the chest where the sounds of the heart are heard best. M, position of apex beat, and sound from mitral valve; T, sound from tricuspid valve; A, sound from aortic valve; P, sound from pulmonary valve.

sentially of a receiving disk and a pair of ear-tubes, connected by tubing. It aids by multiplication of the sound and by excluding outside sounds. Distracting noises, to be avoided, are apt to arise from (1) rubbing of tubes against each other or against clothing, (2) breathing by the listener upon the metal spring holding the ear-tubes, (3) movement of the receiving disk upon the skin, (4) movements or breath sounds of the subject, and (5) talking *by either subject or listeners.* The multiple instrument enables several persons to hear the same sound at once, and therefore is useful in teaching. The ear tubes should be cleansed before inserting them for the first time, to avoid possible infection. The tubes are placed in the ears with the tips pointing inward and upward. The receiving disk is held firmly against the skin. Avoid kinks in the rubber tubes.

Figure 42 shows the position of the heart in the chest, and the letters, *A, P, T,* and *M* mark the areas where the disk is placed in listening to the separate valve sounds. Each letter is connected by a dotted line with a dark spot showing the position of the corresponding valves. These four areas, known as the aortic, pulmonary, tricuspid, and mitral areas, are so named because the sounds made by the closure of the valves named are heard best in those places, but it must be remembered that no one of the valve sounds can be isolated at any point, but that all enter into the composite sounds heard at each area. It is the relative loudness of particular sounds that give the areas the names which they bear.

a. Auscultation over the Lower Part of the Chest.

One student of the group is chosen as subject, and he seats himself in a chair, the others seating themselves closely around him. The receiving disk is first applied over the *mitral area,* viz., at the point where the apex beat is felt, in the 5th intercostal space, slightly within the nipple line. With the disk in this position, listen to the heart sounds for several minutes. Observe (1) the two distinct sounds with a very short interval between them, (2) the greater loudness of the first sound, (3) the booming character of the first sound contrasted with the sharp click of the second. The *first sound,* which marks the beginning of the systole of the ventricle, is a compound sound, composed of the click caused by the closure of the two auriculo-ventricular valves, the sound made by the contraction of the muscular substance of the two ventricles, and by the vibrations of the suddenly tensed chordæ tendineæ. The muscular element which prolongs the sound into the period of systole, helps to give it the booming character. Normally the two ventricles contract together, and the mitral and tricuspid valves close at the same instant, so that the action of the two sides of the heart is represented by a single sound. Compare it with the sound heard by placing the disk of the stethoscope on the muscle of the forearm and causing it to contract rhythmically. The *second sound* is produced by the closure of the aortic and pulmonary semi-lunar valves, which normally close at the same time. Now apply the disk over *the tricuspid area* and observe (1) the greater prominence of the valve sound and lessened muscle sound, (2) the clear and high pitched quality of the sound, (3) the comparative loudness of the first sound as before, and (4) the rhythm, which is also the same as in the mitral area. Change the disk quickly from one of these two areas to the other, so as to bring out distinctly the differences in the sounds. Apply it at intermediate points and observe how the characteristic sounds of one area gradually shade off into those of the other.

b. Auscultation over the Base of the Heart.

Apply the disk over the *aortic area* and observe (1) the greater loudness of the second sound as compared with the first. (2) almost complete absence of booming muscle sound, (3) the same rhythm as before. The sounds heard here are mostly valvular, and the aortic sounds predominate. Listen in same manner at *pulmonary area,* and compare the sounds heard in aortic and pulmonary areas. Move the disk to the four areas in turn, and let the listeners try to recognize the area by the sounds heard. *Use each student as subject.*

In diagnosis it is often necessary to locate an abnormal sound in relation to the pulse beat and thence to the heart cycle. The first sound, produced by contraction of heart muscle and closure of auriculo-ventricular valves, is evidently *systolic.* The second sound, made by closure of semilunar valves, is evidently *diastolic.* Therefore, any sound occurring between the beginning of the first and the beginning of the second normal sounds must be *systolic,* and any sound occurring between the beginning of the second sound and the beginning of the first sound of the next cycle must be *diastolic.*

c. *Time Relations of Heart Sounds, the Cardiogram and Pulse Curve.*

The Cardiogram.

The apex of the heart comes in contact with the wall of the chest at a point a little inside of the mammary line in the fifth intercostal space, and if a receiving tambour or a cardiograph is applied over this region, where the apex beat is best felt, and is connected with a recording tambour, a curve can be obtained which is the combined result of changes in the position, form and volume of that part of the heart. The form of the curve depends, therefore, on the condition of the chest wall, the relation of the heart to the wall, and the changes which the heart undergoes during its action.

The cardiogram, Fig. 43, can be divided into five parts, a wave caused by distention of the ventricle when the auricle completes the filling of the ventricle, the auriculo-ventricular valve closing at the end of auricular systole, (see first dotted line); a more or less sharp rise, marking the period of rising tension in the ventricle, between the beginning of the contraction and the opening of the aortic valve (see second dotted line); a period during which the ventricle is driving the blood out, the aortic valve closing soon after the end of this period. (See end of 0.4 sec.); a more or less abrupt fall caused by the sudden relaxation of the ventricle, the auriculo-ventricular valve opening at some point during the fall (See third dotted line); a period corresponding to the gradual filling of the ventricle.

The rise of the carotid curve, allowing for the time of transmission occurs a short time after the beginning of systole; and the descending limb of the dicrotic notch, which marks the end of the systole, occurs in the course of the descending limb of the heart curve. The record of the radial pulse would of course come somewhat later. The first sound of the heart should occur at the beginning of the fall of the wave caused by the auricular contraction, and the second sound should occur at the beginning of the fall of the curve caused by the relaxation of the ventricle.

EXPERIMENT.—Record a cardiogram and a radial and carotid pulse curve on a drum along with that of a signal connected with a cell and Morse key. Listen to heart sounds and let one listener so work the key that the click of the signal shall exactly coincide with the heart sounds. When he is able to do this well, as tested by all the listeners, run drum at fast speed and record the time of the sounds in relation with the three other curves. The subject should cease to breathe just when the record is to be taken, by holding the breath, without straining, at the close of a quiet expiration. The reaction time to sound varies from 0.15-0.20 sec., according to the observer, hence to have the sound of the heart and the signal coincide, the experimenter will have to anticipate the beat, i. e., determine the rhythm by listening a short time and then *tap at the instant that the beats are to be expected.*

If care be used, a good picture of the relative time of the coming of the sounds of the heart and of the carotid and radial pulse can be obtained.

Notice that the first sound slightly precedes the primary upstroke of the carotid pulse (about .01 sec.), and that the second sound slightly precedes the dicrotic wave. Also observe that the primary wave of the radial pulse begins about half way between the two heart sounds. It is evident, therefore, that the place of any sound of doubtful nature can be located rather definitely in the cycle by its relation to the carotid pulse, but not so well by reference to the radial.

DESCRIPTION OF FIGURE 43.

The diagram assumes that a normal heart is beating at the rate of 75 per minute, and that one complete cycle occupies eight-tenths of a second. Each of the spaces enclosed by the unbroken lines is 0.1 second. In the horizontal spaces we see the duration of the systoles of the auricles and ventricles, and the period of diastasis; the time of occurrence of the heart sounds; the periods when the valves are open, the upper blank space covering the interval when the semilunar valves are open, and the lower blank spaces the interval when the auriculo-ventricular valves are open; changes in the form of what may perhaps be regarded as a typical cardiogram; the waves of the venous pulse; two serial views of the form changes of the auricles and ventricles of the right heart, the large arteries, and the position of the heart valves, (the upper series illustrating the action of the heart with respect to the associated waves of the venous pulse curve, and the lower picturing the relation of the heart to the pressure waves in the arteries); finally, at the bottom of the chart, a sphygmogram of the carotid pulse. The horizontal lines just below each of the hearts represent the chest wall.

The vertical broken lines enclose a space between the 0.1 and 0.2 second, when both semilunar and auriculo-ventricular valves are closed, (see heart 2); and during the 0.5 second a similar space is enclosed marking the interval when the ventricle is again shut off from both auricle and artery, (see heart 6).

Of course the schemes of the heart action are purely diagramatic; the ninth heart picture of the lower series would be a truer representation of the heart. Although the right heart is supposed to be represented, only two curtains of the tricuspid valve are shown; the pulmonary artery is made to lie in close contact with the right auricle, although as it winds around the aorta, it is the aorta which is most intimately related to the wall of the right auricle; the right ventricle is represented as forming the apex of the heart, although in fact it is the tip of the left ventricle that is the apex.

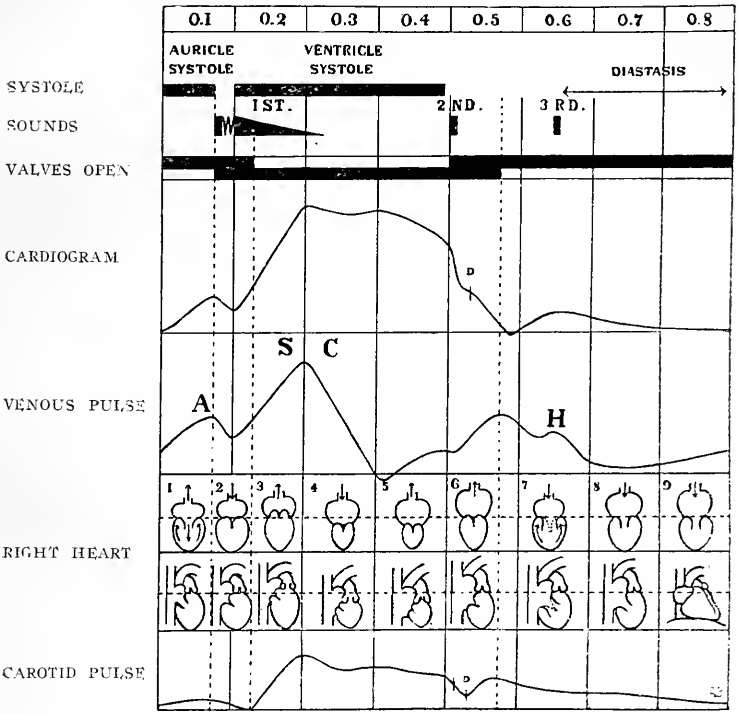


Fig. 43. Diagram of a heart cycle, showing form changes of right side of heart in relation to the cardiogram, the venous and arterial pulse, and the heart sounds.

EXPERIMENT XL.

Thoracic and Abdominal Movements in Respiration.

APPARATUS.—Mount two recording tambours and a time signal to write in a vertical line; connect the signal to clock circuit; connect the two tambours by special rubber tubes to two pneumographs, leaving side tubes open.

EXPERIMENT.—The subject seats himself comfortably, then the cord of one pneumograph is passed around his chest and the cord of the other around his waist. Tie them with a tension that will extend the pneumographs about 2 cm. Subject should sit so as not to see the curves and should pay as little attention to breathing as possible.

a. Normal Record.

After subject has remained quietly seated for at least two minutes, place clips on side tubes, start drum at 2 mm. per second and record curves for one minute. Natural, unconscious breathing is what we wish to study, and hence the subject should try to think of something else.

b. Effect of Using the Voice.

Record normal curves for 10 seconds, then read aloud for 30 seconds. In same manner try the effect of counting aloud in unison with the ticking of the clock. Always mark on curve the time when each test begins and ends, and what was done. Note the effects on rate and character of the movements.

c. Inhibitory Effects of Swallowing.

Take normal record for 15 seconds, then let subject drink a glass of water without stopping, taking record during the drinking and for 15 seconds after.

d. Effects of Effort.

In the same manner observe the effect of trying to hold two pin points as close together as possible without touching, for 15 seconds; of clenching the fists as tightly as possible for 15 seconds; of clenching the fists as rapidly as possible for 15 seconds; of pressing the hands upon the knees strongly for 15 seconds.

Note the effect in the different cases, and explain the difference.

e. Relation of Rate of Respiration to Rate of Heart.

Replace the abdominal pneumograph by a carotid tambour; then study the following cases:

(1) Relative rates of heart and respiration under normal conditions, sitting quietly.

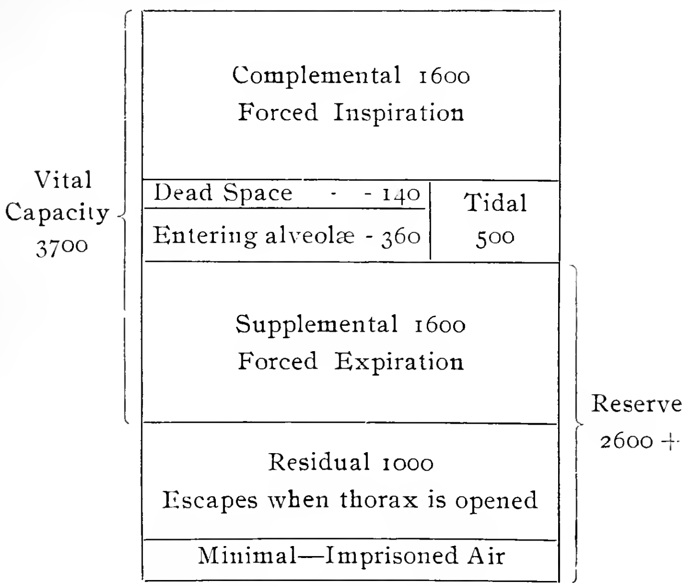
(2) Effect of mental excitement.

It is of course evident that voluntary control of the rate of breathing in all of the foregoing tests lessens their value. Usually it is only in the later tests, after the subject has become accustomed to wearing the apparatus, and the work has ceased to be interesting, that the subject will breathe naturally. It is best, for this reason for all the tests to be made first on one student and later on his associate.

EXPERIMENT XLI.

Measurement of the Expired Air.

The air which is breathed by quiet respirations, the *tidal air,* averages only about 500 cc., and of this amount, only about 360 cc. reaches the alveoli of the lung, the rest remaining in the bronchi and upper air passages. By deeper respirations much more air is taken in and given out, and it is possible by forced inspirations to breathe in 1,600 cc.



more, the complemental air, and to breathe out 1,600 cc. more, the supplemental air. The sum of the tidal, supplemental, and complemental air, gives what is known as the *vital capacity,* 3,700 cc. Ordinarily there remains in the chest 2,600 cc., the reserve air, of which 1,000 cc., the residual air, cannot be expelled by a voluntary effort, but will leave the lungs when they collapse on the opening of the thorax, and a small quantity, the minimal air, which even then does not leave the lungs, but will be imprisoned by the collapse of the bronchi, (See *i,* Exper. XXVIII). These figures are only rough averages, and the values found for different individuals differ greatly.

By means of the air breathed we take in oxygen, and give off carbon dioxide gas, water, and heat. The necessary gaseous exchange would depend, not only on the amount of active tissue, but on the activity of the tissue. Even when no external work is being done, chemical compounds must be broken down to supply the heat needed for the maintenance of the body temperature. The loss of heat is greater for a child than for an adult, because the smaller the body, the greater the surface in proportion to the mass. Vierordt states that for a child one day old, the surface area is 812 sq. cm. for every kilo of body weight, and for an adult it is 301 sq. cm. The amount of katabolism and gaseous exchange should, therefore, be greater per kilo in the child than the adult. The surface area is calculated from the formula 12,312 x $\sqrt[\frac{3}{2}]{G}$, G being the weight in grams. In adults, the weight of inactive tissue, bones and fat, is so variable, that the weight is not a good index of the amount of active tissue and necessary gaseous exchange. The chest measure may not give the story, because in many individuals, respiration is largely diaphragmatic. Finally, the vital capacity depends not only on the present need, but on the way the individual has lived. The length of the body is also a doubtful standard of comparison; never the less, the following table from Vierordt is quoted, as giving an indication of the way the vital capacity is influenced by size of body.

Experiment.—The apparatus will be understood by examining Fig. 44. Notice that the air enters the valve chamber (*V*) through the lower valve, passes to the subject, and is given off by him through the other valve to the outside, if the stop-cock *S* is open, or to the spirometer, if the cock is turned in that direction. On entering the apparatus it collects above the water and raises the bell. *Caution.—When the air is to be expelled always remove the rubber stopper* (*C*).

VITAL CAPACITY AND SIZE OF BODY

Height (cm.)	Vital Capacity (cu. cm.)	Difference
154.5 - 157	2635	
157 - 159.5	2841	206
159.5 - 162	2982	141
162 - 164.5	3167	185
164.5 - 167	3287	120
167 - 169.5	3484	197
169.5 - 172	3560	76
172 - 174.5	3634	74
174.5 - 177	3842	208
177 - 179.5	3884	42
179 - 182	4034	150
182	4454	420
Average	3484	—
Average for every 2½ cm. of length		111

a. Tidal Air.

It is difficult to determine the tidal air, because the character of the respiratory movements alters as soon as one becomes conscious of them. Take a fresh mouth-piece and connect it with the apparatus, and then adjust the rubber between the teeth and lips, so that an air-tight closure will be obtained. Open the three-way cock so that the air will escape freely, and then holding the nose, breathe quietly and as naturally as possible, drawing in the air through one valve and giving it out through the other and the open cock. When the breathing seems to be normal, let your partner turn the valve at the instant you have finished taking in an ordinary breath, and then continue breathing as before but into the spirometer. Count the breaths, note the amount that has been expired, and calculate the average tidal air.

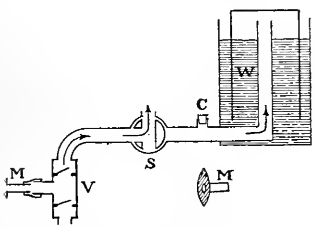


Fig. 44. Apparatus for measuring the expired air. M, mouth piece, consisting of a glass tube and a piece of sheet rubber shaped to fit the space between the teeth and the lips; V, valve chamber; S, three-way cock, permitting the air to escape or to enter the spirometer; C, cork keeping air in spirometer; W, water in spirometer.

b. Supplemental Air.

Breathe quietly as before, holding the nose closed, and having the cock open, then at the end of a *quiet* expiration, let your partner suddenly turn the cock toward the spirometer, and empty your lungs as completely as you can. Make at least three tests. Record in your notes the result of each test and the average.

c. Vital Capacity.

Fill your lungs as completely as possible and then quietly and steadily breathe all the air possible into the spirometer. Make at least three tests, taking the largest volume expired as the vital capacity.

d. Complemental Air.

This can be calculated by subtracting the sum of the average tidal and average supplemental air, from the vital capacity.

Report the results of these experiments in your notes, and try to find an explanation, in case your figures differ widely from those given above.

EXPERIMENT XLII.

Regulation of Body Temperature.

Regulation of temperature depends on adjustment of heat production to heat elimination, or vice versa. Heat production results from the splitting up of chemical componds and oxidation processes in all active cells, but especially in the muscles, because of their greater mass. It is well known that the blood leaving an organ is warmer than that entering it, that the rectal temperature is higher after a meal, and that it may be increased a couple of degrees by active exercise. Heat is given off chiefly from the skin and air passages, by conduction, radiation, and evaporation. It is believed by some observers that there are special centers regulating heat production. The centers which control the flow of blood to the skin, the activity of the sweat glands, and the rate and depth of respiration regulate the elimination of heat.

Experiments.

a. *The Loss of Heat from the Skin.*

1. *The loss by conduction,* noticeable whenever one touches a cold object, the cold points having their temperature suddenly lowered by the loss of heat in warming the object.

2. *The loss by radiation,* can be readily observed by bringing the palm of one hand close over the back of the other, or close to the face, but without touching it, and feeling the heat radiating from the warmer surface; this warms the air, and the heated air excites the warmth spots in the skin.

3. *The loss by evaporation,* can be recognized by moistening the skin, putting the mouth close to it, and sucking air in across the surface. Control this result by repeating the

test at a place where the skin has not been moistened. The evaporation is caused by the heat brought by the blood to the skin, and the heat is lost in evaporating the moisture.

b. The Loss of Heat from the Air Passages.

1. *By conduction and radiation.* This can be recognized by simply breathing on the skin.

2. *By Evaporation.* This occurs in the same way, and the moisture given up to the air in the process can be detected in the moisture which will be deposited when one breathes on a cold pane of glass.

The amount of heat lost by conduction and radiation from the air passages and the skin, will depend on the amount of blood flowing through the surface vessels, and its temperature as compared with that of the object touched, and that of the outside air; and the heat lost by evaporation will depend on the amount of moisture supplied to the surfaces by the mucous membrane and the sweat glands, and the degree of saturation of the air at the time. The body temperature rises when the surrounding air is hot, and especially when it is moist and hot.

EXPERIMENT XLIII.

Artificial Respiration.

Normally air is sucked into the chest by enlargement of the thorax in the antero-posterior and lateral directions, and by the descent of the diaphragm, and is driven out by the elastic recoil of the lungs, the walls of the chest and the walls of the abdomen. The most usual form of artificial respiration used for animals, is to force air rhythmically through an opening in the trachea, into the lungs, by means of a bellows or one of the many forms of air pumps, and either to suck it out, or more commonly, let the elastic forces of the soft parts drive it out through a valve or side opening, (see Exper. XXIX, *c*.) One such form of apparatus, is the pulmotor, which is intended to resuscitate men who are partially drowned or asphyxiated, or are suffering from extreme shock. The air or oxygen under suitable pressure flows in through a mask, which covers the nose and mouth and fits the face tightly, and then is sucked out.

Another method known as the insuflation method, which is used on animals, forces a continuous stream of air, under known pressure, through a tube which has been introduced through the mouth into the trachea as far down as the bronchi, the air escaping through the space between the tube and the walls of the air passages. In this case, the air in the lung is renewed by diffusion of the gases between the upper bronchi and the alveoli. This method is especially of use in experiments in which the chest must be opened and it is desirable that the lungs should be quiet.

Another set of methods try to suck, instead of blow, the air into the lungs. In this case, the negative pressure on the outside of the lungs is rhythmically increased and decreased. By one method, intended to make operations inside of the chest possible, the subject is placed in a pneumatic cabinet, in which the pressure of the air is varied by a pump, and when the chest is opened, the changes in pressure in the cabinet cause contraction and expansion of the lung, and the expelling and drawing in of the air.

Several methods which require no apparatus, have been devised for artificial respiration of men. The best known of these carry the names of Marshal Hall, Howard, Sylvester, and Schaefer.

By the Sylvester method the subject lies on his back; one operator cares for the mouth, keeping it free from mucus, &c., and draws the tongue forward, by grasping it with a dry cloth or by forceps; one or two other operators expand the chest wall by raising the arms and swinging them as far back, above the head as possible, and then compress the chest by bringing the elbows against the sides and pushing down on them.

In the case of very young children, a modification of the above method is quite effective. The hands of the operator grasp the chest close under the arms, and then alternately raise the chest wall by pushing the shoulders up and backward by the ends of the thumbs, and compress it by pressing on the lower part and sides of the chest with the base of the thumbs. The head can be allowed to hang down, so the tongue shall fall forwards.

The Schaefer method is effective, and by far the simplest for adults, (a similar method was proposed by Dr. Kedzie of this state). Since by this method, the subject lies in the prone position with the face towards the side, fluids tend to drain out of the mouth, and the tongue, falling forward, does not interfere with the air passages. The operator kneels at the side or across the subject, facing his head. He places his hands on the small of the back, over the lower ribs, so that the thumbs nearly meet at the spine. Then keeping the arms straight, he swings forward and brings the weight of his body to bear on the back of the subject; this compresses the chest, and by pushing the abdomen against the ground, causes the vicera to force the diaphragm upward. He then swings back and repeats these movements *slowly*, saying 1001, 1002, 1003, by the forward swing, and 1004, 1005 by the backward swing. The rate should be 12—15 to the minute. The forward swing produces an expiration, and by the backward swing, the elastic forces of the chest cause it to enlarge and produce an inspiration.

EXPERIMENT.—Each student is to act as subject and operator, in order that he may gain a better knowledge of where the pressure should be applied to be most efficient. Have the apparatus used to measure the tidal air ready, and let the subject lie down on a sheet of cloth sufficiently near the apparatus, so that the tube connecting with the valve chamber, (*V*, Fig. 44), easily reaches the mouth.

a. The Schaefer Method.

Let the operator perform artificial respiration by the Schaefer method, in the way that both he and the subject recognize to be most effective. When the method has been learned, let the subject breathe as near as possible normally into the spirometer six or seven breaths. The amount recorded should be noted, and the amount of air that is given out by a like number of artificial respirations should be measured.

b. Effect of Apnoea.

Let the subject take 15 or 20 deep, rapid, forced respirations, so as to thoroughly ventilate his lungs and blood, and then *immediately* repeat the experiment of measuring the amount of air given out by artificial respirations.

c. The Sylvester Method.

Repeat the work as described in *a*.

Notes.

State in the notes the figures obtained in the above tests and explain any differences which may have occurred.