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A PRACTICAL COURSE OF GENERAL PHYSIOLOGY

FOR MEDICAL STUDENTS

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FOURTH EDITION

156247
4.10.20.

GLASGOW
JAMES MACLEHOSE AND SONS

PUBLISHERS TO THE UNIVERSITY

1918



PREFACE.

THE objects of this Course are twofold—First, to train the student in the investigation of the many problems of medical science which he has afterwards to face, and to teach him to observe, record, and describe the vital phenomena with which he has to deal.

Second, to give him a real and sound practical foundation for his after study of Physiology, based upon his personal experience and not upon the dicta of his teacher and text-books.

For this reason, the problems to be investigated and the method of investigation are indicated here ; but the results to be obtained and the conclusions to be drawn are left to the student, who must, before all, learn to observe and to experiment without preconceived ideas and without any anticipation of a particular result, but with a mind open to accept whatever result may be obtained. From the result he must attempt the solution of the problem under investigation.

The Course should be taken along with a Course of Lectures and Demonstrations, and it should be so arranged that, in each part, the practical work precedes the lectures.

September, 1908.

THE present Edition has been revised and re-arranged in the light of the experience of the working of the class of General Physiology during the past nine years.

March, 1918.

LIBRARY

The objects of the library
are to provide a collection of
books which shall be available
to the members of the
club for their use and
enjoyment. The library
shall be open to all
members of the club
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by the librarian.
The library shall be
open to all members
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PRELIMINARY.

THROUGHOUT this Course the student must keep careful records of every experiment he performs, and these must be made as the experiment proceeds and not some time after its completion. When apparatus is used, he must make diagrams of its arrangement, and, when tracings are taken, these must be fixed and preserved.

Before beginning an experiment he must first clearly understand its *object*, and no student will be allowed to continue an experiment who has not entered in his note-book the question to be investigated.

He must also, before starting, understand the *method* adopted and how it will throw light upon the question.

While carrying out the experiment he must not confine his attention only to the main *result*, but must observe everything which happens, and record for further investigation anything he does not understand. The experiment must be carried through without any preconceived idea of what the results should be, and an attempt must be made to draw *conclusions from the results obtained*, and to give an answer to the question which is under investigation.

In every experiment the student must record :

1. The Object.
2. The Method used.
3. The Results obtained.
4. The Conclusions drawn.

Every student must be provided with a large note-book, pencil, *strong* sharp-pointed scissors, *strong* dissecting forceps, and a camel's-hair brush.

1877

Received of the Hon. Secy of the Interior
for the purpose of the purchase of
land in the State of California
the sum of \$1000.00

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I. THE ESSENTIAL NATURE OF LIVING MATTER IN ITS SIMPLEST FORM.

1. OBJECT.—To learn something of the essential nature of living matter (protoplasm).

2. METHOD.—Take a very simple form of living matter—the yeast plant—and place it under various conditions. Place a small quantity of yeast on a slide, and add a drop or two of water. Rub up into an emulsion with a glass rod, and transfer a little on the end of the rod to: (A) a test-tube of a solution containing the chemical elements in the yeast, *e.g.* urea $\text{CO}(\text{NH}_2)_2$, glucose $\text{C}_6\text{H}_{12}\text{O}_6$, with traces of sodium phosphate Na_2HPO_4 , potassium sulphate K_2SO_4 , and calcium phosphate $\text{Ca}_3(\text{PO}_4)_2$; (B) a test-tube filled with water.

See that the tubes are quite full. Shake well and examine a drop with the microscope, and make a rough estimate of the number of torulæ in two or three fields of the microscope. Draw one or two torulæ.

At each Bench—

Students at places 1 and 2 at once insert the corks firmly into the tubes. The tubes of 1 are placed in an incubator at 37°C . The tubes of 2 are placed in a vessel of broken ice.

Students at place 3 introduce a few drops of phenol solution, insert the cork, and place the tubes in the incubator.

Students at place 4 boil the tubes before quite filling them, cool them under the tap, fill them with water, insert the corks, and place them in the incubator.

3. RESULTS. (A) ON YEAST.—Next day the tubes are to be examined with the naked eye before and after shaking, and the condition of each tube studied, contrasting it with the condition on the previous day. A drop of the fluid after shaking is to be examined with the microscope, and the number of torulæ in two or three fields to be estimated.

The students at each bench should make a combined table of their results as to gas-formation, change in opacity, and change in number of torulæ, using + and - as signs.

		Gas.	Opacity.	Number.
Tubes with sugar (1) at -	37° C.			
" " " (2) at -	0° C.			
" " " (3) with	Phenol			
" " " (4)	Boiled			
Tube with water (5) at -	37° C.			

(B) ON FLUID.—(a) *Disappearance of Sugar. (Demonstration.)* The original solution (A) and the solution after incubation (B) have been boiled for some time with phenylhydrazine and acetic acid, which forms a yellow insoluble compound with glucose. Note the difference in the amounts in (A) and (B).

(b) *Formation of Alcohol.* Some of the fluid from tubes 1, after being in the incubator, is distilled. To about half an inch of the distillate, add a few drops of potassium bichromate and a little dilute sulphuric acid and warm. Note :

1. Pungent odour—Aldehyde.
2. Green colour.

(c) *Nature of Gas evolved. (Demonstration.)* With a fine pipette add KHO dissolved in alcohol to a Doremus' ureameter in which the solution has been incubated with yeast, and note the absorption of the gas evolved—CO₂.

4. CONCLUSIONS.—(1) What has happened to the yeast in each of the tubes ?

(2) What conclusions do you come to as to the influence upon the yeast protoplasm of the various conditions to which it has been subjected ?

(3) How has the growth of the yeast taken place ?

(a) Where does yeast protoplasm get material for growth ?

(b) Where does yeast protoplasm get energy for growth ?¹

¹For Enzyme Action see *Practical Chemical Physiology*, by Noël Paton, Cathcart and Burns (Fourth Edition), p. 23 *et seq.*



II. THE USE OF ELECTRICITY FOR STIMULATING IN PHYSIOLOGY AND MEDICINE.¹

(The Student must revise his knowledge of Electricity.)

Stimulation of the Nerve-endings in the Skin as determined by Sensation.

METHODS.—A. *Simple Galvanic Current.* Connect thick covered wires with the terminals marked *G* on the table, + for positive (anode) and - for negative (cathode), from the constant current supplied from a generator. Insert into the circuit a *mercury key*, as shown in the diagram, so that when it is closed the current will flow through the terminals (fig. 1). Hold the ends of the wires, one on each side of the tongue, and note the sensations produced when the current

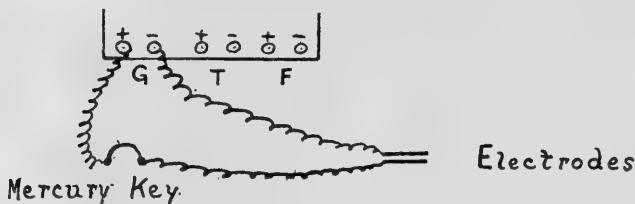


FIG. 1.—Simple Galvanic Current.

is allowed to pass (made) by closing the key, when it is cut out (broken) by opening the key, and when the current is flowing. Note whether the sensations are different or similar at the two poles on closing and on opening and during the flow.

RESULTS.—Taking sensation as the index of stimulation, record on the table below the results of the sudden making

¹The current is supplied from a generator giving from 15 to 30 volts to the switchboards on the tables. The terminals marked *G* are for galvanic stimulation, and give from 0 to 400 milliamperes. The terminals marked *F* are for Faradic stimulation, and give about 1.5 amperes. The terminals marked *T* are connected with a chronograph and interrupt at 1 sec., 0.1 sec., or 0.01 sec., according to the way in which the instrument is set.



and breaking of the electric current, and of its continuous flow.

	Make.	Flow.	Break.
Anode - -			
Cathode - -			

B. *Induced or Faradic Current.* Lead off wires from the screw-terminals *F* on the table to the screws on the top of the end of the primary coil of an induction coil (fig. 2), and introduce a *mercury key* into the circuit. Lead wires from the

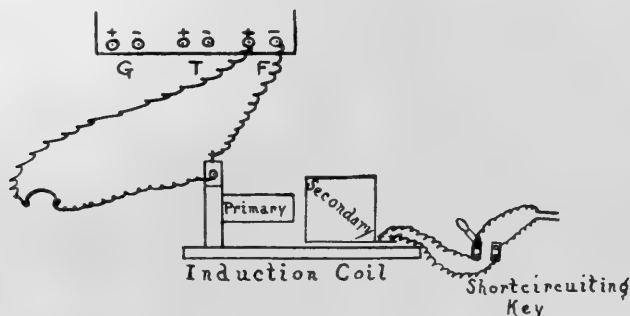


FIG. 2.—Induced Current.

terminals of the secondary coil to a *friction key*, so that when it is closed the current is short-circuited. Lead off two terminal wires from this key. Pull the secondary coil well away from the primary, open the friction key, so that the current may pass to the wires, and use the wires as in the last experiment. Note the effect on the tongue of the sudden appearance and disappearance of the current induced in the secondary coil each time the primary circuit is made or broken.

RESULTS.—

Making Primary.	Breaking Primary.

C. *Rapid Series of Induced Currents.* Connect up an induction coil with the screw terminals marked *F*, inserting the wires into the binding-screws *in the pillars* at the end of the primary coil, so as to bring the Neef's hammer into action (fig. 3). Introduce a mercury key into the primary circuit and a friction key into the secondary circuit as before (fig. 2).

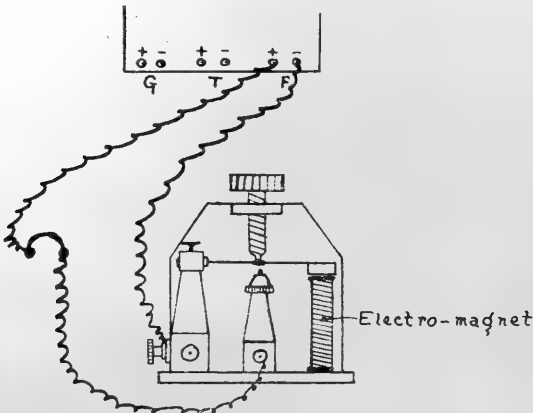


FIG. 3.—End of Coil showing Neef's Hammer.

Note that, when the mercury key is closed, the current passes round the electro-magnet, which pulls down the hammer and spring, and thus breaks the contact at the screw in the middle of the spring. The current is interrupted, the magnet demagnetized and the spring bounds back. The number of interruptions depends on the length of the spring.

Open the friction key and pull the secondary coil well away from the primary and apply the wires to the tongue. Close the mercury key, and if no sensation is experienced push the secondary coil nearer to the primary. Record the resulting sensation.



III. MUSCLE-NERVE.

I. What is the Influence of the Brain and the Spinal Cord on Skeletal Muscle ?

METHOD.—Study, draw and describe the attitude, and note the movements and the effect of touching and of turning the animal on its back—

(1) *in a frog with the brain and spinal cord intact.*

(2) *In a frog with the brain destroyed.* Holding the frog by its hind legs, kill it by a stroke of its head upon the edge of the table, and cut off its head *behind the tympanic membranes.*

After a few minutes, study and describe the attitude, movements, and the effect of touching and pinching. Feel the condition of the muscles as to consistence, and place the animal on its back, noting any difference in its behaviour.

(Reflex Action, p. 27, may be done here.)

(3) *In a frog with the brain and spinal cord destroyed.* Pith the frog by passing a thick pin down the vertebral canal so as to destroy the spinal cord (fig. 4). Note carefully



FIG. 4.—Pithing Frog.

anything that takes place in the muscles as this is done. Study and describe the frog again as to attitude, movements, effect of touching and pinching. Examine the consistence of the muscles.

CONCLUSIONS.—What is the influence of

- (a) The brain, and
- (b) The spinal cord upon the muscles ?



II. What is the Influence of the Nerves upon Skeletal Muscles ?

METHODS.—(A) Stimulation of the nerve, and (B) throwing the nerve out of action.

Connect up a galvanic circuit as in fig. 1 or a Faradic current as in fig. 2, using the pin electrodes provided.

Always make apparatus ready and see that it is working before preparing the animal.

The second frog supplied has been killed by destroying its brain, as in (2). A ligature has then been placed low down,

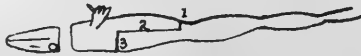


FIG. 5.—Incisions for Separation of Hind Legs.

round all the structures of one thigh excepting the sciatic nerve, and a dose of curare has been injected under the skin. The curare has thus acted on the nerve, but has been prevented by the ligature from reaching the terminations of the nerve in the gastrocnemius muscle.

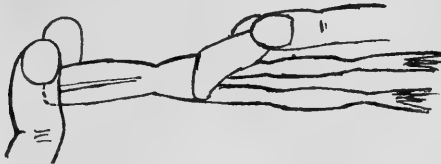
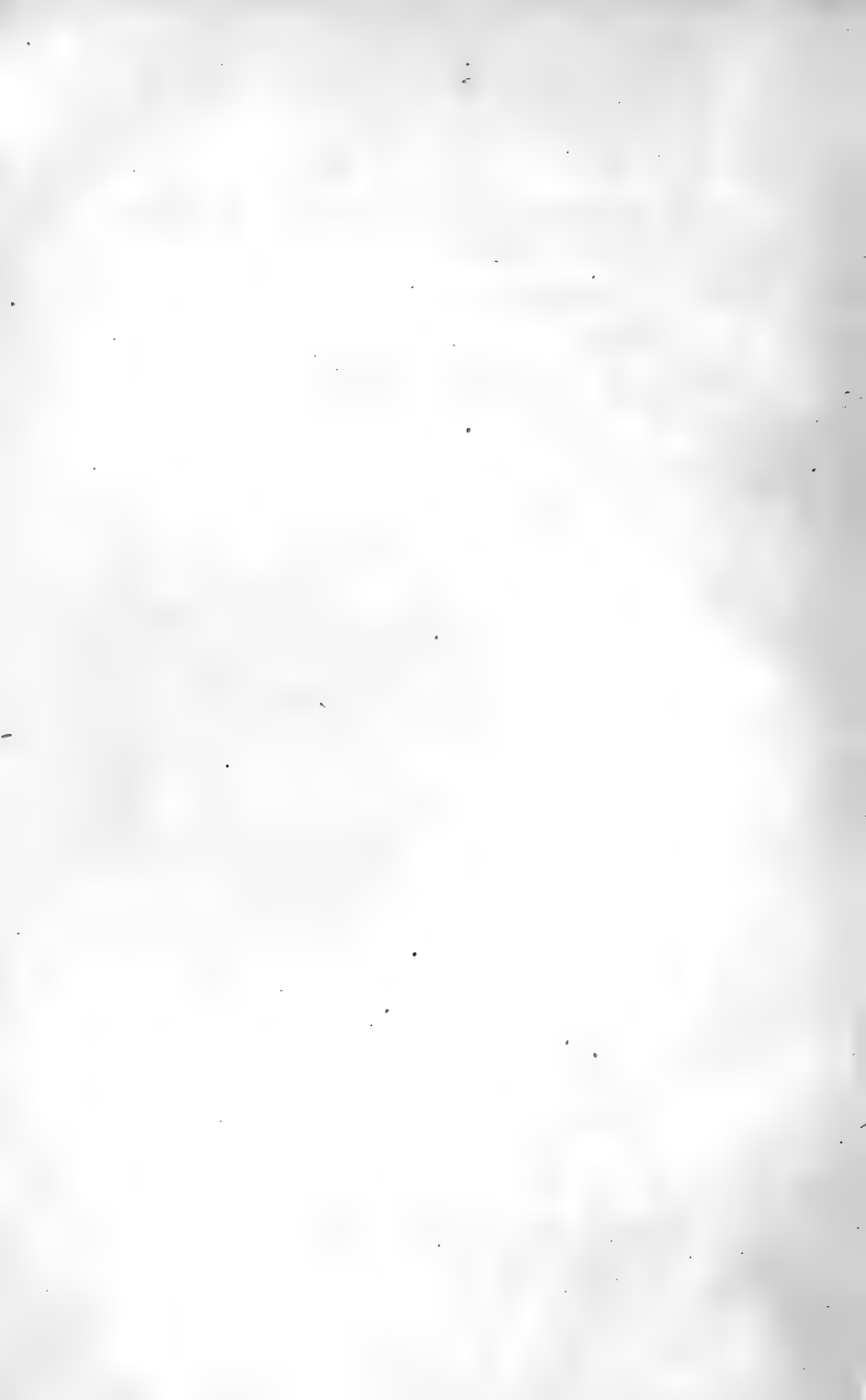


FIG. 6.—Skinning Hind Legs (use cloth round fingers).

Compare and describe the condition of this frog with the normal one before the cord was destroyed (2).

What has been the effect of the curare ?

Remove the anterior part of *both* frogs by three cuts (fig. 5), taking care that the third cut leaves a piece of the vertebral



column connected with the iliac bones. Skin the hind legs, but just before doing so cut through the ligature; then dissect out the sciatic nerve, p 19, (2), (3) and (4) (figs. 6 and 7).

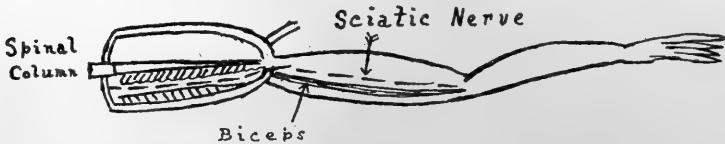


FIG. 7.—Dissection of Sciatic Nerve.

Apply the electrodes to the structures indicated below, and stimulate by closing and opening the mercury key.

RESULT.—

Normal frog, (a) Sciatic nerve.

(b) Gastrocnemius muscle.

Curarised frog, 1. Limb exposed to curare (unligatured).

(a) Sciatic nerve.

(b) Gastrocnemius muscle.

2. Limb protected (ligatured).

(a) Sciatic nerve (above where ligature was applied).

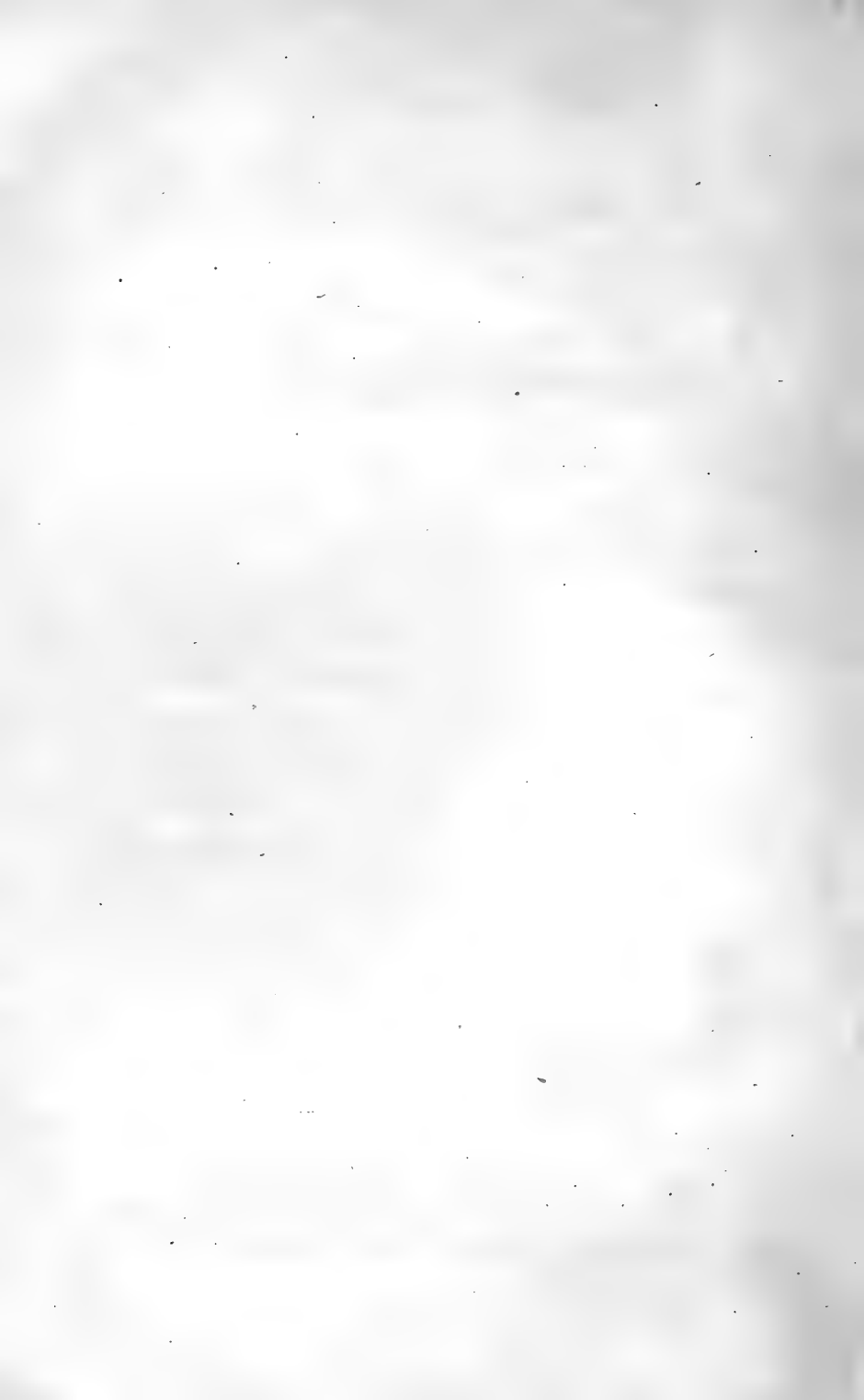
(b) Gastrocnemius muscle.

Record the results on the appended table :

	Normal.	Curarised.	Protected.
Nerve - -			
Muscle - -			

CONCLUSIONS.—

1. What is the influence of nerve upon skeletal muscle ?
2. What is the influence of curare upon (a) nerve, (b) muscle, and (c) the junction of nerve with muscle ?



III. Can a Muscle be Stimulated without the Intervention of the Nerve?

Try to answer this question from the results of the last experiment.

IV. What is the Effect of an Electric Current upon Nerve and Muscle?

A. On the Isolated Nerve-Muscle.

I. GALVANIC CURRENT.

Study the galvanic stimulation of nerve and muscle as in I. A, p. 8, using the normal nerve-muscle preparation already made, and increasing the strength of the current by moving the handle on the switch-board from *W* to *S*. Record any difference you observe at making and at breaking the current.

II. INDUCED CURRENT.

Fit up an induction coil for single induction shocks (p. 9, B) and bring the electrodes upon the gastrocnemius muscle. With the secondary coil well out from the primary, make and break the primary circuit again and again, moving the secondary coil nearer to the primary between each make and break, and record the result on the muscle, noting each time the position of the secondary coil.

Repeat the experiment with the electrodes on the sciatic nerve.

Do the Two Poles act in the same way? (Galvanic Current.)

Make a nerve-muscle preparation as described on p. 13. Dip the end of the nerve furthest from the muscle momentarily into boiling water to kill it. It will not now respond to the electric current although it will conduct it.

Laying the nerve upon a glass slide, place the dead bit of nerve over one electrode, and place the other electrode on the nerve near the muscle. Now make and then break the



current (1) with the positive pole on the living bit of nerve, and (2) with the negative pole on the living bit of nerve, and record your results on the subjoined table :

	Make.		Break.	
	Cath.	An.	Cath.	An.
Strong - -				
Medium - -				
Weak - -				

B. On Nerve and Muscle through the Skin.

Arrange the wires to use the current from the terminals *G*, and introduce a commutator to change the direction of the current when desired (figs. 8 and 9). Put some *saturated* salt solution in a basin and fix the end of one wire in the solution. To the end of the other wire attach a flat zinc electrode, placing a bit of chamois leather saturated with the salt solution between the electrode and the skin. Dip the fingers of the left hand into the salt solution and apply the flat electrode over the back of the thenar muscles.

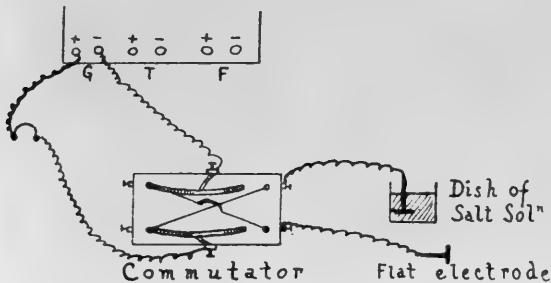
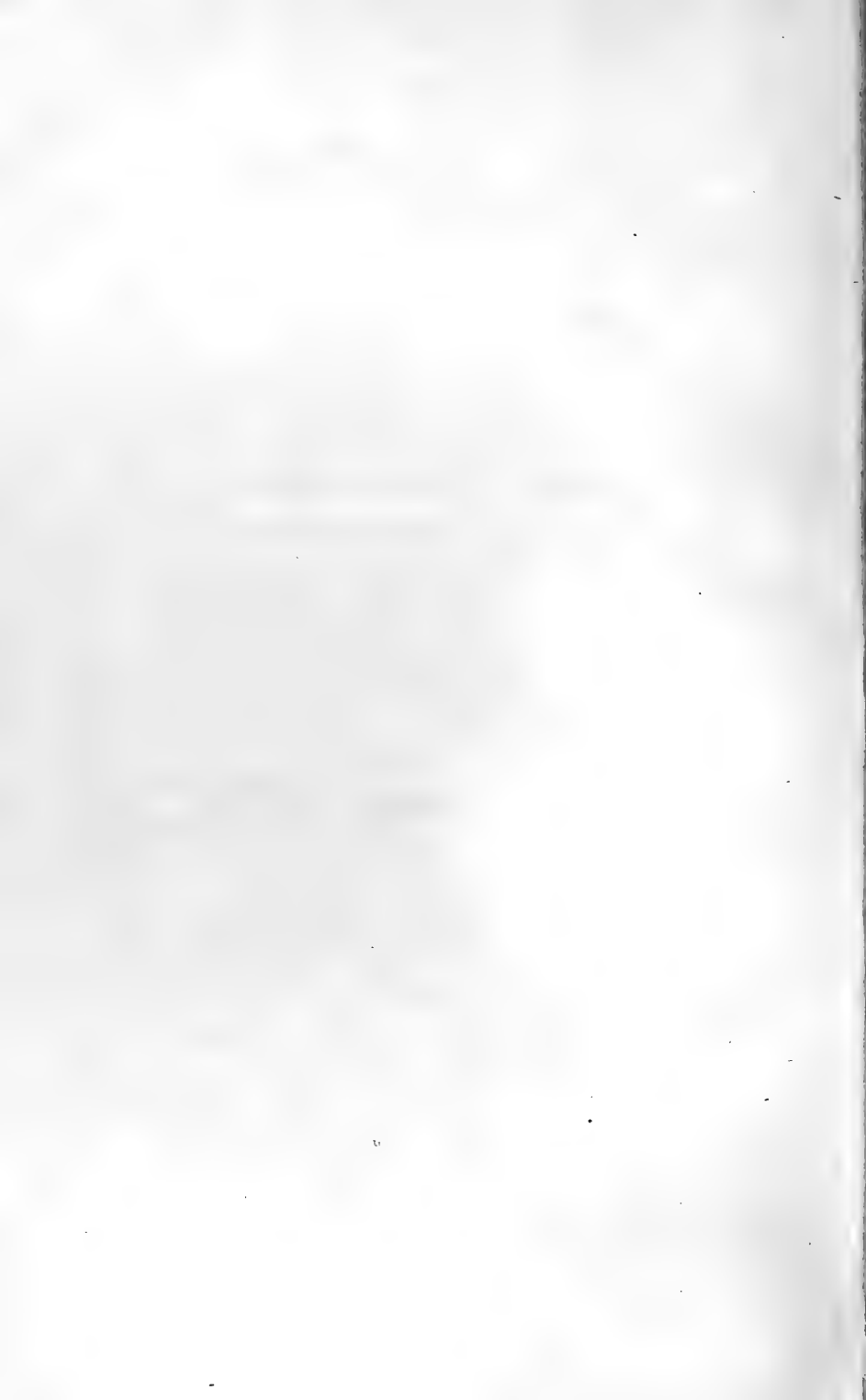


FIG. 8.—Electrical Stimulation of Muscle through Skin.

First use the cathode. Beginning with a strong current, record the results which follow making and breaking the current. Then, by moving the handle on the switch-board from *S.* to *W.*, reduce the strength of the current, and again



record the results which follow making and breaking the current.

Now reverse the direction of the current by means of the commutator, so as to make the pole over the muscles the

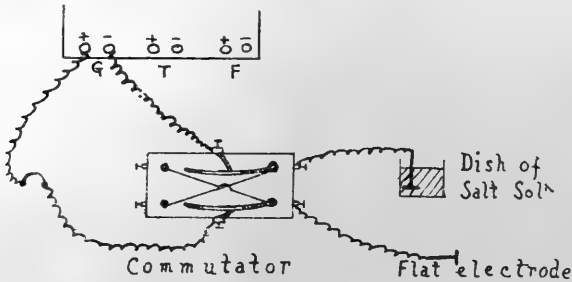


FIG. 9.

anode, and again study the effects of strong, medium, and weak currents at making and breaking.

Record the results obtained on the following table :

Strength of Current.	Make.		Break.	
	Cath.	An.	Cath.	An.
Strong - - - -				
Medium - - - -				
Weak - - - -				

and arrange them according to their relative effectiveness.

Compare them with the results previously obtained on the isolated nerve-muscle of the frog.

V. What happens to a Muscle when made to Contract ?

Examine the biceps muscle when the forearm is flexed, and formulate the results of your observations.

A. Extent of Contraction.

With the hand in supination and the arm semiflexed, measure the length of the biceps. Now flex the forearm to a small

extent and measure the space through which the hand has been lifted.

From the elbow joint measure the length of the forearm and hand to the finger tips, and also to the insertion of the biceps. Make a diagram, and from these data, and from your knowledge of the mechanism of levers, calculate the extent to which the muscle has shortened.

$$\begin{aligned} &\text{Extent of contraction} \\ &= \frac{\text{length of lever from fulcrum to power}}{\text{length of lever from fulcrum to point}} \times \text{height of lift of hand.} \end{aligned}$$

B. Force of Contraction.

Lift a weight of 2 kilograms in the hand, as in the previous experiment, and calculate what weight directly applied to the muscle this represents.

$$= \frac{\text{length of lever from fulcrum to weight}}{\text{length of lever from fulcrum to power}} \times \text{weight lifted.}$$

This is a measure of the force of the particular contraction.

Dynamometer.—Study the dynamometer provided, and determine the force of contraction of the flexors of each hand.

C. Work Done.

From the extent of shortening of the muscle, and from the weight lifted, calculate the work done by the biceps muscle.

$$\text{Work done} = \text{weight lifted} \times \text{extent of contraction.}$$

D. What is the Course of Contraction of a Muscle ?

METHOD.—Make a frog's gastrocnemius record its change upon a moving surface.

A. Apparatus.

(1) Prepare an *Induction Coil* for single induction shocks, putting the *Drum*, covered with smoked paper, in the



primary circuit, so that the two strikers below the drum make and break the circuit as the drum revolves (fig. 10).

- (a) Always keep the key in the primary circuit open unless when using current.
- (b) Always keep the key in the secondary circuit closed unless when stimulating.
- (c) Keep strings clear of the switchboards.

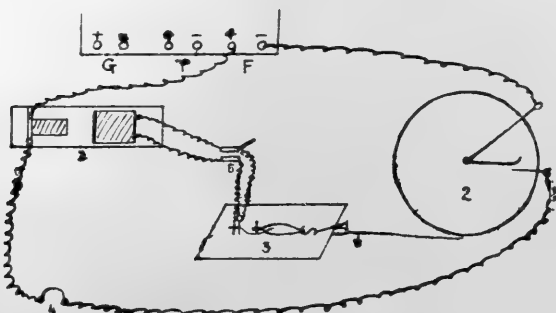


FIG. 10.—Course of Contraction of Muscle.

1. Induction Coil. 2. Drum. 3. Frogboard. 4. Mercury Key. 5. Friction Key.

(2) With the key in the secondary circuit open, with the hand move the drum in the direction in which it is driven by the string so as to make and break the circuit and test the current passing to the electrodes by applying them to the tip of the tongue.

- (a) See that wires are not broken.
- (b) See that all metallic contacts are bright and close.
- (c) See that no short circuits are present.

(3) Arrange the driving cord of the drum to give a fairly rapid speed. (*Spindles—Large to Middle.*)

If two students are working together it is convenient to introduce two strikers under the drum in a straight line with one another, so that each revolution of the drum will give two stimulations of the muscle.

B. Muscle-nerve Preparation.

When everything is ready, *and not before*, make a nerve-muscle preparation.



Prepare Frog.

(1) Kill, decapitate, divide, and skin the hind part as in earlier lesson. (2) Lay the frog on its belly. Raise the urostyle in forceps, holding the lower end and cut up each side. Cut it across at the base, *taking care not to cut the nerves beside it.* (3) Cut across each iliac bone at the upper part and at lower end (*taking care not to touch nerves seen in front*). (4) Divide the spinal column vertically in the middle line. (5) Divide the pelvis vertically in the middle line (*one half to each two students*). (6) Dissect out the sciatic nerve from the spinal column to the lower end of the thigh. (7) Now separate the muscle from the tibia with a glass hook and cut through the fascia of the sole of the foot, into which the gastrocnemius muscle is inserted. (8) Cut away all the thigh but the lower end of the femur (fig. 11 (1, 2, and 3)), *taking care not to injure the nerve.*



FIG. 11.

(9) Cut through the tibia below the knee (fig. 11 (4)), and thus remove it and the foot.

C. Bring the Preparation on to the Apparatus.

(1) Lay the muscle and nerve upon a piece of blotting paper *thoroughly saturated* with .75 % NaCl solution and placed on the cork plate of the frogboard. (2) Attach the tendon by a thread and hook or clip to the middle hole of the short limb of the crank lever. (3) Fix the femoral end of the muscle to the cork plate by a pin passed through the femur, so that the lever is supported in a horizontal position by the thread (fig. 12). (4) Put a small weight, 5 grms., on the lever just clear of the stand. (5) See that the lever is not resting on the screw-pin below it. (6) Place the nerve upon the electrodes, which may be



fixed to the cork by a pin. (7) Make and break the current by moving the drum with the hand in one direction so as not to displace the striker, and move the secondary coil out till breaking alone causes a contraction.

D. Take Trace.

(1) Now bring the point of the lever lightly against the smoked surface of the drum, (a) pointing it in the direction in which the drum travels, (b) and taking care that the movable base-piece of the frogboard is pushed thoroughly home, so that the

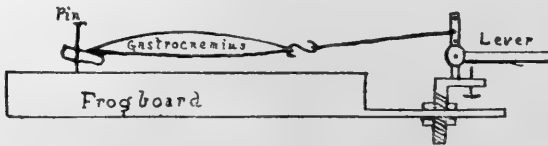


FIG. 12.—Muscle attached to Lever.

lever may be swung off and on to the drum when required. (2) With the finger raise the lever to see that it marks properly, and if necessary adjust lever. (3) With the key in the secondary circuit closed start the drum, and, when it is revolving steadily, open the key in the secondary circuit, so that the current may reach the electrodes and nerve. When the muscle is stimulated it contracts and pulls up the lever and records the contraction on the drum. (4) Whenever the two records are made, close the key again and stop the drum. (Don't reverse the drum and don't move the stand of the frogboard.)

E. Mark the Moment of Stimulation.

To mark the moment of stimulation, revolve the drum slowly with the hand, keeping the key in the secondary shut till the striker is just about to make contact, then open the key and cautiously continue the movement of the drum till the muscle contracts and marks the moment of stimulation. Note the relationship of this mark, which indicates the moment of stimulation, to the upstroke which marks the contraction.

F. Make a Time Trace.

(1) Swing the lever off the paper by using the base-piece (don't move the drum or the myograph stand). (2)



Set the drum going, and, when it is revolving uniformly, strike the tuning fork vibrating one hundred times per second so as to set it vibrating and holding it by the handle, and with the two limbs in the vertical plane, bring the wire attached to one limb against the drum under the muscle trace and run off a time trace. Each tooth on the tracing represents $\frac{1}{100}$ second.

Make two tracings, one for each Student.

G. Record the Nature of Experiment.

With a pin or other sharp-pointed instrument write upon the paper the nature of the experiment and the date.

H. Fix Trace.

Remove the paper from the drum, and fix the trace by passing it through photographic varnish. Hang it up to dry.

I. Read Trace. Work out Results.

When dry, study and measure.

(a) The Duration of—

1st. The time between the application of the stimulation and the contraction.

2nd. The time taken up by the contraction.

3rd. The time of relaxation.

And record them.

(b) Extent of Contraction.

Measure the extent of movement and the length of each limb of the lever, and calculate the actual shortening of the muscle as in A, p. 17.

Measure the length of the muscle, and calculate the percentage shortening.

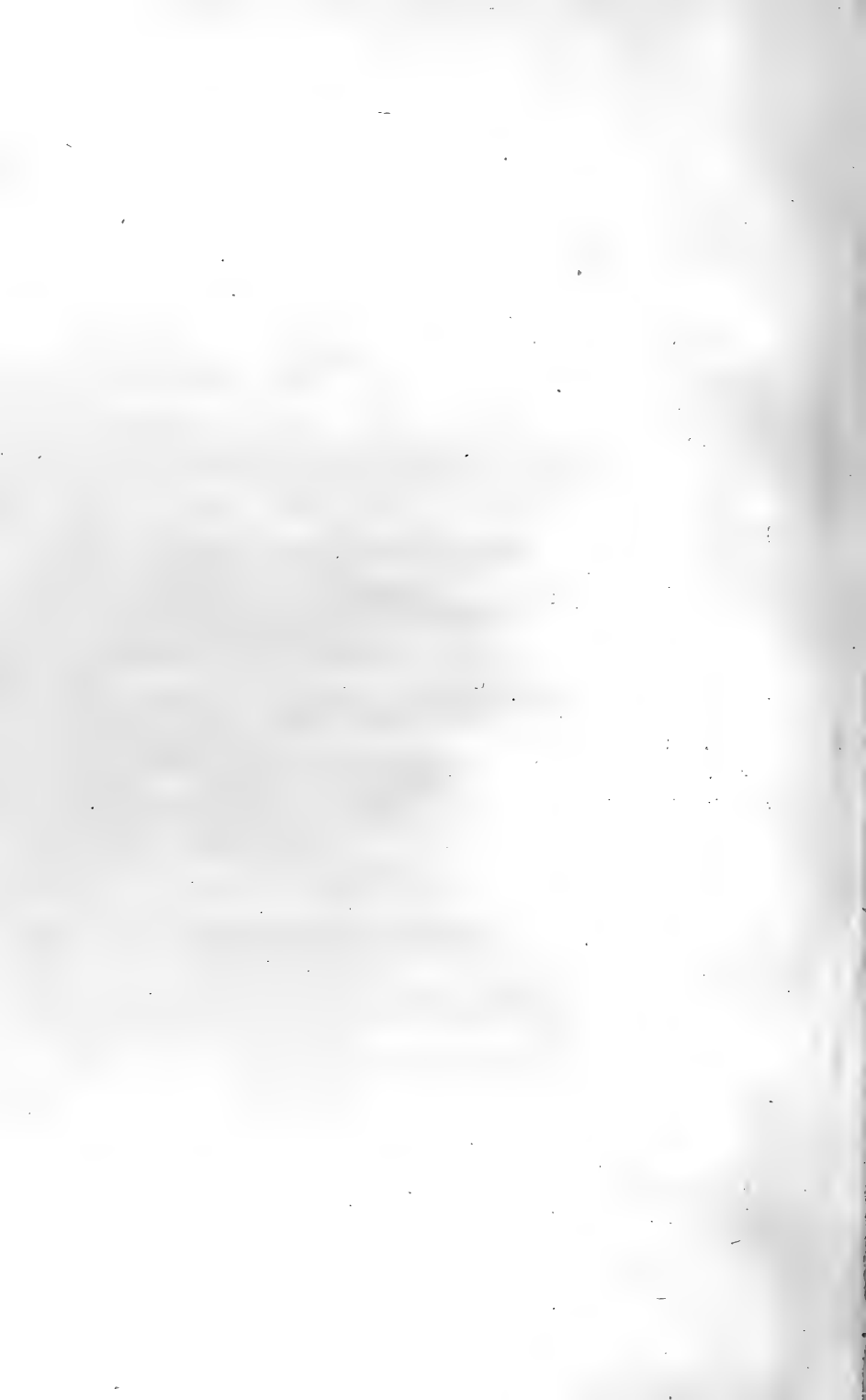
(c) Weight Lifted.

Measure the distance of the weight from the fulcrum, and calculate the actual weight lifted by the muscle as in B, p. 17.

(d) Work Done.

Calculate the work done by the muscle as in C, p. 17.

Preserve the trace and the calculations in your note-book.



VI. Influence of Various Factors upon Muscular Contraction.

Arrange an experiment in the same way as the last, and take a trace of a muscle twitch with a breaking shock. Mark the point of stimulation.

(Those who are to do the effect of Load omit the small weight in the first trace.)

Each pair of students then does one of the following experiments, and then compares their tracings with those of the others at the same side of the table.

I. Effect of Temperature.

METHOD.—Swing the lever off the drum by the base-piece, and cool down the muscle by putting ice round it, separating the ice from the muscle by a piece of blotting paper saturated with normal saline, and after 2 or 3 minutes remove the ice and paper and swing the lever on to the previous abscissal line, raising or lowering the drum if this is necessary, and when the drum is again running at uniform speed take another trace *over the first*.

Then, proceeding in the same way, warm the muscle by allowing normal saline at 25° C. to run over it for 2 or 3 minutes, and take another tracing. (*Put a plate under the frogboard to catch the solution.*)

Number the curves and note "normal," "cold," and "warm" upon them.

Take a time trace, fix, and work out as on p. 21.

II. Effect of Continued Exercise.

METHOD.—Having arranged the apparatus for taking a trace of a muscle contraction, start the drum and let the muscle be stimulated, and record its contraction with each tenth revolution of the drum. To do this, after a contraction or two contractions are recorded, swing the lever off the paper by the base-piece of the stand; let the muscle make



nine contractions, then swing the point of the lever on and record the next two contractions. Repeat this process as long as the muscle contracts. Number the curves and write on the drums the number of stimuli which have preceded each. In this way study the effect of continued exercise on muscular contraction.

Take a time tracing, fix, and work out as on p. 21.

III. Effect of the Strength of the Stimulus.

1. *On the Course of Contraction.* METHOD.—Starting with the smallest stimulus which will give a contraction, *i.e.* with the secondary coil as far out as will give a contraction, take a tracing as described above and note the position of the secondary coil. Then push the secondary coil nearer the primary, *note its distance*, and take a second record, when the drum is running at a uniform speed. Repeat this, each time moving the secondary coil nearer the primary. Number the curves and write upon the drum the distance of the secondary coil from the primary in each. Mark the point of stimulation, take a time tracing and fix.

Study the effect of varying the strength of the stimulus on (1) the duration of the phases and (2) the extent of contraction.

If, with the strongest stimulus used, a shoulder should appear on the ascent of the curve, explain how it has been caused.

2. *On the Extent of Contraction.* METHOD.—(1) Disconnect the drum from the primary circuit, twist the ends of the wires together, and use the mercury key to make and break the current. (2) Bring the lever against the drum unconnected with the driving wheel and, with the drum stationary, record the effect of the minimal effective stimulus, make and break, and of stronger and stronger stimuli, moving the drum about a quarter of an inch between each record, and keeping the make and break upstrokes separate.



A stimulus which is too weak to cause a contraction is called a *subminimal* stimulus.

Mark under each upstroke the distance of the secondary coil from the primary, fix, and work out as on p. 21.

IV. Influence of Load.

1. *On the Course of Contraction.* METHOD.—(1) Take a trace of a muscle twitch when no weight is on the lever, as described on p. 18. (2) Closing the key in the secondary circuit when the trace is made, stop the drum and swing the lever off. (3) Hang a weight of 10 gms. on the lever so that the thread from the muscle and that from the weight are equidistant from the fulcrum, or each at a measured distance from the fulcrum. (4) See that the lever is not resting on the screw pin. (5) Lower the drum till the point of the lever marks the same abscissa as before and take another trace when the drum is running uniformly. (6) Then move the weight to a measured distance further out on the lever, and take another trace. (7) Repeat with the weight still farther out, or put on a greater weight. If the lever is much depressed, shift the pin holding the muscle to make it again horizontal; *but, in doing so, do not move the stand.* Number the traces, and having calculated the actual weight applied to the muscle by p. 17 B, note it upon the drum.

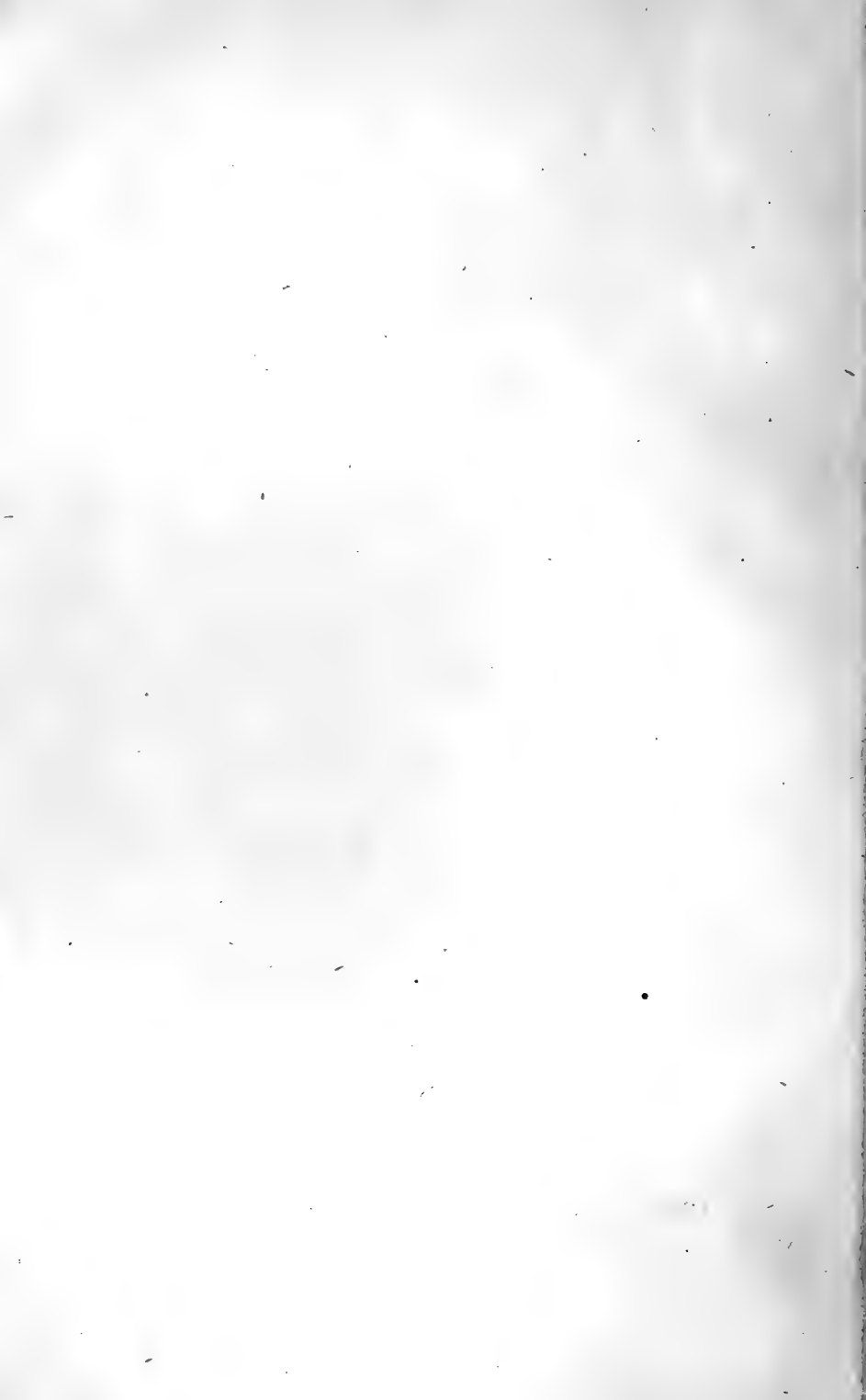
Mark the point of stimulation, take a time trace and fix.

2. *On the Extent of Contraction.* METHOD.—Proceed as in III. 2, but instead of varying the strength of the stimulus go on increasing the weight attached to the lever, when necessary adjusting the level of the drum, and mark under each upstroke the weight used, calculated as directly applied to the muscle.

Make a diagram, showing and comparing the work done with each weight.

V. The Effect of Tension on the Contraction and Work done by the Muscle.

A. With the screw-pin below the lever well depressed, attach a weight to the lever such that the muscle in contracting



raises it to near the maximum, and with the muscle stretched by the weight record a contraction.

B. Now screw up the pin below the lever so as just to prevent the weight stretching the muscle. Adjust the level of the drum so that the lever will be on the same line, and again take a trace over the last on the drum (after loaded muscle).

Mark the moment of stimulation, etc., as before. Fix and compare the two traces, and work out the extent of contraction and the work done.

(After taking each trace formulate your CONCLUSIONS as to the effect of the particular condition.)

VII. What is the Effect of a Rapid Succession of Stimuli ?

METHODS.—1. With a fast drum, arrange the two strikers on the axle, well apart from one another, and, with breaking

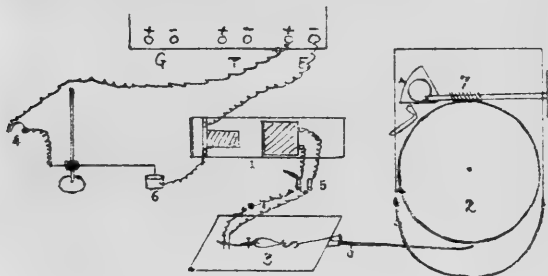


FIG. 13.—Effect of a Rapid Succession of Stimuli

- | | |
|--------------------|--|
| 1. Induction Coil. | 5. Friction Key. |
| 2. Drum. | 6. Vibrating Spring with Cup containing Mercury. |
| 3. Frogboard. | 7. Gear for producing Slow Rotation of the Drum. |
| 4. Mercury Key. | |

shocks, take a trace of two muscle twitches near the bottom of the drum. Mark the moments of stimulation. Then approximate the strikers so that the second contraction will be produced before the first has ceased, move the drum so that the lever writes at a higher level, and take a trace.



Note the relationship of the second contraction to the first, upon which it is superimposed. Mark the moments of stimulation, and take a time trace.

2. Now disconnect the drum from the primary circuit and introduce a spring, so that as it vibrates it makes and breaks the current by dipping into a mercury cup (see fig. 13). Adjust the current to stimulate on breaking. (1) Set the drum going *slowly*, and set the spring so that it makes and breaks 3 to 5 times per second (timing with your watch), and note its length. Bring the point of the lever upon the drum. Start the spring vibrating. Open the key in the secondary circuit and take a trace for about 3 or 4 seconds, then close the key, *but let the drum run till the lever falls to its previous level*.

(2) Now move the lever to another part of the drum, shorten the spring, and take another trace of the same duration.

(3) Repeat several times, shortening the spring, and each time noting the length of the spring.

(4) Finally connect up the Neef's hammer of the induction coil—a very short rapidly-vibrating spring—and take another tracing. Take a time trace of intervals of $\frac{1}{10}$ sec. by means of an electromagnetic marker. Fix the tracings and study the results of a succession of stimuli, and formulate your CONCLUSIONS from these results.

IV. THE NERVOUS MECHANISM.

I. Simple Neuron Action.

i. How is the Activity of the Neuron manifested?

METHODS.—1. Make a nerve-muscle preparation, *leaving the foot attached as a signal* as on p. 19, (1) to (6), dissecting out the whole length of the sciatic nerve to the spinal cord, and taking care to leave attached to the nerve a long piece of the branch to the posterior muscles of the thigh. Stimulate the sciatic nerve, using an induction coil and Neef's hammer. There is no manifest change in the nerve, but there is a change

in the muscle to which the nerve goes. (Keep the preparation cool and moist.)

2. Pinch your ulnar nerve behind the internal condyle of the humerus—a *sensation* is produced.

Where is the change manifested ?

ii. Does the Impulse travel in one or in both Directions ?
(Paradoxical Contraction.)

METHOD.—In the preparation just made, isolate the branch of the nerve to the posterior muscles of the thigh and place it upon the electrodes. Stimulate, and note whether the gastrocnemius contracts.

What is the explanation of this ?

iii. The Excitation of the Nerve may be measured by the Extent of Contraction of the Muscle to which it goes.

Study the records of the experiments, p. 21, I., on the influence of Strength of Stimulus.

iv. Is a Neuron stimulated throughout its whole Extent at once, or does the Change pass along it ?

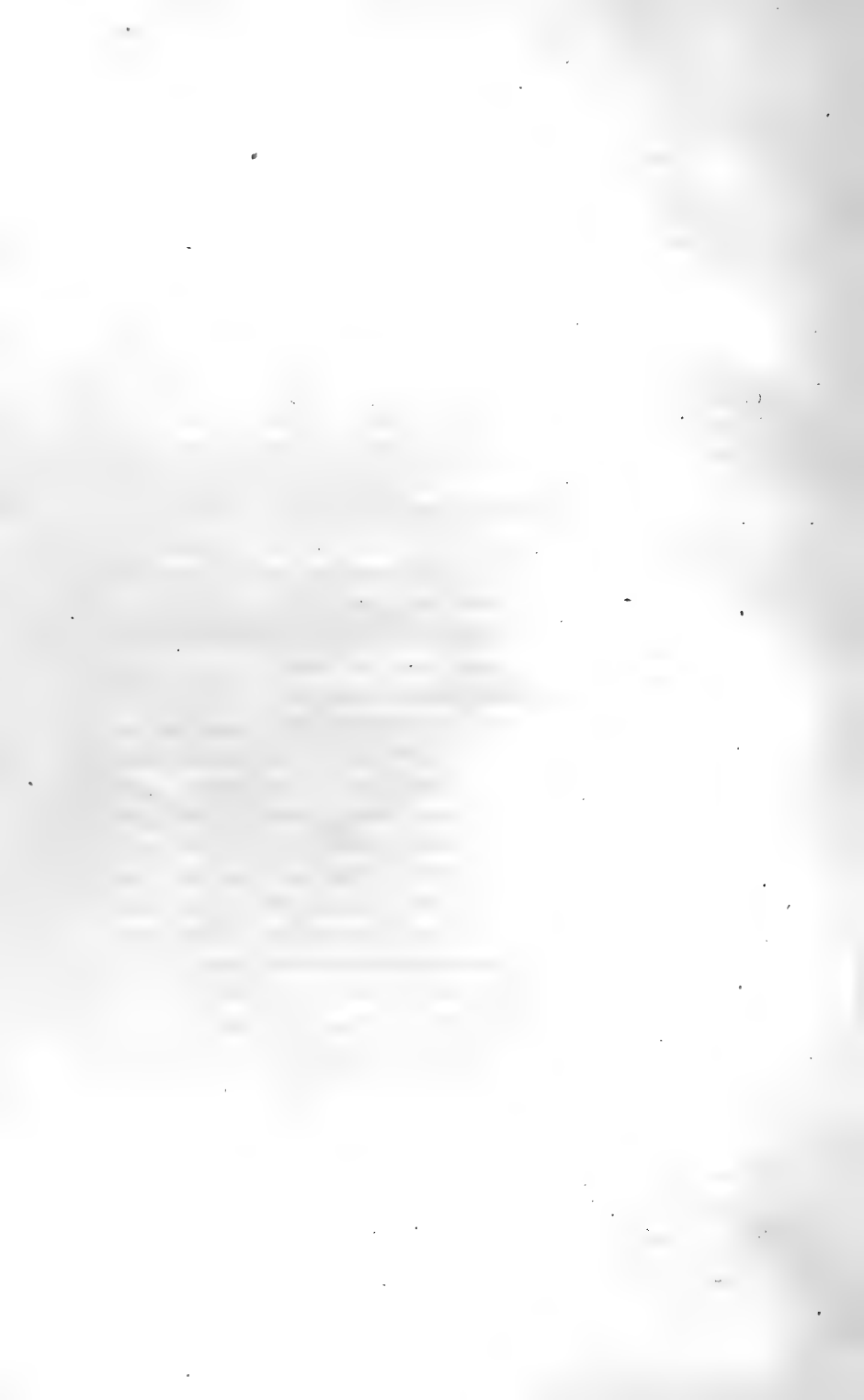
METHOD.—Place a commutator *with the cross wires removed* in the secondary circuit of an induction coil, and connect a pair of pin electrodes with each pair of the terminals, so that, by moving the bridge, the current may be sent into one or other of the pairs of electrodes. Connect the muscle of the preparation with a crank lever (p. 21), and place the electrodes upon the nerve—one pair near to and one pair *as far as possible* from the muscle. Bring the lever against a *very fast drum*, and take a separate tracing of the muscle twitch with the nerve stimulated through each pair of electrodes. Finally, put a time tracing of $\frac{1}{100}$ of a second on the drum and measure the length of nerve between the two electrodes.

Calculate the rate of passage in metres per second.

II. Reflex Action.

1. Phenomena of Reflex Action.

METHOD.—1. Arrange an induction coil with Neef's hammer. Have a basin of water beside you. 2. Decapitate a frog, but



don't pith it. Leave it for 5 minutes. 3. Hang the frog to the edge of the frogboard, fixing it by a pin through the jaw. Pinch the toes of one foot and observe and record what happens.

A. *Are reflex movements co-ordinated?* Apply a *very small* scrap of blotting paper dipped in acetic acid to the flank of the animal. Study and describe the movements.

Having washed off the acetic acid, study—

B. *The relationship of the reflex response to the stimulus?* Pinch the foot with forceps and study the result as regards—

1. Movements which result. (Describe.)
2. Relation of these movements to the strength of the stimulus. Vary the strength of the pinch, or, stimulating with the induced current (Neef's hammer), vary its strength.
3. Duration of the movements. How long are the movements maintained with different strengths of stimulus?
4. Spread of the movements. Study the order of this.

C. *What is the effect of a series of subminimal stimuli in liberating a reflex action?*

Fit up the apparatus as on p. 26, 2, and stimulate the foot, striking the pins lightly into the skin of the foot, with—

1. Single subminimal stimuli.
2. A series of subminimal stimuli.

CONCLUSION ?

2.—A. Is Time taken up in Reflex Action ?

METHOD.—Using the same frog, dip the foot first into the weak acid supplied, and, after washing in the vessel of water, into the stronger acid. Record the difference in the time of onset of the reflex action.

3. Is Reflex Action dependent on the Spinal Cord ?

Now destroy the spinal cord and observe the effect on reflex action. CONCLUSION ?



4. The Knee-jerk.

One student sits with the right leg crossed on the left, closes his eyes and firmly clasps his hands together. Another student strikes the ligamentum patellæ of the right leg with the edge of the ear-piece of a simple stethoscope or with the side of the hand, and observes the contraction of the quadriceps extensor femoris and the movement of the leg.

III. What Time is taken in Nerve Actions when the Brain is involved? (Visual Stimuli.)

METHOD.—Connect in one circuit, through the terminals marked *F*, two mercury keys, *A* and *B*, separated by a considerable length of wire, connected with a time-marker *C*, so that when both keys are closed the current passes and the lever on the marker is depressed. Bring the lever of the marker *C* lightly against the smoked surface of a rapidly revolving drum. One student stands beside the drum and lever watching this lever, holding the handle of the closed mercury key, *A*, which he must open the moment he sees the lever depressed. The other now closes the other mercury key, *B*, in such a way that the subject can neither see nor hear the closing. The lever is thus suddenly depressed. It is released again when the first student opens *A*, when the point of the lever will spring up. A time tracing in $\frac{1}{100}$ sec. is put below the record thus obtained. The tracing is fixed, and the interval between the application of the stimulus and the resulting action is measured and recorded.

IV. What is the Result of Continuance of Reflex Action? Fatigue of the Neuro-muscular Mechanism.

METHOD.—Fit the hand and arm in a Mosso's ergograph to the hook of which a weight of 3 kilograms has been attached. Bring the writing point against a *very* slowly moving drum. Set a metronome beating about 60 times per minute, and as each beat is heard raise and lower the weight with the finger to the fullest extent as long as it is



possible to move the weight, then study the record of the onset of fatigue upon the drum. Compare your record with those of others.

The trace upon the drum must not be looked at during the experiment.

V. RECEPTOR MECHANISMS—THE SENSES.

How do different External Conditions act upon the Body ?

Sensations, changes in the condition of consciousness, are largely used in the study of these questions, and the precautions required for such psychological methods must be observed. The element of expectancy is apt to interfere with the reliability of the observations.

I. CONTACT WITH GROSS MATTER. TOUCH.

With the eyes shut, touch any object, *e.g.* the table, and try to formulate all that you can learn about it through the sense of touch.

Hardness or softness—how determined ?

Roughness or smoothness—how determined ?

Temperature—how determined ?

I. Is Contact felt equally all over the Surface ?

METHOD.—(1) Fit two or three brush bristles of different strengths into split wooden matches. One student now lays his hand on the table, palm downwards, and closes his eyes. The other touches various points close together over a small part of the back of the hand, about $\frac{1}{2}$ inch square, and the student experimented upon says whether he feels the contact or not. The points on which contacts are most clearly felt are mapped out (Pressure Spots). By more firm pressure Pain Spots may also be discovered and mapped.

(2) Holding a small fragment of soft cotton wool in the hand, pass it lightly over different areas of skin, and note the sensation produced, and whether all parts are equally sensitive.



II. What Differences of Pressure can be distinguished ?

METHOD.—One student lays his hand on the table, palm upwards. He keeps his eyes closed while another student applies to the palmar aspect of the proximal phalanx of the middle finger the different weights supplied. The weights must be applied to the same place in the same way each time, and at as nearly as possible equal intervals of time. They must be left on for the same time. As each weight is applied the subject of the experiment says, “the same,” unless he is *sure* that there is a difference, in which case he says “heavier” or “lighter.”

Recording the result of each observation, the experimenter then calculates and records the smallest percentage difference of weight which can be appreciated with certainty.

III. Can Points of Contact be discriminated equally well at different Parts of the Surface ?

METHOD.—This may be determined by finding how near to one another two contacts may be made and felt as two and not simply as one contact.

One student closes his eyes and lays his hand, palm downwards, on the table. The experimenter then takes a pair of compasses, and, holding them loosely in the hand with the points somewhat separated from one another, he lightly brings either one point or the two points simultaneously down upon the back of the subject's hand. The subject must say “one” unless he is *certain* that he feels two points of contact. Working in this way, and recording the result of each observation as to the distance of the points and the resulting sensation, the experimenter determines and records how far the points must be apart on the back of the hand to give rise with certainty to a double sensation.

The observation is next to be repeated on the palmar aspect of the terminal phalanx of the forefinger.

IV. Can Contacts be distinguished however rapidly they follow one another ?

METHOD.—Place the finger upon the toothed wheel first when it is rotating slowly and then when it is rotating rapidly,



and note in each case if a *series* of sensations or a continuous sensation is experienced. The contacts are practically instantaneous. What **CONCLUSIONS** do you draw as to the duration of the sensations ?

II. HOW IS THE TEMPERATURE OF EXTERNAL OBJECTS DETERMINED? TEMPERATURE SENSE.

I. Is the actual Temperature appreciated ?

METHODS.—Take three basins. 1. Fill one with water so warm that the hand can be just comfortably held in it. 2. Fill another with cold water. 3. Fill the third with water at a temperature intermediate between 1 and 2.

Place one hand in 1 and the other in 2, and after keeping them there for a few minutes place both in 3 and record the sensation in each hand. What **CONCLUSION** do you draw as to the precise stimulus of the temperature sense ?

II. What Factors modify the Sensation ?

METHOD.—Bring a piece of metal and a piece of flannel, which have been kept at the room temperature, upon the skin and notice the difference in the sensation produced. What is the explanation ?

III. Is the Power of determining Temperature equally distributed over the Skin ?

METHOD.—With a cold metal point gently touch the back of the hand between the fourth and fifth metacarpal bones, and notice if the sensation of cold is produced by contact everywhere or only at certain spots.

Repeat the experiment with the metal at a higher temperature than the body.

Repeat the experiment on the back of the forearm.
CONCLUSIONS ?

IV. What is the smallest Difference of Temperature which can be appreciated ?

METHOD.—Take two large test-tubes and place a thermometer in each. Half-fill them with water at between 35° and



40° C., making one slightly colder than the other. Now find the smallest difference of temperature which can be appreciated (*a*) with the tubes on the side of the face, (*b*) with the tubes on the back of the forearm.

III. TASTE.

Is the Sensibility to Taste the same all over the Tongue ?

METHOD.—Solutions of

- (1) Sugar,
- (2) Quinine,
- (3) Hydrochloric Acid,
- (4) Common Salt,

are given you. One student rinses out the mouth with water, and another applies, with a camel's-hair brush, one or other of the solutions to some part of the tongue and notes the sensation which is said to be produced. The mouth is again rinsed and the process repeated, and thus the various parts of the tongue are investigated for their sensibility to the different substances. The results should be recorded as a diagram.

Cocaine may be painted upon the tongue and the tactile and gustatory responses studied.

IV. VISION.

A. Structure.

I. Ox Eye out of Formalin.

Examine the eye. Identify the cornea and sclerotic, and notice the entrance of the optic nerve to the inner side of the posterior axis. Note the shape of the pupil. Now divide the eye into an anterior and a posterior half by cutting through the equator of the sclerotic with a sharp razor.

Note the gelatinous vitreous humour in the posterior chamber. Note the black-coloured choroid coat inside the sclerotic. In the anterior segment note that the capsule of the



vitreous (hyaloid membrane) is firmly attached to the front of the choroid and that it holds the lens in a capsule behind the pupil. Strip the hyaloid membrane and the lens in its capsule from the choroid, and observe how firmly attached it is to a series of ridge-like thickenings of the choroid just behind the junction of the cornea and sclerotic—the ciliary processes. Examine these processes. Note that the iris is continued forward from them to the edge of the pupil.

Shell the crystalline lens out of its capsule. Study its shape and note its elastic character.

Observe the aqueous humour in front of the lens and behind the cornea, filling the anterior chamber.

Now make a section through the cornea and sclerotic at right angles to the last cut. Study and draw the cornea-sclerotic junction.

In the posterior segment of the eye note the entrance of the optic nerve, and observe the thin membrane-like retina spread over the choroid. Note the iridescence in front of the choroid in the eye of the ox. Observe the blood vessels entering in the optic nerve and spreading over the front of the retina. (In the eye of the ox there is no special development of a macula lutea in the posterior optic axis.) Make drawings of the various structures seen.

Revise the histology of the different structures.

II. Examination of the Eye in Life.

Ophthalmoscope.

Make a model eye by unscrewing the lower lens of a microscope eyepiece and placing inside it a piece of paper with some mark upon it. Look through the upper lens, and observe that the chamber is dark and the paper is not distinctly seen.

Direct Method.—In the optical room fix the model eye in the holder, and bring the electric light beside it so that it does not shine on the front of the model. Using the mirror with a hole in the centre, reflect light into the model eye, and look into it through the hole. Begin at a distance of two feet from the eye, and approach it keeping the light reflected



into it.. Gradually the mark on the paper becomes distinctly visible. Is it erect or inverted? (*The observer's eye must be kept accommodated for distant vision.*)

Indirect Method.—With the mirror about three feet from the model eye reflect the light into it. Now insert a biconvex lens at about 4 or 5 inches in front of the model, and try to see the image of the mark on the paper. Is it erect or inverted?

The human eye may be examined in the same way.

B. Vision with One Eye.

I. The Focussing Mechanism.

I. The Formation of Images in the Retina.

METHODS.—A. Study the formation of images on an obscure glass screen behind a lens as to—

1. Where an object held above is focussed on the screen and where an object on the right is focussed. Is the image erect or inverted?

2. Can a near object and a far object be focussed at the same time?

3. What is the relationship of the size of the image to the distance of the object?

Revise your knowledge of the optical properties of a convex lens.

B. Examine the image of a candle formed on an obscure glass plate placed over a hole cut in the back of a *fresh* eye of an ox.

II. At what Surfaces of the Eye are the Rays of Light refracted?

Note the formation of a reflected image from each of the two refracting surfaces of a biconvex lens. Study, (1) how the size of the image varies with the curvature of the lens, (2) the position, erect or inverted, of the image from each surface of the lens, and (3) the direction in which it moves when the object is moved.

METHOD.—*Sanson's Images.* In a dark room hold a candle to the outer side of the eye of a fellow student, and

notice that three reflected images are to be seen—one large, clear, distinct, erect image from the anterior surface of the cornea, one small distinct inverted image from the posterior surface of the lens, and one much less distinct erect image, larger than the first and apparently lying almost behind it and seen best from the side away from the light, from the anterior surface of the lens. From the size of these images draw conclusions as to the relative curvatures of the different surfaces.

Why is no image formed from the posterior surface of the cornea?

From the results of these observations, make a diagram of the Physiological Lens of the Eye.

III. Can Near and Far Objects be seen at the same Time?

METHODS.—A. Close one eye and fix the other on the far corner of the room, and then hold up a pencil at about a foot from the eye and see if *at the same time* both objects can be distinctly seen. Another student should note any change in the pupil when the eye is directed to the pencil.

B. *Scheiner's Experiment.* Make two holes in a horizontal line in a sheet of paper so near that they both fall within the diameter of the pupil. Now stand at about two or three yards from a wall on which a small vertical line is drawn and look at it through the holes. While keeping the eye fixed on the line, bring a needle vertically in front of the holes at about eight inches from the eye, and note the appearance of the needle when the distant line is looked at, and of the line when the needle is looked at.

Make a diagram of the experiment and formulate the conclusions to be drawn.

IV. Is the Power of Focussing Limited or Unlimited?

METHOD.—Bring a pencil point held vertically nearer and nearer to the eye; a point is reached within which it cannot be distinctly seen—the **near point**. Measure the distance of this from the eye and record it.



V. What Change takes place in the Eye in Near Vision ?

METHOD.—Repeat the experiment on the refracting surfaces of the eye (p. 35, II.), when the observed eye is looking at a distant and at a near object.

Examine again, using a Phacoscope as demonstrated.
Make a diagram of the results arrived at.

II. Action of the Retina and Brain.

I. Are Visual Sensations produced by Light only ?

Press upon the eye-ball far back, and note the effect of such mechanical pressure on the retina.

II. Is the whole Retina stimulated by Light ?

METHODS.—1. *Mariotte's Experiment*. Make two marks horizontally about 4 inches apart upon a piece of plain paper.

With the left eye closed, *fix* the right eye on the left-hand mark with the head about 18 inches from the paper.

Are both marks visible ? Does any change take place as the paper is gradually brought towards the face ?

Make a diagram of the results of the experiment.

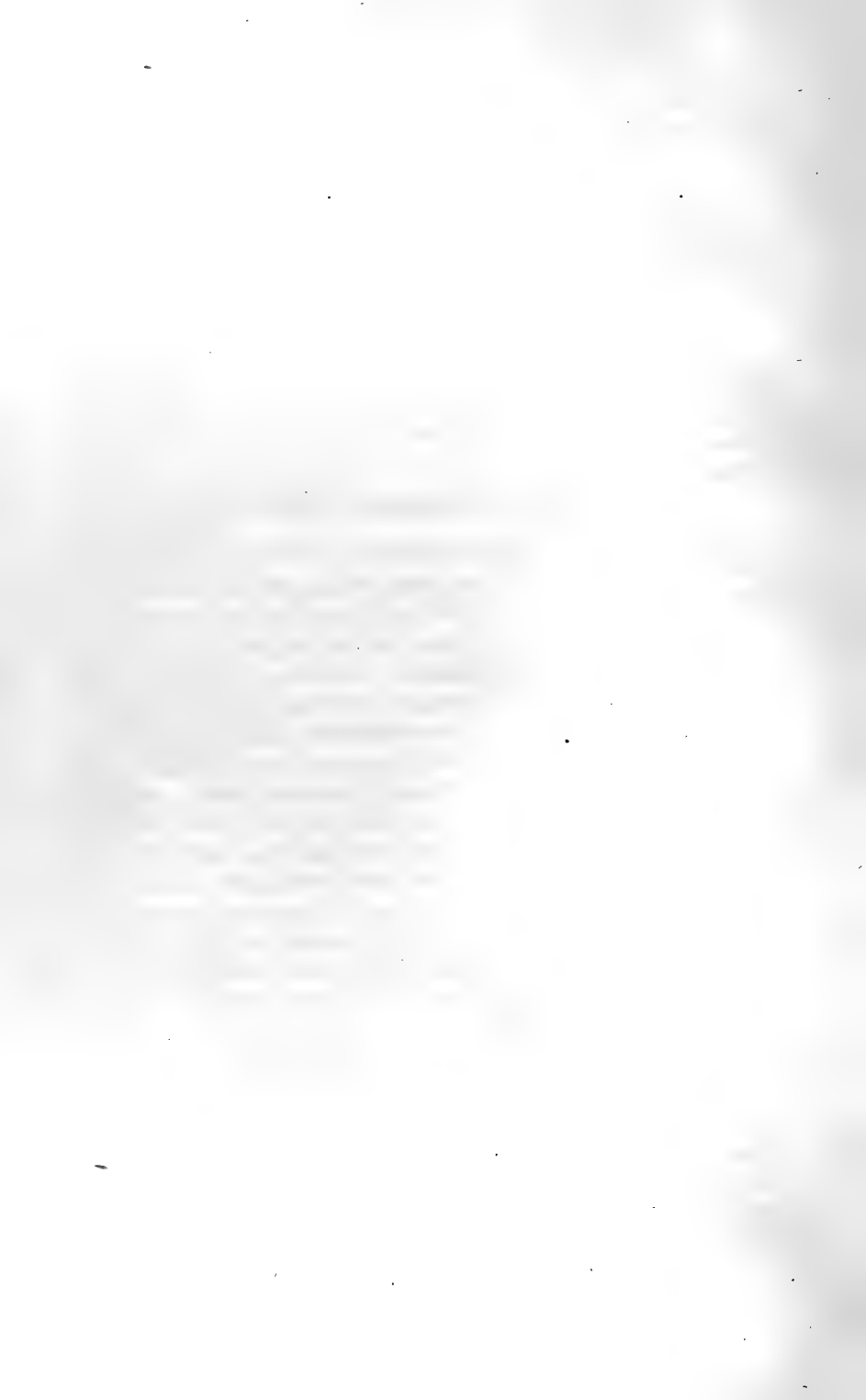
2. Make a mark on the left side of a piece of plain paper. Holding the head firmly fixed at about a foot from the paper and closing the left eye, keep the right eye *fixed* upon the mark, and move the point of a pencil, held nearly horizontally, slowly towards the right side of the paper. Note any change in the appearance of the point of the pencil you may observe.

Make a diagram of the experiment. CONCLUSIONS ?

3. Map out the blind spot by moving the point of the pencil from the part of the paper where it is invisible to where it becomes visible. Mark the limits of the invisible area in all directions from its centre.

III. What Layer of the Retina is acted upon by Light ?

METHOD.—*Purkinje's Images*. In a dark room stand side on against a uniformly coloured wall, with the eyes turned towards the wall. By means of a lens another student



directs a powerful ray of light through the exposed sclerotic coat of the eye, and, on moving the light up and down, and from side to side, any appearance on the wall is noted. The lines seen are shadows of the retinal blood vessels. Revise your knowledge of the distribution of the blood vessels of the retina. CONCLUSION? Is it the front layer of retina or a back layer which is acted upon by light?

IV. Is the Power of Localising the Source of Light equally developed all over the Retina?

METHOD.—Prepare an experiment as on p. 37, II. 2, but instead of a pencil take a pair of compasses. Bring the points close together, and place the points on the central mark, and note whether both can be seen. Now, keeping the eye fixed on the central mark, draw them along the paper away from the central mark, and note when two points can no longer be distinguished. Separate them till they are again seen as two and draw them still further out, and note what happens. Record the result on a diagram and formulate your conclusions.

**V. What Range of Objects can be seen at one Time?
The Field of Vision.**

METHOD.—A. *Black and White.* Describe a semicircle on a blackboard with the free ends of the line finishing at one side. Mark the centre of the circle at the edge of the board and the middle point in the circumference with an X. This forms a rough "Perimeter."

Keeping one eye closed, the observer places his other eye at the centre and directs it steadily towards the middle point in the circumference. A fellow student slowly draws a piece of chalk along the circumference from below. The observer notes when it becomes visible, and the other marks this point.

Now, starting from above, the experimenter again draws the chalk along the circumference until it becomes visible, and marks the point where it comes into view. The angle thus formed with the centre of the circle and these points subtends the vertical field of vision. Measure this angle and record it.



Now turn the blackboard into the horizontal plane, or use the top of the table, and map out the horizontal field of vision.

B. Colours. Using coloured papers, map out the field of vision for the different colours, red, green, blue and yellow, noting the points at which *the colour* becomes clearly distinguishable. Measure and record the angles. Draw a section of the eye and mark upon it the parts of the retina which react to black and white, red, green, yellow and blue.

Repeat these observations using a Perimeter.

VI. How are Colours perceived ?

Revise your knowledge of the physical nature of colour. Study the spectrum produced by a prism.

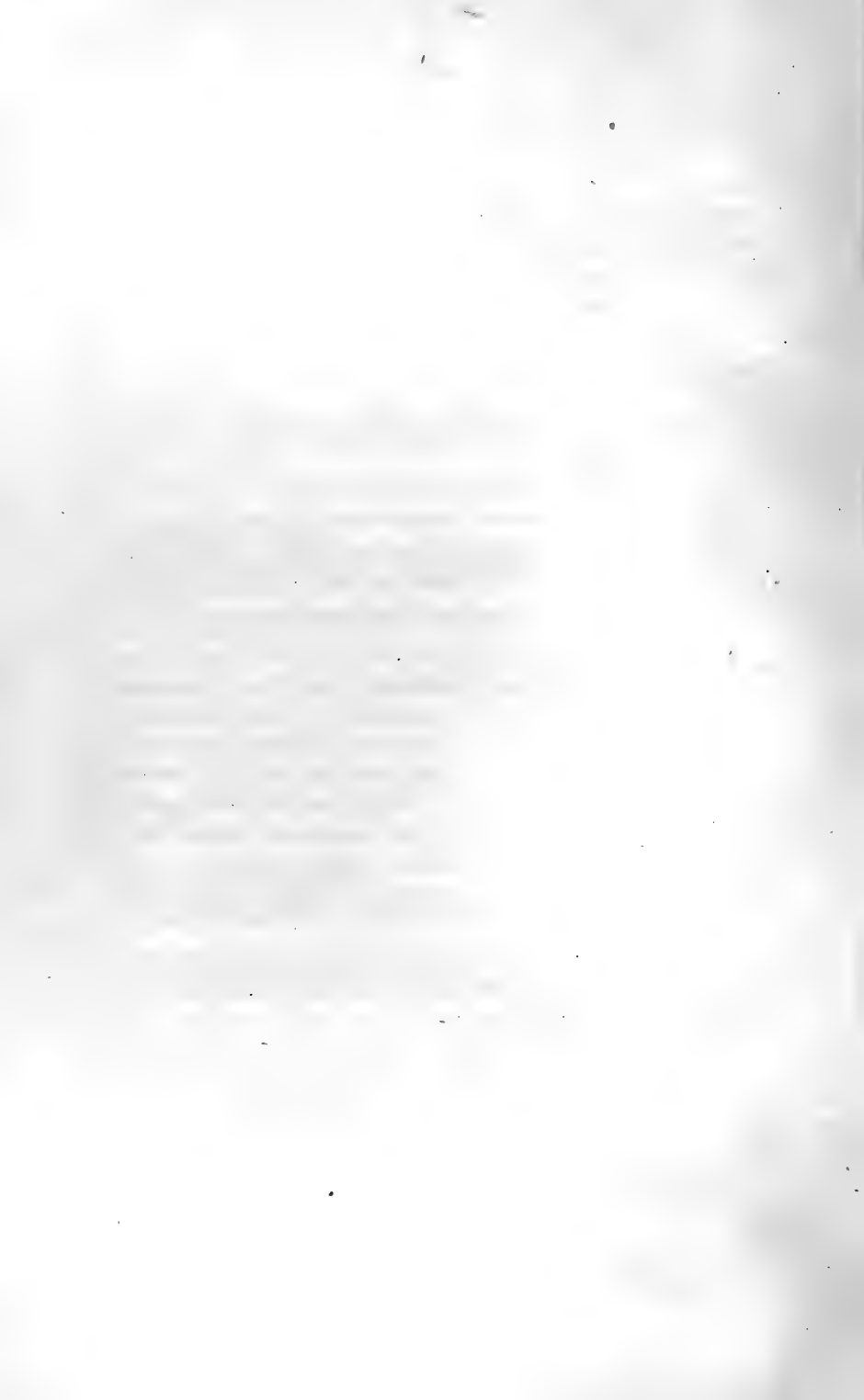
1. How are the various Colours in Nature produced ?

1. METHODS.—Fix a disc of pure spectral colour, *e.g.* red, on the rotating wheel in a good light, and after rotating the disc and observing it, introduce, by means of the slit, (*a*) a segment of white, rotate and observe ; (*b*) a segment of black, rotate and observe ; (*c*) a large segment of bluey green, rotate and observe. Record your results, and draw conclusions as to the effect upon the colour sensation of mixing a spectral colour with (*a*) white (diluting it), (*b*) black (decreasing the illumination), and (*c*) another part of the spectrum.

2. Are Colour Sensations produced only by Ethereal Vibrations of different Lengths ?

METHODS.—(1) Insert the tip of the little finger into the external angle of the eye, getting it as far back as possible and turning the eye inwards. Now press, and notice if any colour sensation is produced.

(2) Make a white cardboard disc with one half blackened, and draw lines as shown in the disc provided. Put a needle through the centre and rotate it as rapidly as possible in a good light, and notice the effect produced. **CONCLUSION ?**



3. What is the Effect of prolonged Stimulation of the Eye with any one Part of the Spectrum ?

METHOD.—Put a disc of red paper upon a white ground in a strong light. Look steadily at it for half a minute, then remove it and continue to look at the white surface, and note what happens. Repeat this with discs of different colours.

The colour which appears is said to be complementary to the first.

4. What is the Effect of combining these Complementary Colours ?

METHOD.—On a black surface place two discs of complementary colours. Between them place vertically a sheet of glass. Now tilt the glass towards one of the discs, and on looking through it the image of the disc is thrown on the other disc. Note the colour change produced.

5. Is the Power of appreciating Colour equal all over the Retina ?

Study the result recorded on p. 39, B, and draw your conclusions.

6. Can all Individuals distinguish Colours equally well ?

METHODS.—Take a set of Holmgren's wools. Give a student a red wool and let him pick out all that are of the same sort of colour. Find if any member of the class is colour blind.

VII. Effects of Strong or Prolonged Stimulation ?

METHODS.—(a) After keeping the eyes closed for two minutes look steadily at a white mark on a black surface for a few seconds and then close the eyes.

Describe the image that appears and also any change in its intensity as time passes—Positive After Image.

(b) Look steadily at the same mark for three minutes and then close the eyes.



Describe the image as above—Negative After Image.

(c) *Colour*. Using the coloured squares supplied study the after images as in (a) and (b).

VIII. How far does our Visual Perception give us a true Knowledge of our Surroundings ?

Modified Visual Perceptions.

METHODS.—1. Two squares of equal size are fixed upon paper : one is white placed upon a black ground, and one black placed upon a white ground. Which appears larger, and why ?

2. Place three equidistant dots in a straight line on a piece of paper and subdivide one division by a series of dots. Which part appears longer, and why ?

3. (a) A red square is placed on a white ground and another on a green ground. Which appears redder in colour ?

(b) A red paper is placed on the table with a grey one a foot away on one side and a green one a similar distance away on the other.

Does the red appear redder after looking at the grey or at the green sheet ?

4. Rule a square with parallel diagonal lines, and place short vertical and horizontal lines upon the alternate diagonals. Do the latter now appear parallel ? If not, why not ?

From these experiments draw your CONCLUSIONS as to the necessary accuracy of the knowledge gained by vision.

C. Vision with Two Eyes.

I. What are the Advantages ?

1. Extent of Field of Vision.

With the perimeter investigate the field of vision in the horizontal plane first for the right eye, then for the left eye,



and then for the two eyes together, taking care not to move the head. Make a diagram of the result, and compare the optical angle in vision with one and with two eyes.

2. Estimation of Contour.

(a) Lay a prism edge on to you on the table, look at it first with one then with two eyes, and consider how the idea of relief is arrived at.

(b) With the **Stereoscope** study how the projection of slightly different pictures on the two retinae gives the idea of relief.

3. Estimation of Distance.

Set up a stick vertically at one end of the laboratory, and with one eye closed walk up to it quickly and, without hesitating, try to touch it with the outstretched finger. Repeat this experiment with both eyes open, and note any difference of result. What conclusion do you draw from this ?

II. Why is there normally **Single Vision with Two Eyes** ?

I. Is **Single Vision** possible if the **Eyes** do not move together ?

METHODS.—1. With the tip of the finger fix one eye in its socket and move the head about, looking at external objects, and notice whether they remain single.

2. Looking straight forward, press with a finger upon one eye to alter its direction, and note the effect upon vision.

CONCLUSION ?

Study the anatomy of the eye in the socket and the action of various muscles which move it. Note that they act round **three axes** of rotation. Now get an orange and take the pip to represent the pupil. Thrust a knitting needle through each of the **three axes** of rotation and study the influence of each



of the three pairs of muscles upon the direction of the pip or pupil.

II. Can Double Vision be produced when the Eyes move freely together ?

METHOD.—Set up a stick vertically about 3 feet from the eyes, and another at about 10 feet. Look at the near one and see what happens to the image of the far one. Close one eye and observe what happens. Now look at the far one and notice the image of the near, and again close one eye. Make a diagram of the experiment, and explain the result.

V. HEARING.

Revise your knowledge of the physics of sound vibrations.

I: What Qualities of Sounds are perceived ?

1. Loudness.

2. Pitch. Is the perception of pitch limited ? Using tuning forks for the lower limit and the steel cylinders supplied for the upper limit, determine the range of perception of musical sounds.

3. Quality. (a) Sound the tuning fork Ut_4 strongly, and note the character of the resulting sensation.

(b) Repeat the experiment, and immediately after sounding the fundamental tone, sound the three partials *me*, *soh* and *doh* above, and note the character of the resulting sensation.

Formulate your conclusions as to the influence of overtones upon the quality of musical tones.

II. Do Sound Vibrations influence the Internal Ear only through the External ?

METHODS.—Sound a tuning fork lightly, and hold it to the ear until the sound has quite died away. Now place the end of the fork against the closed teeth. Describe the resulting sensation. What **CONCLUSION** do you draw ?



III. Is the Power of localising the Source of Sound well developed ?

Test the power of localisation by making a faint clicking noise—as by closing sharply a pair of forceps—in the neighbourhood of the head of the subject whose eyes are closed. The latter must make a definite statement as to where the sound comes from.

VI. HAVE WE THE POWER OF DETERMINING THE POSITION AND MOVEMENTS OF THE VARIOUS PARTS OF OUR BODIES ?

METHODS.—With the eyes closed, (a) put the various parts of the arm, hand and fingers in any position, and try if the position of each part can be determined ; (b) get some one to put the same parts in any position, and again try if the positions can be accurately described.

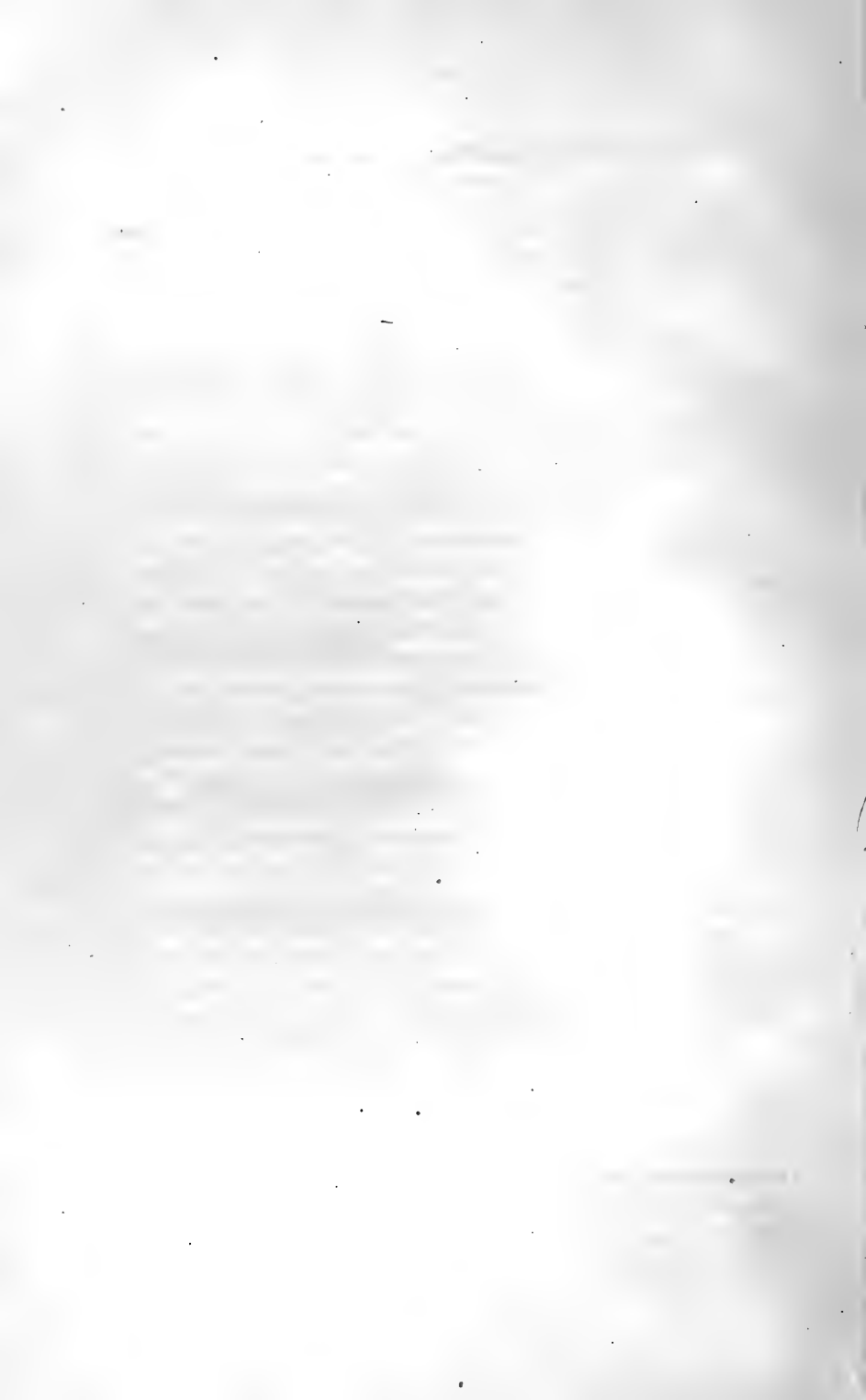
(c) Take a weight in the hand and study how an estimate of the weight held is arrived at. Has the condition of the muscles, tendons, and joints anything to do with it, and if so, what ? This may be called the MUSCLE-JOINT SENSE of weight.

To test this sense find the smallest difference of weight which can be detected, as in Appreciation of Pressure, p. 31, II., but keeping the hand free of the table and using the muscles of the arm.

(d) By passing the hand over some object with the eyes shut, study how this sense, in conjunction with touch, gives information as to the distance, shape and size of external objects.

VII. HAVE WE THE POWER OF DETERMINING THE MOVEMENTS OF THE BODY IN SPACE ?

Consider the absence of sensation of movement in smooth-running trains, and the sensation of movement on starting and stopping.



1. Spin rapidly round several times, stop and observe the sensation produced.

2. Hold a short stick or poker vertically with its point on the ground. Place the forehead on the top and rapidly walk three times round it. Then raising yourself straight, try to walk to the door. Notice the effect produced and try to explain it.

Revise your knowledge of the anatomy of the semicircular canals of the internal ear on the models supplied, and consider how they may act in the above experiments.

VI. CIRCULATION.

A. Heart.

I. Structure.

(Drawings must be made of the various structures.)

1. Use the sheep's heart supplied. Open the right auricle by a horizontal cut. Open the right ventricle by an inverted V incision as demonstrated.

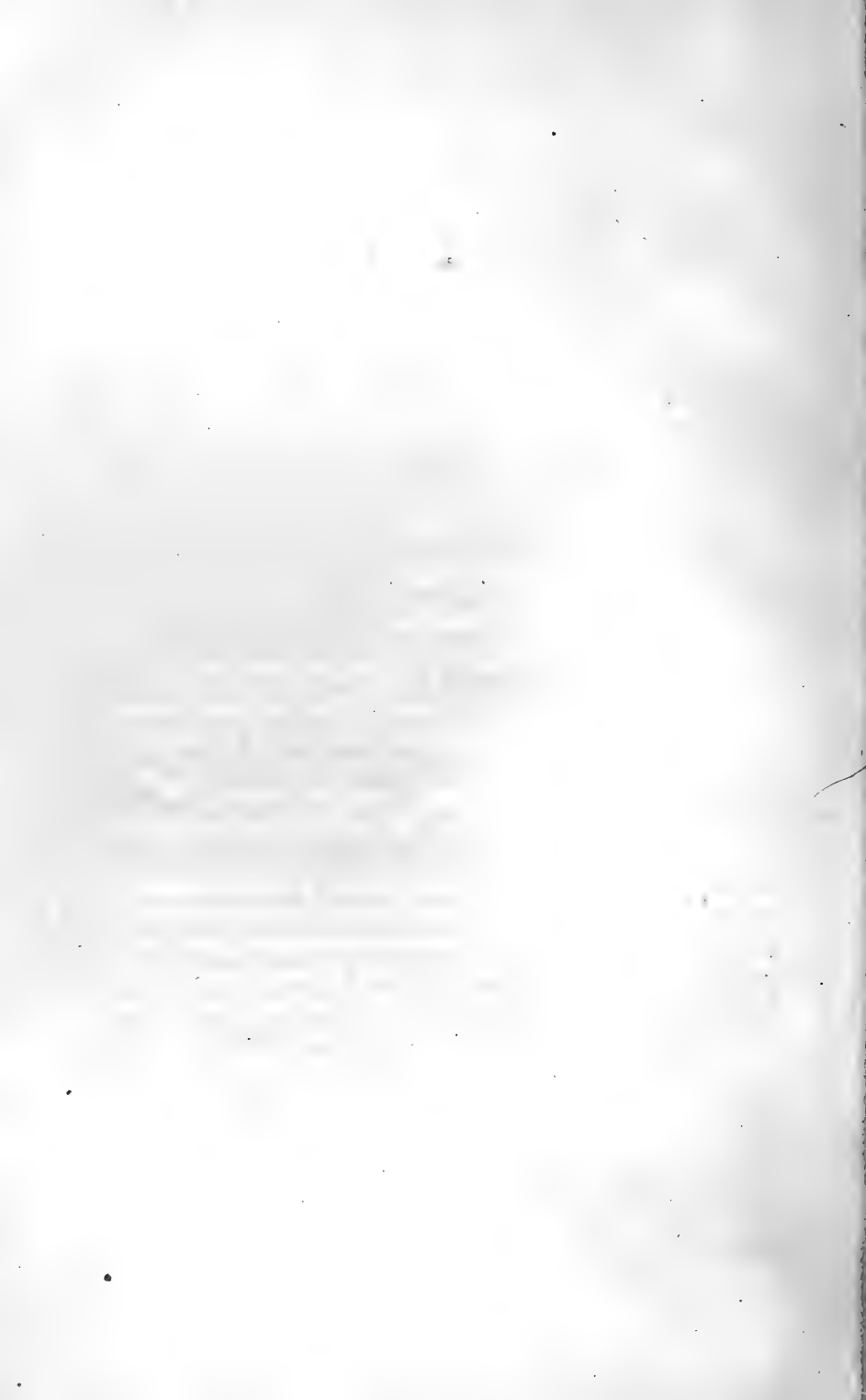
Examine the tricuspid valve and papillary muscles.

Slit up the pulmonary artery and examine the semilunar valves.

Open the left auricle and ventricle by a vertical antero-posterior incision through the left auriculo-ventricular orifice and middle of the aorta, and examine the mitral valve and papillary muscles, the relations of the anterior cusp of the mitral to the posterior aortic wall and the aortic semilunar valves and mouths of the coronary arteries.

On the septum between the ventricles note that a special band of muscular fibres passes from the auricles to the ventricles.

2. On the models of the thoracic organs, study the attachments and relations of the heart to the anterior and posterior chest wall, to the central tendon of the diaphragm and to the lungs.



3. In a boiled sheep's heart, twist off the auricles, aorta and pulmonary artery, and examine the auriculo-ventricular and pulmonary fibrous rings.

Clear off the visceral pericardium of the ventricles and study the course of the muscle fibres.



FIG. 14.—Heart of Frog from behind.

- | | |
|---------------|-----------------|
| 1. Ventricle. | 4. Sinus. |
| 2. Auricle. | 5. Great Veins. |
| 3. Crescent. | 6. Aorta. |

4. In the longitudinal section of the heart given in the Histology Class, study the various parts under a low power.

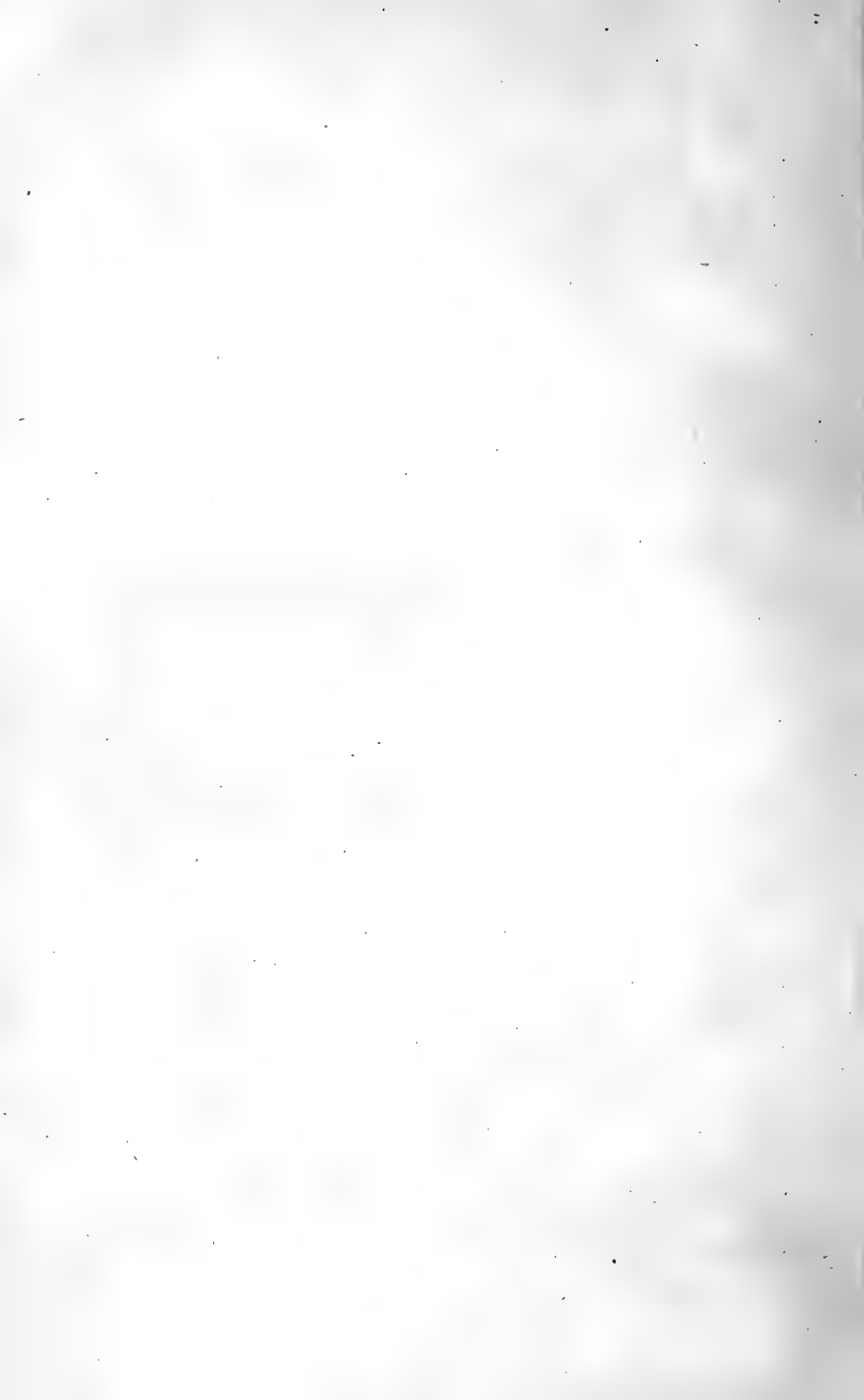
5. Dissect the heart of a dead frog. Identify the sinus, auricles, ventricle and bulbus arteriosus (fig. 14). Thrust a small test-tube down the gullet to stretch it, and dissect out the vagus nerve and follow its cardiac branch down to the heart.

II. Mode of Action of the Heart.

THE CARDIAC CYCLE.

1. *Study the exposed heart in the frog.* Pith a frog and pin it out on its back on a cork plate. Open the abdomen by an incision a little to one side of the middle line to avoid the anterior abdominal vein, and carry the incision up to the xyphisternum. Then snip through the shoulder girdle in the *anterior median line*, taking care that the point of the scissors does not injure the heart. Separate widely the two sides of the girdle, pinning each back, and thus expose the heart in the pericardium. Snip through the pericardium and study the auricles, ventricle and bulbus as seen from the front.

Study and describe the changes in shape which each part undergoes—the relative duration of each change in each part



and the sequence of events in the different parts—and record your observations. Time and note the number of contractions of the ventricle in one minute.

Now take the tip of the ventricle in the forceps and lift it up and observe a fold of pericardium, the fraenum, which is attached to it behind. Tilt the hind part of the frog up and carefully snip this through, and then turn the ventricle freely forward and study the changes which occur in the sinus venosus, and the relation of these changes to the changes in the other parts of the heart.

2. *Is the heart's action automatic?* Excise the heart *with the sinus attached*, and place it in a watch glass and study its movements, counting the number of beats per minute.

3. *Influence of Temperature.* Now place the watch glass upon ice and observe the effect. When a marked change in the rate has taken place and been recorded, remove the watch glass from the ice and place it upon the palm of the hand and record any change in the rate.

Method of Recording the Cardiac Cycle and of Studying the Nervous Control of the Heart.

1. Connect up the apparatus for giving a series of induced shocks (Neef's hammer), inserting a commutator *without* crossed wires into the secondary circuit with two pairs of electrodes attached.

2. Set a recording drum on the slow gear, and connect to a small driving spindle.

3. Kill a frog and remove the brain *in front of* the tympanic rings by cutting the head across at that level. Then cut the spinal column and cord across between the shoulder blades and pith the lower part, thus leaving the medulla oblongata isolated and intact with the vagi passing from it to the heart.

A. TO RECORD THE CARDIAC CYCLE.

Place the cork plate with the frog directly under the heart lever. Pin the frog firmly on the board by two pins close to the heart, but not through the vagus nerve, and attach the



lever to the *apex* by means of a small clip, *seeing that the thread is vertical* (fig. 15). Adjust the lever (*a*) by its height on the stand, (*b*) by the spiral spring, so that each heart beat causes the largest range of movement. Then bring the glass point of the lever *lightly* against the drum; start the drum at a *very slow rate*, and take a record of several cardiac cycles. Remove the lever and put a time record in tenths of a second under the trace. Fix the tracing.

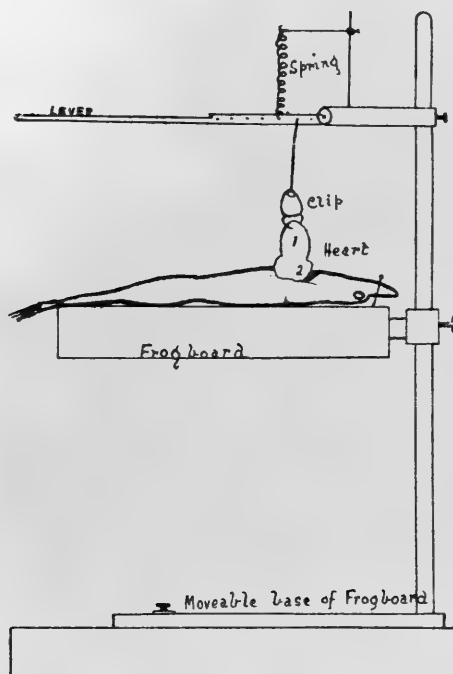


FIG. 15.—Arrangement of Frogboard.

When fixed determine—

- (1) the rate of recurrence of the cardiac cycle, *i.e.* the rate of the heart ;
- (2) the duration of the ventricular systole ;
- (3) the duration of the auricular systole, if this is marked upon the trace.



B. TO STUDY THE NERVE CONTROL OF THE HEART.

1. *Intra-Cardiac Mechanism.* Fix one pair of electrodes from the commutator by means of a pin to the cork so that their points touch the crescent, which may be seen as a white crescentic mark between the sinus and auricles on their *posterior* aspect (fig. 14), and, with the point of the lever swung off the drum by means of the base-piece, stimulate by closing the key in the primary circuit and opening that in the secondary. The current must not be very strong. If no change in the rate of the heart occurs, increase the strength of the current till a change occurs. Don't continue to stimulate after an effect is produced. At once close the key in the secondary. Now swing the lever on and take a tracing. Let the drum run till the rate of the heart is restored.

What CONCLUSION do you draw ?

2. *Extra-Cardiac Mechanism.* Thrust the electrodes connected with the other side of the commutator into the medulla, fixing them on the cork of the frogboard by a pin. Tilt the bridge of the commutator to send the current through them, and with the lever off the drum stimulate and, if necessary, increase the strength of the current till a distinct effect is produced, stopping the stimulation whenever this occurs. Then swing on the lever. Again stimulate and take at race, allowing the drum to run till the rate of the heart is restored.

What CONCLUSION do you draw ?

3. *Effect of Drugs.* Leaving the electrodes in position as in 1 and 2, paint the heart with 0.1 per cent. solution of atropine sulphate. Allow two minutes to elapse and then stimulate (1st) the crescent, (2nd) the medulla. Note any difference from the previous reaction. Take a tracing and formulate your conclusion.

4. *What is the Influence of the Sinus? Stannius Experiment.* By means of a needle, pass a piece of thread under the two aortae, and, turning the ventricle forward, tie a loose loop between the auricles and the sinus

(figs. 16 and 18). When the heart has recorded a few contractions, tie the loop tightly so as to separate the auricles from the sinus. Note and record the result.

C. CHARACTER OF A SINGLE VENTRICULAR CONTRACTION.

After the ventricle has been stopped take a trace on a moderately fast drum (*slow-gear—large spindle to the smallest on the drum*) of the contraction caused by touching the ventricle. The touch will record the moment of stimulation on the drum. Take a time trace in $\frac{1}{10}$ th sec. and measure the duration of the phases.

Again put the drum on very slow speed and tie another loose loop round the whole heart, and tighten it so that it exactly separates the auricles from the ventricle. Record the result. CONCLUSION ?

D. THE EXTERNAL MANIFESTATIONS OF THE CARDIAC CYCLE IN MAN.

1. *The Cardiac Impulse—Cardiograph.* Get ready and study the mode of action of a cardiograph, which should have a long lever on the recording tambour. Find the position of the cardiac impulse on the front of the chest of a fellow student and investigate its characters. Mark its position with an aniline pencil and then apply the cardiograph with the button upon the impulse. Adjust the pressure of the button by means of the screw till the lever gives the largest possible excursion, and take a tracing on a slow-moving drum. This is best done with the subject leaning forward and to the left. The breath may be held for a few seconds. Take a time tracing in seconds. Make an enlarged drawing of a part of the trace and try to explain the various elevations and depressions.

2. *Sounds of the Heart.* With the stethoscope provided, listen over the cardiac impulse and over the middle sternum opposite the second rib. Put a finger on the cardiac impulse and try to time the sounds heard in relationship to this. Note the characters of the sounds.



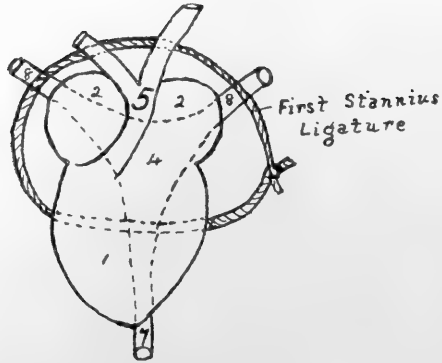


FIG. 16.

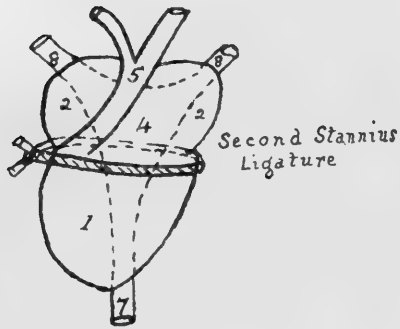


FIG. 17

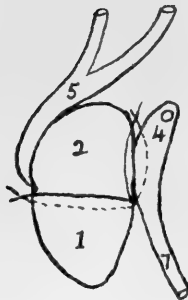


FIG. 18 (side view).

1. Ventricle
2. Auricle.
4. Sinus.

5. Aorta.
7. Inferior Vena Cava.
8. Superior Vena Cava.



3. Do the movements of the heart cause movements of the air in the air passages? *Cardio-pneumatic Movements.*

Fill the mouth, nose and pharynx with tobacco or other smoke. Hold the nostrils. Insert a glass tube drawn to a somewhat fine point into the mouth. Stop breathing and keep the glottis open. Note any movement of the smoke in the tube, and time it with the cardiac impulse. CONCLUSIONS ?

B. Circulation in the Blood Vessels.

I. Blood Pressure.

1. *General Distribution.* Examine the schema of the blood vessels made of elastic tubes given you, and identify the parts representing arteries, capillaries and veins. Attach the arterial end to the water tap, and fix vertically in stands the two glass tubes connected with the arteries and veins respectively. Cautiously turn on the water and measure the pressure in the arteries and in the veins, and calculate it in mm. of mercury. Note the effect of (a) varying the force of inflow by turning off and on the tap, (b) varying the resistance to outflow by constricting the arteriole tubes.

2. *The Arterial Pulse.*

(1) With the finger, compress and relax the arterial tube near the tap at regular rhythmic intervals of about a second, so as to imitate the interrupted inflow of blood from the heart. Note the effect of this upon the arterial and venous pressures, and study the further effect of constricting the arterioles.

(2) Place a finger on the arterial tube and note the expansion, the *pulse*, with each inflow. Study the same thing in the venous tubes. Explain any difference which may be observed.

(3) *Radial Pulse.* Place a finger of the left hand on the radial artery at the right wrist while feeling the cardiac impulse with the right hand, and note what is felt in the artery. Determine whether the change is simultaneous with the cardiac impulse.



(4) Place the finger on the radial artery of a companion and study the pulse as to (a) rate, (b) rhythm, (c) force, (d) size, (e) form of wave.

(5) Does the wave develop simultaneously throughout the arterial system or does it pass out to the periphery? Place one finger over the carotid and another over the radial artery and time the appearance of the wave under each.

(6) Using Dudgeon's or Marey's sphygmograph, under the direction of the demonstrator, take a tracing of the radial pulse. 1. Feel the radial pulse (*note its rate*). 2. Mark the artery with an aniline pencil. 3. See that the pad on the spring of the sphygmograph is over the artery. 4. Strap the instrument on, varying the tightness of the band to give the best range of movement. 5. Vary the tension of the spring by means of the eccentric till the largest range of movement of the lever is secured. 6. Slip the smoked papers under the wheels and under the point of the lever, using a pin to raise the point of the latter if necessary. 7. Now start the clockwork and run off a tracing. 8. Mark upon it the name and age of the subject, the date and the rate of the heart per minute, and fix it. Copy it carefully, and try to explain the various elevations and depressions with reference to the events in the cardiac cycle.

3. *Blood Pressure in Man.* Make an observation of the arterial blood pressure of a companion by the—

Riva Rocci Instrument.

(a) Examine the manometer and see that the cap is removed and that the mercury is at zero.

(b) Enclose the upper arm of the subject in the armlet and, with the arm horizontal and at the level of the heart, place one finger on the radial pulse and raise the pressure in the instrument some 3 cm. above the point at which the pulse disappears. (*Take care not to pull on the tube.*)

(c) Release the pressure gradually and note carefully the exact height of the mercury at the moment when the pulse returns at the wrist. This is the *maximum systolic* pressure.



Repeat the observation, but instead of feeling the pulse listen over the artery above the elbow with a stethoscope, and note the pressure at which a sound is first heard (systolic pressure), and go on slowly releasing till sound disappears (diastolic pressure).

4. *Blood Pressure in Rabbit.*—*Demonstration of the Method of Recording this by the Mercurial Manometer* (Kymograph).

Demonstration of the effects upon the Arterial Pressure and upon Respiration of—

1. Nitrite of Amyl—inhalation.
2. Adrenalin—intravenous injection.
3. Section of one vagus.
4. Stimulation of the lower end of the cut vagus.
5. Section of other vagus.
6. Increase of CO₂ in air breathed.
7. Asphyxia.

II. Flow of Blood.

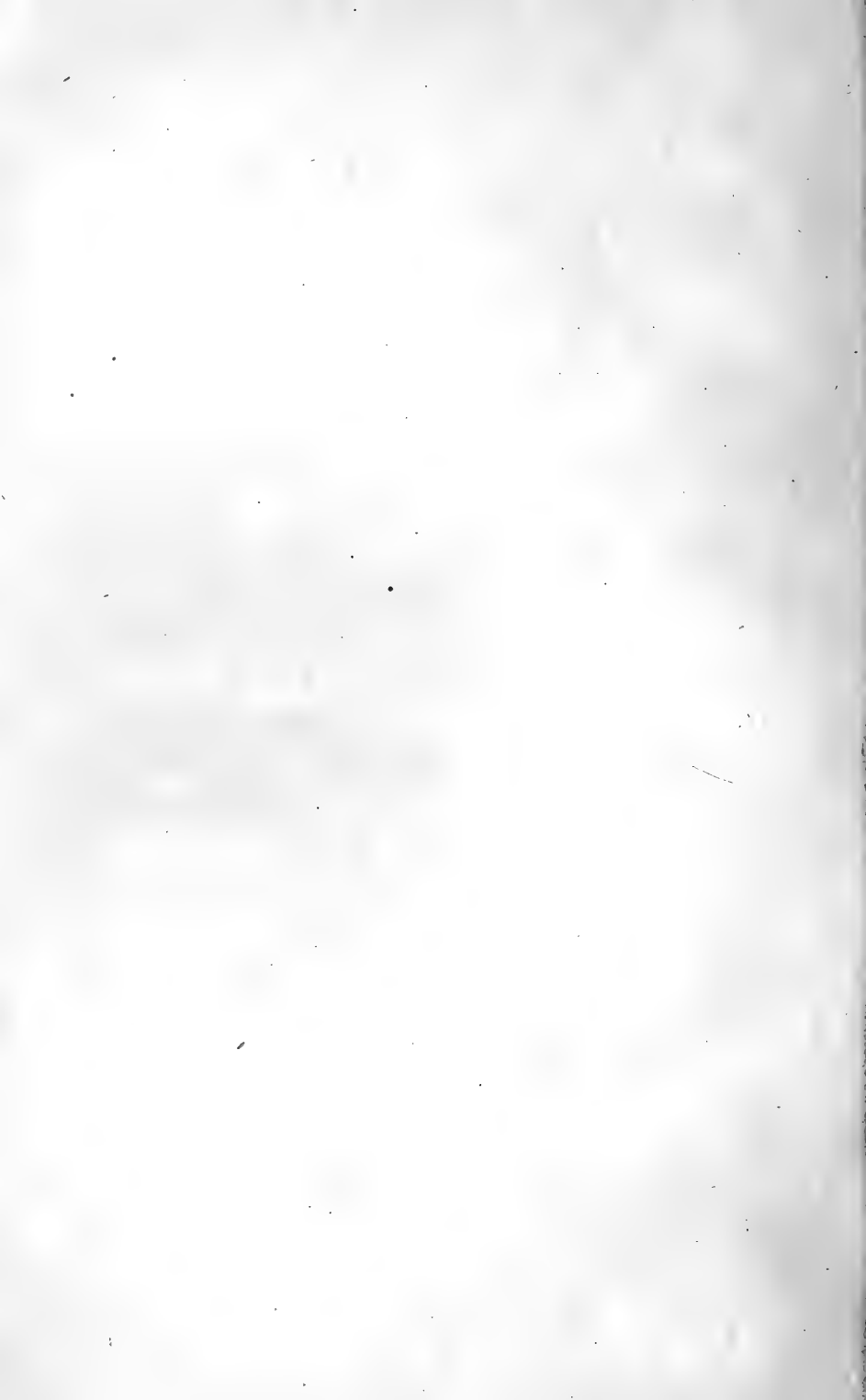
Study the circulation in a frog's foot under the microscope, and by means of an eye-piece micrometer try to measure the rate of blood-flow in the capillaries.

VII. RESPIRATION.

1. **What changes take place in the chest during breathing?**

(a) With a tape, measure the circumference of the chest of a companion in full expiration and in full inspiration and record the result. (b) With the *cyrtometer* provided take a tracing of a section of the chest in expiration and in inspiration and compare them, measuring and recording the diameters.

(c) Now place the middle finger of the left hand flat on the sixth right intercostal space in front of the chest and strike it firmly with the middle finger of the right hand. Do this during expiration and during inspiration, and note any difference in the sound produced. The air-containing lung yields a resonant note, the solid liver yields a dull note. Record your conclusion as to the vertical extent of the lung in expiration and in inspiration.



2. **What sounds are produced during breathing?** With a stethoscope listen (*a*) over the windpipe and (*b*) over the middle of the right side of the chest in the axillary line while the person breathes, and describe the sounds heard at each place, timing their relationship to inspiration and expiration.

3. **What is the rate of respiration?** Count the number of respirations in a person who has been and is sitting still and whose attention is directed to something other than his breathing, and again in the same person after taking violent exercise.

4. **Why do the lungs collapse when the thorax is opened?** Distend the rabbit's lungs given you by blowing into the trachea and then observe their elastic collapse. Measure the force of this with a water manometer.

5. **How to record the movements of respiration.**

(1) To record the movements of the air. Arrange a *very* slowly moving drum. Connect a recording tambour by means of a piece of rubber tubing with a short piece of glass tube. Insert the glass tube into one nostril, and breathe with the mouth closed, recording the movements of the lever. Now put a time record in seconds on the drum and measure the duration of inspiration and of expiration.

(2) To record the movement of the chest wall. Insert in the course of the rubber tube a glass T tube with a clamp. Connect the glass tube with a toy balloon, and place it under the waistcoat or a bandage round the chest, and slightly distend the balloon. Take a tracing.

These records should be taken with the subject sitting still.

6. **What is the influence of CO₂ on the respiration?**

(1) Examine the pulse (p. 53, 4). Record the rate. Run several times up and down stairs to increase the CO₂ in the blood, and again record the respiration from the nostril and examine the pulse, recording the rate.

(2) While taking a trace of normal breathing by means of a tube in the nostril, hold the breath till a marked desire to



breathe again is experienced ; then allow respirations to recur and record one or two. Measure the length of the absence of breathing (*Apnœa*).

Now breathe deeply and forcibly for about two minutes, so as to clear the CO_2 out of the blood, recording the last two or three respirations. Then hold the breath as above, and measure the length of the absence of breathing, and compare it with the last. Another student should observe any change in the appearance of the face, and must examine the pulse.

7. Effect of mental and muscular work on the circulation and respiration.

A. 1. Have ready the apparatus to record the respiration from the nostril of a fellow student.

2. Place the bag of the Riva Rocci apparatus round his arm.

3. The subject holds the other hand out from the side, and the observer determines at what level of the hand the veins disappear while the subject is sitting still.

4. Note the colour of the face.

B. Having recorded the respiration and systolic blood pressure, counted the pulse and measured the height of the hand above the heart at which the veins collapse, make the subject perform 10 minutes' strenuous mental work and again examine and record systolic arterial blood pressure, pulse, venous pressure and respiration, and note the colour of the face.

C. Now make him take strenuous muscular exercise till he is breathless, and repeat all the observations.

Formulate your conclusions as regards the effect of mental work and of muscular work upon—

The rate of the heart.

The systolic arterial pressure.

The venous pressure.

The rate and depth of respiration.

8. Demonstration of the influence of CO_2 , and of various nerves on the breathing of an anaesthetised rabbit.



9. **What changes take place in the air breathed ?**

- (1) Breathe upon a piece of cool clean glass.
- (2) Breathe out repeatedly through the vessel of lime water provided, and note the change produced.
- (3) Breathe out repeatedly through the weak solution of potassium permanganate provided, and note the change produced.
- (4) Light the candle in the bottle provided, and continue to breathe the air of the bottle through the tube attached.

Note your results and conclusions.

10. What changes take place in the blood in passing through the lungs ? (See *Practical Chemical Physiology*, Noël Paton, Cathcart and Burns, p. 20.)

VIII. VOICE.

(*Revise the anatomy of the larynx.*)

Laryngoscope. Fix the mirror of the laryngoscope on the forehead. Gently warm the small mirror on the handle. Place a fellow student in one of the stalls in the dark room with a light beside his head, and let him open his mouth widely. Hold down the tongue in a fold of handkerchief. Reflect light into the mouth by means of the mirror on the forehead, and insert the small mirror through the pillars of the fauces and try to see the upper opening of the larynx reflected in it.

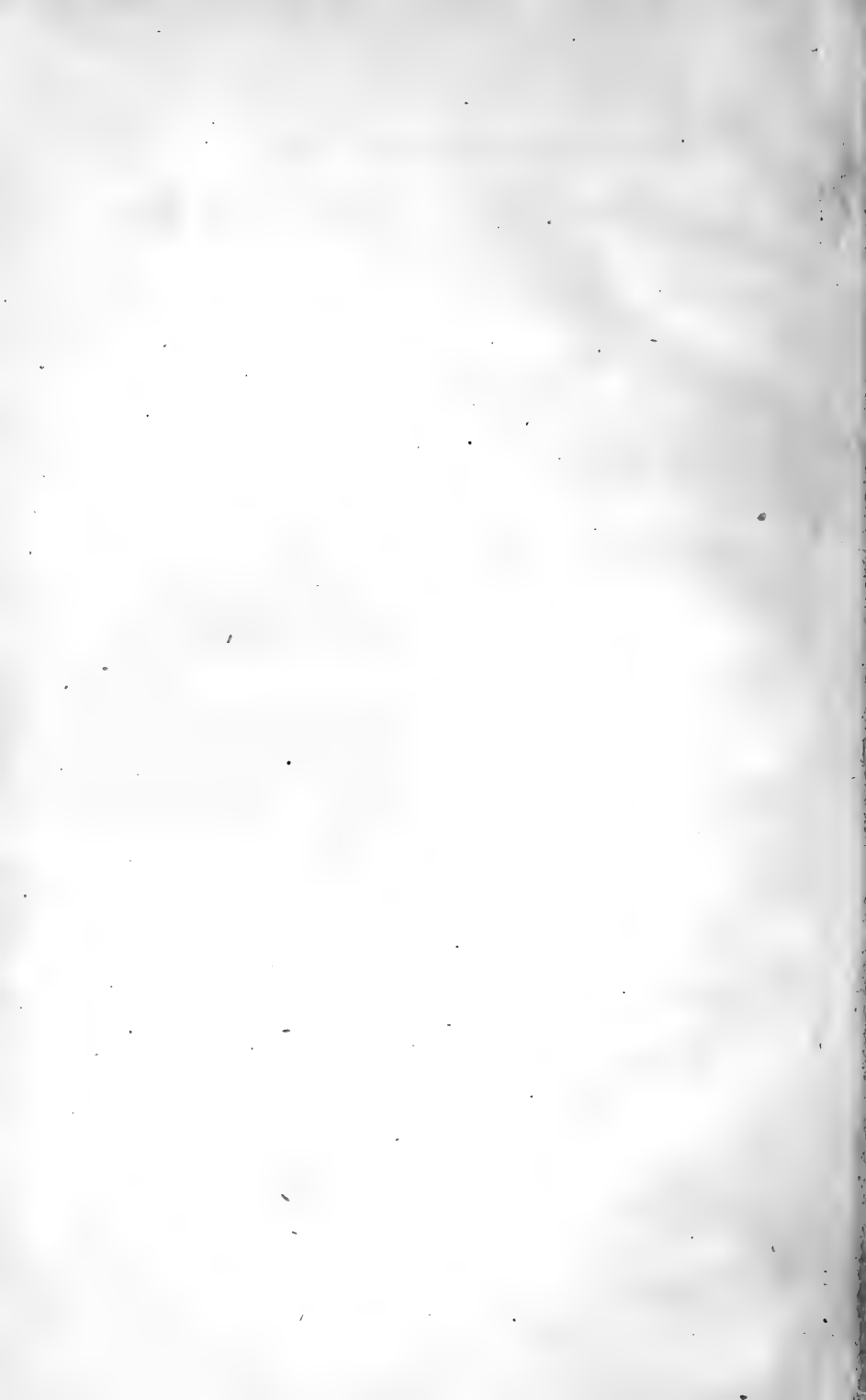
Identify the structures seen, and then make the observed person sound a high note, a low note, and take a deep inspiration.

IX. DIGESTION.

Swallowing.

1. Swallow a mouthful of water or saliva and, with the finger, determine the changes in the position of the tongue, hyoid bone and larynx.

2. Swallow some water coloured with methylene blue, and then examine the posterior aspect of the epiglottis with the laryngoscope.



3. Try to swallow with the mouth empty, and note the result.

4. Paint the pharynx and base of the tongue with 5 per cent. cocaine solution, taking care not to swallow any. Try to swallow.

5. Listen with a stethoscope over the left side of the 10th dorsal vertebra when a large mouthful of water is being swallowed, and note the sounds that are heard. *This and the breath sounds (p. 55) are best heard with the clothes removed.*

6. Try this again after a rapid series of swallows.

Passage of food through the ileo-cæcal valve.

About 4 to 6 hours after breakfast listen for some time with a stethoscope in the right iliac region, and note any sounds observed.

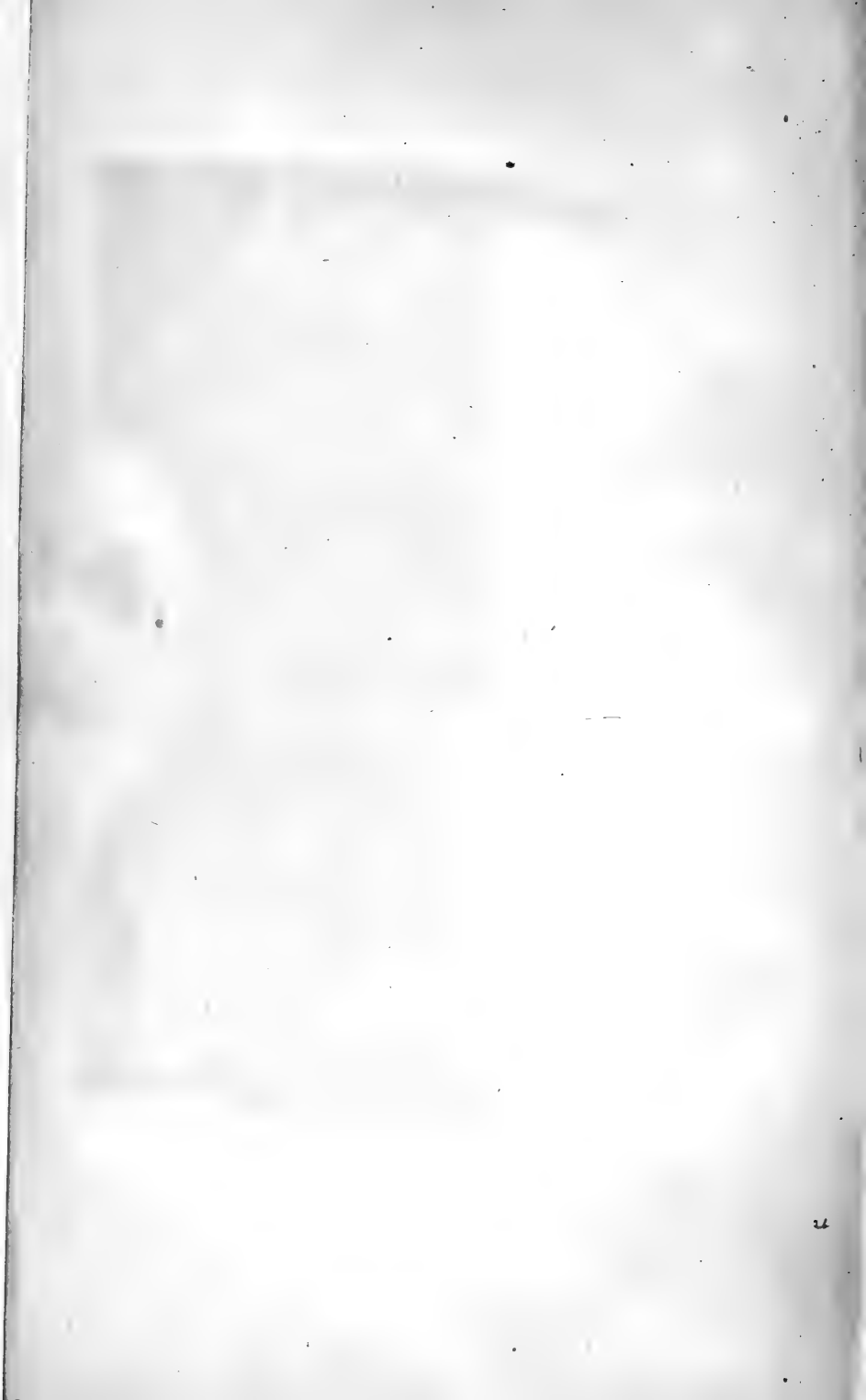
X. TEMPERATURE.

The student should provide himself with a one-minute clinical thermometer.

1. (a) Take the temperature in the axilla and in the mouth, and (b) take the temperature in the mouth night and morning for a week, and record your results on a chart.

2. Take the temperature of (a) the palm of the hand, and (b) the anterior surface of the chest, placing the thermometer under a layer of flannel, and (c) take the temperature between the shirt and waistcoat.

3. Take the temperature in the mouth and axilla after a spell of violent muscular exercise, and repeat the observations at five-minute intervals till it is again normal.



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