with warmest regards. — G. H. C.

A PRACTICAL COURSE

OF

GENERAL PHYSIOLOGY

FOR MEDICAL STUDENTS

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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 to 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, but the results to be obtained and the conclusions to be drawn are left to the student, who must before all be taught 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, and from that result to 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.

D. N. P.
G. H. C.

September, 1908.

PRELIMINARY.

Throughout this Course the student must keep careful records of every experiment he performs. When apparatus is used he must make diagrams of its arrangement, and when tracings are taken these must be fixed and preserved.

Before beginning any 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 how the method adopted will throw light upon the question.

While carrying out the experiment he must not confine his attention 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 *from the results obtained* an attempt must be made to give an answer to the question which is under investigation.

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

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

To learn something of the essential nature of living matter (protoplasm) a very simple form is taken—the yeast plant—and it is placed 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 few drops on the end of the rod to a test-tube containing a solution of urea $CO(NH_2)_2$, glucose $C_6H_{12}O_6$, with traces of sodium phosphate Na_2HPO_4, and potassium sulphate K_2SO_4, which contains the chemical elements in the yeast. See that the tube is quite full. Shake well and examine a drop with the microscope. Note the few scattered torulae. Draw one or two.

On each bench—

Students at places 1 and 2 at once insert the cork firmly into the tube. The tube of 1 is placed in an incubator at 36° C. The tube of 2 is placed in a vessel of broken ice.

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

Students at place 4 boil the tube, cool it under the tap, insert the cork, and place it in the incubator.

Next day examine the tubes with the naked eye and the fluid with the microscope and study the condition of each tube, contrasting it with the condition on the previous day.

(1) What has happened to the yeast in each of the tubes?

(2) What conclusions do you come to as to the influence of temperature and of phenol upon the yeast protoplasm?

Changes in the Solution.

I. (*a*) *Disappearance of sugar.* The original solution (A) and the solution after incubation (B) have been boiled for some time with phenylhydrazine and acetic acid to demonstrate the presence of glucose.

A. Note abundant glucosazone crystals.

B. Note disappearance of glucose.

(*b*) Is *alcohol formed*? To about half an inch of the fluid add about half an inch of strong sulphuric acid and warm to boiling Then run in a solution of potassium bichromate and note the change of colour produced by the reducing action of the alcohol.[1]

[1] The yeast must be alcohol free.

II. *Nature of gas evolved.* With a fine pipette add KHO dissolved in alcohol to a Doremus ureameter in which the solution has been incubated with yeast, and note absorption of the gas evolved—CO_2.

Formulate your conclusions as to action of yeast upon glucose.

Where does yeast protoplasm get material for growth ?

Where does yeast protoplasm get energy for growth ?

II. MUSCLE NERVE.

The Employment of Electricity for Stimulating.

A. Connect thick covered wires with the terminals on the table marked *G*, + for positive and − for negative, from the constant current supplied at about 15 volts from a dynamo. Insert into the circuit a mercury key, as shown in the diagram,[1] so that when it is closed the current will flow through the terminals. Hold the ends of the wires between the moistened finger and thumb, and note the sensations produced when the current is allowed to pass by closing the key, and when it is cut out or broken by opening the key, and when the current is flowing. Repeat, holding the wires upon the tongue. Note whether the sensations are different or similar at the positive and at the negative pole on closing and on opening.

B. Instead of using the galvanic current direct, insert an **induction coil** into a circuit made by connecting two wires with the terminals from the dynamo marked *F*.

Introduce a mercury key into the circuit, and connect the ends of the wire with the screws on the top of the primary circuit of the induction coil as shown in the diagram. Lead wires from the terminals of the secondary coil to a friction key so that when it is closed the current

[1] The diagrams are upon the screen.

is short circuited. Lead off two terminal wires from the key. Pull the secondary coil well away from the primary, open the friction key and use the wires from it as in 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.

Taking sensation as the index of stimulation, formulate the results of the sudden making and breaking of the electric current and of its continuous flow.

Connect up an induction coil with the electric current, using the terminals on the uprights at the *end* of the coil so as to introduce the Neef's hammer, and introducing a mercury key into the primary circuit and a friction key into the secondary circuit as before as in the diagram.

Note that when the mercury key is closed the current passes round *A*, which becomes a magnet, and pulls down the spring and hammer and so breaks the contact at *B*. The current is interrupted and *A* is 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, and note the resulting sensation.

The Influence of Brain, Spinal Cord, and Nerve on Skeletal Muscle.

I. Study the attitude, movements, and effect of touching a normal frog. Try to place the animal on its back.

II. 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 the attitude, movements, and

the effect of touching and pinching. Feel the condition of the muscles as to consistence, and try to place the animal on its back.

III. Now pass a thick pin down the vertebral column so as to destroy the spinal cord. Note carefully anything that takes place in the muscles as this is done. Study the frog again as to attitude, movements, effect of touching and pinching. Examine the consistence of the muscles.

Formulate your conclusions as to the action of

A. The brain, and

B. The spinal cord upon the muscles.

IV. The second frog supplied has been killed by destroying its brain. A ligature has then been placed round all the structures of one leg excepting the sciatic nerve, and a dose of curare has been injected under the skin.

Compare the condition of this frog with the normal one before the cord was destroyed.

What has been the effect of the curare?

V. Remove the anterior part of the frog by three cuts, as shown by the demonstrators. Skin the hind legs and dissect out the sciatic nerve in the thigh as demonstrated. Pinch the nerve in the normal and in the curarised frog in each leg, and record your results.

VI. Connect up a galvanic circuit as in p. 7 A, using the pin electrodes provided.

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

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.

B. Gastrocnemius muscle.

Record the results.

Formulate your conclusions as to—

1. Influence of nerve upon skeletal muscle.
2. Influence of curare upon nerve, muscle, and junction of nerve with muscle.
3. Whether a muscle can be stimulated without the intervention of nerve.

Galvanic Stimulation of Nerve and Muscle.

A. On the Isolated Nerve Muscle.

Study the galvanic stimulation of nerve and muscle as in A, p. 7, altering the strength of the current by moving the handle on the switch-board from *W* to *S*. Record any difference you may observe at making and at breaking the current.

Do the Two Poles act in the same way?

Pull out the tongue of the curarised dead frog and split it down the middle, leaving each part attached to the front of the lower jaw. Pin the lower jaw to the cork plate. Stretching out each strip of the tongue, pin it in place, and attach a wire in circuit, as in VI. above, to each pin. Now make and break the current, and observe any difference at the positive and negative poles on making and on breaking the current.

In the table below write your results on using a strong, medium, and weak current, on making and breaking the current, and during its flow.

Observe any difference at the positive and negative poles.

	Make.		Flow.		Break.	
	+	–	+	–	+	–
Strong						
Medium						
Weak						

B. Electrical Stimulation of 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, as shown in the diagram. 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.

Beginning with a strong current, record the results which follow making and breaking the current. Then by means of the resistance reduce the strength of the current and record the changes.

Now reverse the direction of the current, by means of the commutator, and again study the effects of strong, medium, and weak currents.

Record the results obtained on the following table:

Strength of Current.	Pole.			
	Negative.		Positive.	
	Make.	Break.	Make.	Break.
Strong				
Medium				
Weak				

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

Stimulation of Muscle by Induced Electricity.

Fit up an induction coil for single induction shocks (p. 7 B), and make a muscle-nerve preparation of a frog's leg. Bring the electrodes upon the gastrocnemius muscle, and, 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.

Change in the Shape of a Muscle when Stimulated.

A. Extent of Contraction.

With the hand in supination measure the length of the biceps. Now flex the forearm to a small extent and measure the space through which the hand has been moved.

From the elbow articulation 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 your knowledge of the mechanism of levers, calculate the extent to which the muscle has shortened.

Extent of contraction

$$= \frac{\text{length of lever from fulcrum to power}}{\text{total length of lever}} \times \text{height of lift of hand.}$$

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 without the lever this represents.

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

Force of contraction may be expressed by—

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

C. Work Done.

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

Work done = force of contraction × extent of contraction.

D. Course of Contraction of Muscle.

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

1. Prepare an *Induction Coil* for single induction shocks, putting the *Drum* covered with smoked paper in the primary circuit, so that the bar on the drum makes and breaks the circuit as the drum revolves. With the hand move the drum 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. Arrange the driving cord of the drum to give a high rate of speed.

2. When everything is ready make a muscle nerve preparation, isolating the gastrocnemius from its connection with the foot, cutting away all the thigh but the lower end of the femur and cutting through the tibia below the knee, and thus removing it and the foot. Attach the tendon by a thread and hook to the short limb of the crank lever. Lay the muscle and nerve upon a piece of blotting paper wet with ·75% NaCl solution lying on the cork plate. Fix the femoral end of the muscle to the cork plate with a pin, so that it supports the lever by the thread in a horizontal position. Put a small weight on the lever so as just to clear the stand.

3. Now place the nerve upon the electrodes, and making and breaking the current by moving the drum with the hand, move the secondary coil out till breaking alone causes a contraction.

Now bring the point of the lever lightly against the smoked surface of the drum, pointing it in the direction in which the drum travels, and taking care that the movable base-piece is pushed thoroughly home. With the key in the secondary circuit closed, start the drum and, when it is revolving steadily, open the key so that the current may reach the electrodes and nerve. When the muscle is stimulated and contracts it pulls up the lever and records the contraction on the drum. Whenever the record is made, close the key again and stop the drum, and swing the lever off the paper by using the base-piece.

4. To mark the moment of stimulation, revolve the drum with the hand till the bar just makes and breaks a contact, and raise the lever with the finger so as to make a mark. Remove the lever from the drum. Note the relationship of this mark, which indicates the moment of stimulation, to the upstroke which marks the contraction.

5. To measure the duration of the different phases of the contraction, connect the electro-magnetic time-marker with the time-marker set to mark $\frac{1}{100}$ of a second; set the drum going, and, when it is revolving uniformly, bring the tip of the time-marking lever against it, and let it record its vibrations for a whole revolution. Each tooth represents $\frac{1}{100}$ second.

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

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

8. When dry study the trace and measure 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.

E. Extent of Contraction.

Measure the extent of contraction and the length of each limb of the lever, and calculate the actual shortening of the muscle as in A, p. 12.

F. Weight Lifted.

Measure the position of the weight upon the lever, and calculate the actual weight lifted by the muscle as in B, p. 12.

G. Work Done.

Calculate the work done by the muscle.

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

Influence of Various Factors upon the Course of 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.

I. Effect of Temperature.

Now 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 take another trace.

Then warm it by allowing normal saline at 25° C. to run over it for 2 or 3 minutes, and take another tracing.

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

II. Effect of Continued Exercise.

Let the muscle recover its former temperature, and, by raising or lowering the drum bring the point of the lever against another part of the surface, start the drum and let the muscle be stimulated, and record its contraction with each revolution of the drum. In this way study the effect of continued exercise on muscular contraction.

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

III. Effect of Strength of Stimulus.

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 trace of the muscle twitch. Then push the secondary coil nearer the primary and take a second record, and then again nearer and get a third record.

Study the effect of varying the strength of the stimulus on the duration of the phases and 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.

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

IV. Influence of Load.

Take a trace of a muscle twitch when no weight is on the lever, and then when a weight of 10 grams is on the lever, and compare them.

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

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

Influence of Various Factors upon the Extent of Contraction.

Strength of Stimulus upon Extent of Contraction.

Disconnect the drum from the primary circuit, and make and break by a mercury key. Bring the lever against the drum unconnected with the driving wheel and, with the drum stationary, record the effect of the minimal effective stimulus and of stronger and stronger stimuli, moving the drum about a quarter of an inch between each record.

Mark under each upstroke the position of the secondary coil.

Load upon the Extent of Contraction.

Perform the above experiment, but instead of varying the strength of the stimulus go on increasing the weight attached to the lever 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.

Effect of a Rapid Succession of Stimuli.

1. Arrange two strikers on the axle of the drum, and with them far apart take a trace of the muscle twitches at the top of the drum. Then approximate the strikers so that the second contraction will be produced before the first has ceased, and move the drum so that the lever writes at a lower level.

Note the relationship of the second contraction to the first, upon which it is superimposed.

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 diagram). Set the drum going *slowly*, and set the spring so that it makes and breaks 5 to 10 times per second. Bring the point of the lever upon the drum. Open the key in the secondary circuit and take a trace for about 1 or 2 seconds.

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

3. Repeat with a still shorter spring. Finally connect with wires with the Neefs hammer of the induction coil—a very short rapidly-vibrating spring—and take another tracing. Fix the tracing and study the results of a succession of stimuli and formulate these results.

NEURONS.

I. Simple Neuron Action.

A. How is the Activity of the Neuron manifested ?

1. Make a nerve muscle preparation, dissecting out the whole length of the sciatic nerve to the spinal cord, taking care to leave attached to the nerve a long piece of the branch to the posterior muscles of the thigh. Stimulate the nerve. There is no manifest change in it. There is a change in the muscle to which the nerve goes. (Keep the preparation cool and moist.)

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

Where is change manifested ?

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

In the secondary circuit of an induction coil place a commutator with the cross wires removed, and connect a pair of wire 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 (A. 1., above) with a crank lever, 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 fast drum, and take a separate tracing of the muscle twitch with the nerve stimulated by 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.

Formulate your conclusions.

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

Isolate the branch of the nerve to the posterior muscles of the thigh and place the electrodes upon it. Stimulate, and note whether the gastrocnemius contracts.

What is the explanation of this?

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

Study the results of the experiments, p. 16, III., on the influence of Strength of Stimulus.

E. Effect of Repeating a Subminimal Stimulus.

Pull out the secondary coil till breaking the primary circuit gives a subminimal stimulus. Set the Neefs hammer vibrating so as to give a series of such stimuli and note the result.

F. Is a Nerve more easily stimulated from its Termination or from its Middle?

Destroy the brain of a frog and expose one sciatic nerve, without injuring it, by passing a bristle under it to raise it to the surface.

Using the reflex contraction of the other foot as an index of the extent of stimulation stimulate with forceps, first the termination of the nerve in the toes, and then the exposed nerve, and note any difference in the result.

II. Reflex Action.

1. Phenomena of Reflex Action.

Prepare an induction coil with Neef's hammer. Having destroyed the brain as in Lesson 2, hang a frog to the frog-plate, fixing by a pin through the jaw.

A. Apply a scrap of blotting paper dipped in acetic acid to the flank of the animal. Study the movements.

Having washed off the acetic acid—

B. Pinch the foot with forceps and study the result as regards—

1. Movements which result.
2. Relation of these movements to the strength of the stimulus.
3. Duration of the movements.
4. Spread of the movements.

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

C. Stimulate the foot with—

1. Single induced shocks,
2. A series of shocks of the same strength interrupted by Neef's hammer,

and compare with result of E. p. 19.

2. Time of Reflex Action.

A. Using the same frog as above, lay it on the cork board of a myograph, fixing the lower end of the femur and the tibia with a pin.

Free the tendo-Achilles and attach it to the lever. Bring the electrodes from the secondary coil of an induction apparatus upon the toes of the same foot and arrange the primary circuit for tetanising shocks with Neef's hammer. Attach a piece of copper wire to the striker on the drum so as to make a prolonged contact with the knife edge. Adjust the coil so that each stimulation gives a reflex response to the gastrocnemius.

Now start the drum, and when it is rotating smoothly stimulate by opening the key in the secondary circuit, and get a record of the moment of contraction. Then mark the moment of stimulation.

Now remove the myograph and with the drum going uniformly put a time marking off $\frac{1}{100}$ of a second under the tracing. Remove the tracing and measure the latent period, and compare with the latent period in a simple muscle twitch (p. 14).

B. Suspend the frog by the head and dip the opposite

foot first into the weak acid supplied, and, after washing in the vessel of water, into the stronger acid. Note the difference in time of onset of the reflex action.

3. **The Knee-jerk.**

Sit with the right leg crossed on the left, and with the edge of the ear-piece of a simple stethoscope or with the side of the hand strike the ligamentum patellæ of the right leg, and observe the contraction of the quadriceps extensor femoris and the movement of the leg.

III. Cerebral Action, Time of (Visual Stimulus).

Connect in one circuit through the terminals marked *F* two mercury keys, *A* and *B*, separated by a considerable length of wire, and a time-marker *C*, so that when both keys are closed the current passes and the lever on the time-marker is depressed. Bring the lever of the time-marker (*C*) lightly against the smoked surface of a rapidly revolving drum. The subject stands beside the drum and lever with a closed mercury key, *A*, which he must open the moment he sees the lever depressed. The observer now closes the other mercury key, *B*, in such a way that the subject can neither see nor hear when this is done. The lever is thus momentarily depressed and released again by the opening of *A*. 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. Fatigue of Neuro-muscular Mechanism.

Fit the hand and arm as instructed in a Mosso's ergograph, to the hook of which a weight of 3 kilograms has been attached. The writing point is brought against a very slowly moving drum. Set a metronome beating about 60 times per minute, and as each beat is heard raise the weight with the finger to the fullest extent as long as it is possible to move the weight, then study the record upon the drum of the onset of fatigue.

RECEPTOR MECHANISMS—THE SENSES.

Exteroceptive Mechanisms.

I. 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?

Appreciation of Pressure.

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 determines and records the smallest difference of weight which can be appreciated.

Appreciation of Locality of Contact.

The acuteness of this may be determined by finding how near to one another two contacts may be made and still give rise to a sensation of two and not simply of 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.

Appreciation of Contact in Time.

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. Temperature Sense.

I. Take three basins.

1. Fill one with water so hot 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. What conclusion do you draw as to the nature of the temperature sense?

II. 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. 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 anywhere or only at certain spots.

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

IV. Repeat the experiment on the back of the forearm.

III. Taste.

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 response studied.

IV. Vision.

A. STRUCTURE.

1. 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 humor 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 humor 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 and study the corneo-sclerotic junction and draw it.

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.

2. 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 artificial eye in the holder. Using the mirror with a hole in the centre reflect the appropriate light into the eye, looking through the hole. Begin at a distance of two feet from the eye, and gradually approach it, keeping the light reflected into it. Gradually the mark on the paper becomes distinctly visible. Is it erect or inverted?

Indirect Method.—With the mirror about three feet from the eye reflect the light into it. Now insert a biconvex lens at about 4 or 5 inches in front of the eye, 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.

MONOCULAR VISION.

B. DIOPTRIC MECHANISM.

The Eye is a Camera Obscura.

Study the formation of images on the obscure glass screen behind a lens.

1. Where are objects above focussed on the screen and where are objects on the right focussed? Is the image 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 optical properties of a convex lens.

Examine the image formed on an obscure glass plate placed in a window cut in the back of a fresh ox's eye.

Refracting Surfaces of the Eye.

Note the formation of a reflected image from each of the two refracting surfaces of a bi-convex lens. Study how the size of the image varies with the curvature of the lens, the position of the image from each surface of the lens and the direction in which it moves when the object is moved.

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 posterior surface of cornea?

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

Can Near and Far Objects be seen at the same time?

Close one eye and fix the other on the far corner of the room, and then hold up a pencil close to the eye and see if *at the same time* both objects can be distinctly seen. When the eye is directed to the pencil note any change in the pupil.

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 six inches from the eye, and note the appearance of the needle when the distant line is looked at, and the line when the needle is looked at.

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

Is the Power of Focussing Limited or Unlimited?

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.

What change takes place in the Eye in Near Vision?

Repeat the experiment on the refracting surfaces of the eye (p. 27), 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.

C. RETINAL STIMULATION.

1. Is the whole Retina stimulated by Light?

1. **Mariotte's Experiment.**—Make two marks 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 fixed at about a foot from the paper, with the right eye *fixed* upon the mark, the left eye being closed, move the point of a pencil 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.

Map out the blind spot.

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

Purkinje's Images.—In a dark room hold the head sideways against a uniformly coloured wall, with the eyes turned towards the wall. Now direct a powerful ray of light through the sclerotic coat of the eye that is thus exposed, and on moving the light up and down, and from side to side, note any appearance on the wall. The lines seen are the shadows of the retinal blood vessels. Revise your knowledge of the distribution of the blood vessels of the retina. Is it the front layer of retina or a back layer which is acted upon by light ?

3. What range of objects can be seen at one time ?

The Field of Vision.

Describe a semicircle on a blackboard with the free ends of the line finishing at the side. Mark the centre of the circle and the middle point in the circumference drawn with an X. This forms a rough "perimeter."

With one eye closed, the observer places his other eye at the centre and directs it steadily towards the middle point in the circumference. A piece of chalk in the hand of a fellow student is slowly drawn along the circumference from below. Note when it becomes visible and mark 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 point X at the centre of the circle and these two points subtends the vertical field of vision. Measure the angle.

Now turn the blackboard into the horizontal plane and map out the horizontal field of vision.

Using coloured chalks, 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.

4. Colour Vision.

Colour sensations may be produced in various ways:

(*a*) By the action of light waves of various lengths. Study the spectrum produced by a prism (spectroscope).

(*b*) By mechanical stimulation of the retina. Press on the eyeball as far back as possible and describe the resulting sensations.

(*c*) By the simple alternation of white and black upon the retina.

Using the black and white disc supplied, rotate *as rapidly as possible* in a good light. Describe the resulting visual sensations.

(*d*) By the admixture of different parts of the spectrum a sensation similar to that produced by some other part may be produced.

Use the coloured discs supplied and combine them in different ways.

Describe the resulting visual sensations.

5. After Images.

(*a*) **Positive.** After keeping the eyes closed 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 intensity as time passes.

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

Describe the image as above.

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

6. Modified Visual Perceptions.

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. Contrasts—(*a*) *Simultaneous.* A red wafer is placed on a white ground and another on a green ground. Which appears deeper in colour?

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

Does the red appear more intense after looking at the grey or 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?

BINOCULAR VISION.

1. With the perimeter investigate the field of vision in the horizontal plane first for one eye and then for the two eyes, taking care not to move the head and make a diagram of the result.

2. Lay a prism edge on to you on the table, and study how the idea of relief is arrived at.

With the stereoscope study how the projection of slightly different pictures on the two retinae gives the idea of relief.

3. 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?

V. Hearing.

(a) Limits of Perception of Musical Sound.

Using tuning forks for the lower limit and the steel cylinders supplied for the upper limit, determine the range of perception of musical sounds.

(b) Conduction of Sound.

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?

(c) Localisation of Sound.

Test the power of localisation by making a faint clicking noise—as by the closing sharply of 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.

Proprioceptive Mechanisms.

1. **Kinaesthetic.** 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?

To test this sense find the smallest difference of weight which can be detected, as in Appreciation of Pressure, p. 22, but keeping the hand free of the table and using the muscles of the arm.

Study how this sense, in conjunction with touch, gives information as to the distance, shape, and size of external objects by passing the hand over some object and ascertaining the distance of objects with the eyes shut.

2. **Labyrinthine.** (1) Revise the anatomy of the semicircular canals and study the model. Spin rapidly round several times, stop and observe the sensations produced. Try to explain them. Hold a short stick or poker verti-

cally with its point on the ground. Place the forehead on the top of the poker 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.

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 semi-lunar 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.

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.

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. 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. Cardiac Cycle.

1. 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 the two sides of the girdle, pinning each back, and then expose the heart in the pericardium. Snip through the pericardium and study the auricles, ventricles and bulbus as seen from the front.

Study 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.

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. 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. Set a recording drum on the slow gear.

Place the cork plate with the frog under the heart lever and attach the lever to the apex by means of a small clip, seeing that the thread is vertical. Adjust the lever so that each heart beat causes the largest range of movement. Then bring the 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 seconds under the trace.

Now 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. Fix the tracing.

3. **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 second.

4. **Influence of Temperature.**—Now place the watch glass upon ice and observe the effect. When a marked change in the rhythm 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. Describe the influence of cold and heat upon the living heart.

5. **The Cardiac Impulse—Cardiograph.** 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 applying the cardiograph, with the button upon the impulse try to get a tracing. This is best done with the subject leaning forward and to the left. Make an enlarged drawing of a part of the trace, and try to explain the various elevations and depressions.

III. Nerve Control of the Heart.

1. Connect up the apparatus for giving a series of induced shocks.

Kill a frog and remove the brain in front of the tympanic rings by cutting the head across, thus leaving the medulla oblongata intact, and thrust a pair of pin electrodes into the medulla.

Expose the heart of the frog and attach to a lever.

Record a normal cardiogram.

A. **Intra-Cardiac Mechanism.** Stimulate the crescent, which may be seen as a white crescentic mark between the sinus and auricle on their posterior aspect. The current must not be very strong. If no change in the rate of the heart occurs, increase the strength of the current.

Take a tracing. What conclusion do you draw?

B. **Extra-Cardiac Mechanism.** Using the pin electrodes in the medulla, stimulate as in A and record the result. What conclusion do you draw?

C. **Effect of Drugs.** Leaving the electrodes in position as in B, paint the heart with 0·1 per cent. solution of atropin. Allow two minutes to elapse and then stimulate. Note any difference from the reaction in B. Take a tracing and formulate your conclusion.

IV. 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. When the heart has recorded a few contractions, tighten the loop so as to separate the auricles from the sinus. Note and record the result. If the ventricle stops contracting, stimulate it by touching with a needle and record the course of contraction and the latent period.

Tie another loose loop round the whole heart after the ligature has been tied, and when ready tighten it so that it exactly separates the auricles from the ventricle. Record the result.

V. Sounds of the Heart.

With the stethoscope provided listen over the front of the left side of the chest. Put a finger on the cardiac impulse and try to time the sounds heard in relationship to this.

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.** 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 effect of constricting the capillaries.

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.

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.

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.

Using Dudgeon's or Marey's sphygmographs, under the direction of the demonstrator, take a tracing of the radial pulse. 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 mercury is at zero.

(*b*) Enclose the upper arm of the subject in the armlet and raise the pressure in the instrument some 3 cm. above the point at which the pulse disappears.

(*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.

(*d*) Still releasing the pressure slowly, note the mean pressure which allows the largest movement in the mercury. This is the *diastolic* pressure.

Gaertner's Instrument.

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

(*b*) Using a rubber band or tube, bandage the finger to be experimented on tightly up to the knuckle, beginning at the finger tip.

(*c*) Having removed the rubber from the second and terminal phalanges, leaving it only on the proximal one, place around the second phalanx the ring bag connected with the manometer and air pump.

(*d*) Raise the pressure above that anticipated in the vessels and then remove the constricting bandage.

(*e*) Release the air pressure very gradually until the moment at which the finger first shows a slight red tinge. The reading on the manometer gives in mm. of mercury the systolic pressure in the arterioles.

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.

RESPIRATION.

1. Study the changes 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.

(*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. With a stethoscope listen over the windpipe and over the right side of the chest while the person breathes, and describe the sounds heard at each place, timing their relationship to inspiration and expiration.

3. Count the number of respirations in a person who has been sitting still and again in the same person after taking violent exercise.

4. 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.

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