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PHYSIOLOGY AT HARVARD

John G. Curtis

BY

WILLIAM TOWNSEND PORTER, M.D.

ASSOCIATE PROFESSOR OF PHYSIOLOGY IN THE
HARVARD MEDICAL SCHOOL

SECOND EDITION

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P83
1903*

THE UNIVERSITY PRESS

Cambridge, Mass.

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PREFACE TO THE SECOND EDITION

THIS book is written to explain a new method of teaching, sound in theory and feasible in practice; to provide the Harvard Medical School with a precise account of the work done by each student in Physiology; and to create for students and instructors alike a working-plan by which they may find their way unvexed through much detail.



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CONTENTS

I

THE NEW METHOD

THE NEW METHOD	1
WAYS AND MEANS	4
COURSES OFFERED IN 1902-1903	8

II

THE FIRST-YEAR COURSE

INSTRUCTION GIVEN EACH STUDENT	9
PROGRAM	11
INSTRUCTIONS TO STUDENTS	12
LABORATORY EXPERIMENTS	14
Pairing — Distribution of time — Experiments performed.	
GENERAL PHYSIOLOGY, INCLUDING MUSCLE AND NERVE .	17
Methods of electrical stimulation — Stimulation of muscle and nerve — Chemical and mechanical stimulation — Irritability and conductivity — The electromotive phenomena of muscle and nerve — The change in form.	
ADDITIONAL EXPERIMENTS ON MUSCLE AND NERVE . .	20
Methods of electrical stimulation — Chemical and mechanical stimulation — Irritability and conductivity — The electromotive phenomena of muscle and nerve — The change in form.	
SPINAL CORD AND BRAIN	23

SYMPATHETIC	24
CUTANEOUS SENSATIONS	24
Sensations of temperature — Sensations of pressure.	
GENERAL SENSATIONS	24
Tickle — Pain — Motor sensations.	
TASTE	25
SMELL, HEARING	25
PHYSIOLOGICAL OPTICS	25
Introduction — Refraction in the eye — The schematic eye — Accommodation — Ophthalmoscopy.	
VISION, FERMENTATION, DIGESTION, ABSORPTION, LYMPH, BLOOD, SECRETION, RESPIRATION, METABOLISM	27
THE CIRCULATION OF THE BLOOD	29
The pressure-pulse — The innervation of the heart and blood-vessels.	
APPARATUS	31
LABORATORY NOTE-BOOK	32
CONFERENCE	32
WRITTEN TESTS	33
SPECIAL DEMONSTRATIONS	35
RECITATIONS	36
THESES AND THE READING OF INVESTIGATIONS	37
Instructions for thesis.	
THESES TO BE DISCUSSED IN 1903	40
THESES TO BE WRITTEN BUT NOT DISCUSSED IN 1903	42
BIBLIOGRAPHIES FOR THE THESES TO BE DISCUSSED IN 1903	45
LECTURES	65
Calendar.	
OPTIONAL LECTURES	65
SPECIAL EXPERIMENTAL WORK	66

CONTENTS

ix

EXAMINATIONS	67
Practical examination — Written examination.	

III

THE ADVANCED COURSE	74
-------------------------------	----

IV

PHYSIOLOGICAL RESEARCH	75
----------------------------------	----

V

THE SUMMER COURSE	80
-----------------------------	----

APPENDIX

APPARATUS	81
REQUISITION BLANK	90
FIRST ISSUE OF APPARATUS	91
SECOND ISSUE OF APPARATUS	93
FIRST RETURN OF APPARATUS	94
THIRD ISSUE OF APPARATUS	95
FOURTH ISSUE OF APPARATUS	96
FIFTH ISSUE OF APPARATUS	96
SECOND RETURN OF APPARATUS.	97
THIRD RETURN OF APPARATUS	99
APPARATUS LIABLE TO BE BROKEN	101

PHYSIOLOGY AT HARVARD

I

THE NEW METHOD

THE new method of teaching physiology proposed in the *Boston Medical and Surgical Journal*,¹ December 29, 1898, and more fully explained in the *Philadelphia Medical Journal*,² September 1, 1900, was adopted by the Harvard Medical School in 1899.

The traditional method of teaching physiology consists of a systematic course of lectures illustrated by occasional demonstrations. For thirty years or more, especially in England, this didactic teaching has been further illustrated by certain experiments performed by the students themselves. Laboratory experiments, therefore, have long been a valued part of the instruction in physiology in many universities. When the new method of teaching was introduced in the Harvard Medical School, and two hundred students worked daily in the physiological laboratories, it was said that this was only doing in a large way that which had been done in a small

¹ Porter, W. T.: The teaching of physiology in medical schools, *Boston Medical and Surgical Journal*, December 29, 1898, pp. 647-652.

² Porter, W. T.: The teaching of physiology, *Philadelphia Medical Journal*, September 1, 1900.

way for many years. The enterprise was held to be valuable because it showed that large numbers of first-year medical students could be carried simultaneously through a long series of experiments many of which had been thought beyond their powers; it was a lesson in faith and an example of administration, but nothing more.

It will be obvious that this criticism is based upon a misapprehension. The new method is not an extension of the old. It is a fundamentally different process. The old method is chiefly didactic. The new is a systematic course of experiment and observation by the student himself. In the old the student rests upon the dictum of the professor and the text-book. In the new he relies upon the fundamental experiments done with his own hands. In the old his experiments follow the lecture and attempt to verify its statements. In the new the lecture follows his experiments and discusses them in relation to the work of other observers. In the old the stress is upon the didactic teaching. In the new the stress is upon observation. Under the old method, students in the Harvard Medical School used to ask, "Who is the authority for that statement?" Under the new, they ask, "What is the experimental evidence?" The old method insensibly teaches men to depend upon authority, but the new directs them to nature.

In the old method the experiments performed by the students are almost exclusively such as are quickly and easily done, for example, the simpler experiments in the physiology of muscle and of the circulation of the blood. They are

intended to illustrate physiological experimentation rather than to disclose step by step the groundwork of the science of physiology.

In the new method, on the contrary, the fundamental experiments and observations which form the solid ground in every field of physiology are divided into sufficiently small groups and arranged in the most instructive sequence. With the fundamental experiment of each group are placed the accessory data. The meaning of this term will be clear from the following example. Consider the function of the roots of spinal nerves. The fundamental experiment here is Johannes Müller's well-known section and stimulation of the nerve-roots. The accessory data are such of the observations and opinions of his successors as are necessary to give a clear picture of the present state of knowledge of this subject. The student makes for himself the fundamental observation, and immediately afterward considers the accessory data provided in text-book and lecture. He proceeds systematically from the fundamental experiment and accessory data of one group to those of the next, in an ordered and logical series.

The fundamental experiment and the accessory data are taken as directly as possible from the original sources, and the reference is given in each case.

It should be observed that this new method serves for the instruction of all students, from beginners to those engaged in research. The beginner performs the fundamental experiment in each group and studies the accessory data.

The advanced student performs the fundamental experiments and as many of the accessory experiments as may give him the special training he desires. The research student has before him the classical observations and the original sources of the problem he has chosen.

It should be noticed also that the new need not violently push aside the old method of instruction, but may replace it chapter by chapter as the means and the energy of the instructors shall permit.

It has been urged against the new method that there are fundamental experiments which require more time than the student can possibly give, or which are too complicated to be successfully performed by him. The number of these has certainly been much exaggerated, and is daily lessened by inventions that secure simplicity without loss of accuracy. Pending such labor-saving inventions, the experiments which consume much time may well be done by committees of students, and the results reported to the entire class, who will compare them with the account given by the original discoverers.

WAYS AND MEANS

The new method requires :

1. Printed accounts of the fundamental experiments and observations in physiology, taken from the original sources, and arranged in the most instructive sequence. The reference to the original source should be given in each case.

2. Accessory data grouped about the fundamen-

tal experiments. The accessory data should also be taken as directly as possible from the original sources, and the reference given in each case.

3. Apparatus of precision designed with the utmost simplicity upon lines that permit its manufacture in large quantities at small cost.

It is obvious that these conditions cannot be met without prolonged labor. Collections of fundamental and accessory experiments in several fields have been printed in an abbreviated form for the temporary use of Harvard Medical students and other interested persons.¹ These collections are being completed and improved as rapidly as possible, and the data for the remaining fields are being brought together. In its final form this material will constitute "A Laboratory Text-book of Physiology."²

Especial consideration should be given to the apparatus for the laboratory teaching of large numbers of students. The making of physiological apparatus distinguished by simplicity of design, sound workmanship, and low cost is at

¹ Porter, W. T. : An Introduction to Physiology. Part I. The Physiology of Muscle and Nerve, pp. 1-235. Second edition, January, 1901. Part II. The Circulation, pp. 237-314. Parts I and II are bound together in green cloth. Part III. The Spinal Cord and Brain, *in preparation*. Part IV. Physiological Optics, pp. 1-99. Bound in gray paper. Pending the publication of the remaining parts of the Introduction to Physiology and of the Laboratory Text-book of Physiology, the experiments not mentioned in Parts I, II, and IV, of the Introduction, and now performed by students in the Harvard Medical School, are printed in *Experiments for Harvard Medical Students*, 1903, third edition. These deal more or less fully with the spinal cord, brain, cutaneous sensations, taste, vision, metabolism, respiration, blood, and fermentation.

² This title is copyrighted by W. T. Porter.

present of high importance to the development of physiology. The ordinary student of physiology is essentially a book man, while the professional physiologist is essentially a laboratory man. Student and professor should go the same path,—the only road that ever has led or ever will lead to a sound knowledge of a natural science. Few steps can be taken along this road without apparatus of precision. Physiological apparatus has heretofore been made upon the “model” plan, each piece for itself, without regard to the number of mechanical “operations” required, and with little or no thought as to the subsequent maintenance of the apparatus in good condition. The Harvard Medical School requires more than one hundred duplicates of each apparatus, for example more than one hundred kymographs, more than one hundred inductoriums, etc. The course now given requires the issue of at least twenty-five thousand articles, and this number increases steadily with the increase in the experimental work. It is clear that the cost of such an equipment made on the old lines would be beyond the means of any large school. Hence, the sound training of large classes in physiology depends absolutely upon the invention of apparatus that shall serve for exact experimentation, i. e. the repetition of classical experiments, and that shall also be designed with reference (1) to its “manufacture,” (2) to its storage and issue, and (3) to its maintenance in good condition. By “manufacture” is meant technically the making of a number of pieces of the same apparatus consecutively, by preference upon special lathes

and with special tools. Thus in the machine shop of the Harvard Physiological Laboratory the parts of five hundred moist chambers were made at one time. For economy, the number of steps or "operations" should be the fewest possible, as each operation must be repeated many times, — five hundred times in the example just given. The labor of setting a turret lathe which will make eight consecutive operations upon the same piece of metal is as great for one piece as for a thousand. Astonishing economies may also be secured by the use of special automatic tools.

Further, it is essential that the apparatus be compact, and that important parts be protected so that they may not be injured when the apparatus is handled rapidly by persons of small experience. Storage and issue must be carefully studied to prevent hopeless confusion and the rapid deterioration of the plant.

Finally, the apparatus should be designed with special reference to durability and cleanliness; otherwise there will be a heavy charge for maintenance.

The supply of apparatus of this type bears the same relation to the advance of physiology that the commissariat bears to the advance of an army.¹

¹ The Harvard Physiological Apparatus has been especially devised for the laboratory teaching of large numbers of students. It has been described in part in a catalogue entitled "The Harvard Physiological Apparatus, manufactured by the mechanics of the Harvard Laboratory of Physiology under the direction of Professor W. T. Porter:" also in *Science*, 1901, xiv, pp. 567-570; and also in the Proceedings of the Fifteenth Annual Meeting of the American Physiological Society published in the *American Journal of Physiology*, 1903, viii.

COURSES OFFERED IN 1902-1903

1. First-Year Course.
2. Advanced Course.
3. Research.
4. Summer Course.

II

THE FIRST-YEAR COURSE

THE first-year course is required of all students. It is designed to give the general introduction to physiology that every Doctor of Medicine should possess. It is valuable also to biologists not intending to become physicians. The medical students who take this course have spent the first four months of the collegiate year in the study of anatomy, histology, and embryology. The mornings of the second four months, February, March, April, and May, are given to physiology, and the afternoons to physiological and pathological chemistry.

The instruction in physiology given each student is shown in the accompanying tables, which are followed by a description of the several exercises.

TABLE I

SHOWING THE INSTRUCTION GIVEN EACH STUDENT IN
THE FIRST-YEAR COURSE

Number of Exercises.	Character of Exercise.	Hours of Instruction.
79	Laboratory experiments. Professors Porter and Cannon, and Dr. Maxwell. <i>Daily, except Saturday.</i>	168
79	Conference. Professors Porter and Cannon. <i>Daily, except Saturday. First to sixteenth week, inclusive.</i>	40
79	Written tests. <i>Daily, except Saturday. First to sixteenth week, inclusive.</i>	26
16	Written tests. <i>Mondays. First to sixteenth week, inclusive.</i>	11
50	Lectures, with demonstrations. Professors Porter and Cannon. <i>Daily, except Saturday. Sixth to fifteenth week, inclusive.</i>	25
15	Special demonstrations. Professors Porter and Cannon. <i>Saturdays. First to fifteenth week, inclusive.</i>	15
15	Recitations. Professor Bowditch. <i>Saturdays. First to fifteenth week, inclusive.</i>	15
50	Discussion of theses. The entire class and the Staff. <i>Daily, except Monday. Sixth to fifteenth week, inclusive.</i>	40
24	Optional lectures. Professors Porter and Cannon. <i>In May.</i> (For dates and subjects, see page 65.) Thesis. Written by each student from the original sources. Reading of investigations. The reading of one or more investigations in the original source and the discussion of these when the theses upon the same subjects are discussed. Bibliography. The making of a bibliography of one of the subjects listed under "Theses not to be read," p. 42. Special experimental work. Optional during the fifteenth and sixteenth weeks, for selected students.	18

TABLE II
PROGRAM OF FIRST-YEAR COURSE

SECOND HALF-YEAR.					
PHYSIOLOGY. FEBRUARY 3 TO MARCH 7.					
MONDAY.		TUESDAY. WEDNESDAY.	THURSDAY. FRIDAY.	SATURDAY.	
9-9.30	Conference. Room A.	Conference. Room A.			
9.30-9.50	Written Test. Rooms B and H.	Written Test. Rooms B and H.			
9.50-12	Laboratory Experiments. Rooms B and H.	Laboratory Experi- ments. Rooms B and H.		10-11	Recita- tion. Room A.
12-1	Written Test. Rooms B and H.			11-12	Demon- stration. Room A.
MARCH 9 TO MAY 25.					
9-9.30	Lecture. Room A.	Lecture. Room A.		9-9.45	Discus- sion of Theses. Room A.
9.30-10	Conference. Room A.	Conference. Room A.			
10-10.20	Written Test. Rooms B and H.	Written Test. Rooms B and H.		10-11	Recita- tion. Room A.
10.20-12.15	Laboratory Experiments. Rooms B and H.	Laboratory Experi- ments. Rooms B and H.			
12.15-1	Written Test. Rooms B and H.	Discussion of Theses. Room A.		11-12	Demon- stration. Room A.
MAY 26 TO JUNE 1.					
Laboratory experiments. Rooms B and H.					

INSTRUCTIONS TO STUDENTS

Four weeks before the beginning of the course the following letter is sent to each student:¹

Form A.

DEPARTMENT OF PHYSIOLOGY,
HARVARD MEDICAL SCHOOL,
January 1, 1903.

DEAR SIR:—

Since many of the laboratory experiments in physiology require two men for their successful performance, the class will be divided into pairs. Students may work with whom they please, provided those desiring to work together give written notice to Professor W. T. Porter not later than January 24. Where no preference is expressed the pairing will be made from an alphabetical list. The distribution of the pairs at the laboratory desks will be posted on the bulletin board January 30. Students are advised to provide themselves with the following articles:

1. A dissecting case, including scissors, one large and one small forceps, and a seeker.
2. A small towel.
3. A piece of cotton cloth about 40 × 40 cm.
4. A microscope with a hinged standard allowing the stage to be tilted to a perpendicular position. One member of each pair may rent a microscope by applying to the Department of Histology. Students now using a microscope of the required kind may there arrange to keep it

¹ Letters, lists of apparatus, and similar matter for the use of students are printed upon the Rotary Neostyle.

and their microscope locker during the second half-year

5. The pamphlet entitled "Physiology at Harvard."

6. The Physiological Laboratory Note-book.

7. An Introduction to Physiology, Parts I and II, bound together in cloth. To be had from W. B. Clarke Company, corner of Park and Tremont Streets, Boston.

8. Experiments for Harvard Medical Students, Third Edition, bound in gray paper.

9. An Introduction to Physiology, Part IV, bound in gray paper.

10. The Physiological Thesis Book.

Articles 1, 2, 3, 5, 6, 8, 9, and 10 are sold by the Co-operative Society.

First-year medical and dental students, advanced students, and students taking the course a second time, will meet Professor Porter in Room A, February 3, at 9 A.M.

At 9.30 A.M. the students will find their desks in Rooms B and H. Each desk bears the names of the owners upon a printed slip. Each student will receive a key to the locker in his desk. For each key a deposit of one dollar will be required, to be refunded when the key is returned.

Within the cupboard and drawers of the locker will be found the apparatus necessary for the first work of the course, together with a printed list of the apparatus (see Appendix, Form G, page 91). Articles marked * will be found in the small wooden boxes. The list should be veri-

fied and signed by each student. This receipt will be retained by the Department.

The apparatus is issued in good condition, and students will be held responsible for its return in good condition. The cost of cleaning, repairing, or replacing articles which become damaged will be charged to the students to whom they were issued. A list of the articles liable to be broken beyond repair is posted in the laboratories, with the cost opposite each (see Appendix, Form O, page 101). Students desiring additional apparatus must present a signed requisition for the desired article (see Appendix, Form F, p. 90).

Frogs and tortoises will be issued on the presentation of signed requisitions. Students using more than the average number of animals will be charged ten cents for each additional medium-sized frog, and twenty-five cents for each large frog and each tortoise.

Every charge will be divided equally between the two members of the pair represented by the name on the requisition.

You are advised to keep this letter for reference.

Very truly yours,

W. T. PORTER.

LABORATORY EXPERIMENTS

The student works in the laboratory fourteen hours a week during six weeks, and ten hours a week during the ten other weeks of the course.

Pairing.— Many of the experiments cannot be done by one person. Others are performed more rapidly and with better results by two

workers than by one. Moreover, discussion and mutual criticism are valuable. The class is therefore divided into pairs. Students are urged to select their comrades for themselves. Those who fail to choose are paired by lot. The pair usually decides to divide the experimental work so that upon one day the preparation of the frog, or other material, shall fall to one student, while the arrangement of the apparatus shall fall to the other; the next day, these duties are exchanged.

Distribution of Time. — The sixteen weeks of experimentation are divided as follows:

February 3–March 6. General physiology, including muscle and nerve.

March 9–17. Spinal cord and brain.

March 18–19. Cutaneous and general sensations.

March 20–24. Taste, smell, hearing.

March 25–30. Physiological optics.

March 31–April 2. Vision.

April 3–17 and April 27–May 1. Fermentation, digestion, absorption, lymph, blood, secretion, respiration, metabolism. (April 19–25. Spring recess.)

May 4–29 and June 1. Circulation.

May 30. Memorial Day — a holiday.

June 2–5. Practical examination.

General physiology, including the physiology of muscle and nerve heads the list, for the logical reason that contractility and irritability are the primary attributes of living tissues and should be studied first, and for the practical reason that no field has been so thoroughly worked as this, and

none is so well adapted to train the beginner in physiological technique and the physiologist's habit of thought.

It will be observed that the time given to this subject is relatively greater than that given to any of the others. The greater training power of the physiology of muscle and nerve accounts for this in part. But the student's lack of skill and knowledge is the chief cause. When the students begin the study of general physiology they are as a rule unacquainted with experimentation upon living tissues. During the first two weeks they are slow and awkward. During the third week a remarkable change begins. At the fifth week it may be said without exaggeration that most of the students are rapid and fairly accurate experimenters. The experiments upon general physiology, which require the mornings of five weeks at the beginning of the course, could at the end of the course be easily done in three. The experiments upon the circulation, which require four weeks in their present position, would require at least six if placed at the beginning of the course.

It should be said, further, that the work upon muscle and nerve includes certain experiments that are commonly taught under the heading of the nervous system.

The students who enter the physiological course have already studied the special anatomy of organs the structure of which would otherwise be described by the physiologist. This rational preparation materially shortens the time required for certain chapters in physiology.

The space assigned the vegetative functions is small because the laboratory work in the chemistry of the carbohydrates, fats, proteids, bone, cartilage, muscle, and of some other portions of chemical physiology is pursued at present in the Department of Chemistry.

Experiments Performed. — Following is a complete list of the experiments performed. Students are not permitted to pass to a new experiment until the one in hand has been performed to the satisfaction of the instructors. Only work well done is accepted.

GENERAL PHYSIOLOGY, INCLUDING MUSCLE AND NERVE

Methods of Electrical Stimulation. — The preparation of the gastrocnemius muscle, p. 4.¹ The nerve-muscle preparation, p. 6. Galvani's experiment, p. 12. Make and break induction currents as stimuli, p. 40. Tetanizing currents, p. 42. Exclusion of make or break current, p. 43.

Stimulation of Muscle and Nerve. — Opening and closing contraction, p. 61. Changes in intensity of stimulus, Experiments 1 and 2, pp. 62 and 63. Polar stimulation of muscle, Experiment 5, p. 68. Tonic contraction, p. 70. Physiological anodes and cathodes in rectus muscle, p. 72. Law of contraction, p. 75. Changes in irritability,

¹ The page numbers refer to "An Introduction to Physiology." It has been found that students usually require four days for the methods of electrical stimulation; ten days for the stimulation of muscle and nerve, and for irritability and conductivity; ten days for the electromotive phenomena, and for the change in form.

Experiment 1, p. 79. Changes in conductivity, Experiment 2, p. 85. Stimulation of human nerves, p. 89. Stimulation of motor points, p. 92. Polar stimulation of human nerves, p. 93. Reaction of degeneration, p. 97. Influence of duration of stimulus, Experiment 2, p. 101. Rhythmic contraction, Experiment 1, p. 103. Polar fatigue, p. 108. Polar inhibition by the galvanic current, Experiment 1, p. 114.

Chemical and Mechanical Stimulation. — Effect of distilled water, p. 124. Strong saline solutions, p. 125. Drying, p. 125. Normal saline, p. 126. Importance of calcium, p. 126. Constant chemical stimulation may cause periodic contraction, p. 126. Mechanical stimulation, p. 127.

Irritability and Conductivity. — The independent irritability of muscle; curare experiment, p. 132. Minimal and maximal stimuli; threshold value, p. 137. Summation of inadequate single stimuli, p. 138. The same nerve fibre may conduct impulses both centripetally and centrifugally, Experiment 1, p. 144. Speed of nerve impulse, p. 146.

The Electromotive Phenomena of Muscle and Nerve. — Polarization current, p. 25, and Experiment 1, p. 106. Demarcation current of muscle, Experiment 1, p. 150 (omit last three lines). Uninjured muscle, p. 153. Stimulation by demarcation current, Experiment 1, p. 153. Measurement of electromotive force of demarcation current; compensation method, p. 158. Demarcation current of nerve, p. 159. Action current of muscle, Experiments 1 (rheoscopic frog) and 2, p. 166. Action current of heart, Experiments 1

and 2, p. 173. Secretion current from mucous membrane, p. 183.

The Change in Form. — Volume of contracting muscle, p. 194. The duration of the several periods, p. 196. The excitation wave, p. 199. The contraction wave, p. 201. Influence of load on height of contraction, p. 204. Influence of temperature on form of contraction, p. 205. Superposition of two contractions, p. 209. Superposition in tetanus, p. 210. Graduation of isometric spring, p. 218. Isometric contraction, p. 219. Artificial tetanus of human muscle, p. 221. Natural tetanus of human muscle, Experiments 1 and 2, p. 221. Spontaneous contractions of smooth muscle, p. 221. Influence of load on work done, p. 223. Absolute force of muscle, p. 224. Time relations of developing energy, p. 226. Elasticity and extensibility of a metal spring, p. 229. Of a rubber band, p. 230. Of skeletal muscle, p. 230. Fatigue of skeletal muscle of frog, Experiments 1 and 2, p. 232. Fatigue of human skeletal muscle, Experiment 1, p. 233.

Students better prepared than the average will finish the experiments on muscle and nerve in less than the prescribed time. Such men may perform the additional experiments on muscle and nerve provided below.

ADDITIONAL EXPERIMENTS ON MUSCLE AND
NERVE

[To be begun only in case the first list is finished in less than the prescribed five weeks. These additions comprise the experiments in "An Introduction to Physiology," Part I, not included in the first list.]

Methods of Electrical Stimulation. — Surface tension, p. 15. Surface tension altered by electrical energy, p. 16. The cell, p. 21. Electrolysis of potassium iodide, p. 27. Graduation of the electrometer, p. 28. Magnetic induction, p. 30. Magnetic field; lines of force, p. 33. To produce electric induction, the lines of magnetic force must be cut by the circuit, p. 33. Electromagnetic induction, p. 33. Make and break induction, p. 34. The inductorium, pp. 35–37. Empirical graduation of inductorium, p. 38. The extra currents at the opening and closing of the primary current, Experiments 1 and 2, pp. 41–42. Induction in nerves, p. 43. Unipolar induction, Experiments 1, 2, 3, 4, 5, and 6, pp. 44–49. Changes in intensity of stimulus with indirect stimulation, Experiments 1 and 2, pp. 63–64. Polar stimulation of muscle, Experiments 1, 2, 3, and 4, pp. 65–67. Polar stimulation in heart; monopolar method, p. 74. Changes in irritability, Experiments 2 and 3, pp. 79–81. Changes in conductivity, Experiment 1, p. 82. Galvanotropism, p. 98. Influence of duration of stimulus, Experiments 1, 3, 4, and 5, pp. 100–102. Rhythmic contraction; skeletal muscle, p. 104. Continuous galvanic stimulation of nerve may cause the periodic discharge of nerve impulses, pp. 105–

106. Polarization current; positive variation, p. 107. Opening and closing tetanus, Experiments 1, 2, 3, and 4, pp. 108–110. Polar excitation in injured muscle, p. 112. Polar inhibition in veratrinized muscle, p. 116. Stimulation affected by the form of the muscle, p. 117. Effect of the angle at which the current lines cut the muscle fibres, p. 118. The induced current, Experiments 1, 3, and 4, pp. 119–121. Polar stimulation by the induced current, Experiment 2, p. 120.

Chemical and Mechanical Stimulation. — Idiomyocardial contraction, p. 127.

Irritability and Conductivity. — Nerve-free muscle, p. 130. Muscle with nerves degenerated, p. 131. The nerve-free embryo heart, p. 131. Irritability and conductivity are separate properties of nerve, Experiment 1, p. 134. Alcohol, Experiment 2, p. 136. Threshold value independent of load, p. 138. Relative excitability of flexor and extensor nerve fibres; Ritter-Rollett phenomenon, p. 139. Specific irritability of nerve greater than that of muscle, p. 141. Irritability at different points of same nerve, p. 142. The excitation wave remains in the muscle or nerve fibre in which it starts, p. 143. The same nerve fibre may conduct impulses both centripetally and centrifugally, Experiment 2, p. 145.

The Electromotive Phenomena of Muscle and Nerve. — Demarcation current of muscle, Experiment 2, p. 151. Oblique section, p. 152. Stimulation by demarcation current, Experiments 2, 3, and 4, pp. 154–155. Interference between the demarcation current and a stimulating current;

polar refusal, p. 155. Measurement of electromotive force of demarcation current, Experiment 1, p. 157. Nerve may be stimulated by its own demarcation current, p. 160. The action current in tetanus; stroboscopic method, p. 168. Rheoscopic muscle tetanus, p. 169. Action current of human muscle, p. 172. Action current of heart; the action current precedes the contraction, p. 174. Current of action of human heart, p. 175. Action current of nerve, Experiments 1 and 2, pp. 178 and 179. Positive variation, p. 179. Positive after current, p. 180. Contraction secured with a weaker stimulus than negative variation, p. 180. Current of action in optic nerve, p. 181. Errors from unipolar stimulation, p. 183. Negative variation of secretion current, p. 184. Electrotonic currents, p. 186. Negative variation of electrotonic currents; positive variation (polarization increment) of polarizing current, p. 188. The electrotonic current as a stimulus, p. 191. Paradoxical contraction, p. 191.

The Change in Form. — Relation of strength of stimulus to form of contraction wave, p. 203. Influence of veratrine on the form of the contraction, p. 208. Muscle sound, Experiments 1, 2, 3, 4, and 5, pp. 211–214. Relation of shortening in a single contraction to shortening in tetanus, Experiments 1, 2, and 3, pp. 215–217. Simple contraction of smooth muscle, p. 222. Tetanus of smooth muscle, p. 223. Total work done; the work adder, p. 224. Total work done estimated by muscle curve, p. 226. Extensibility increased in tetanus, p. 231. Fatigue of skeletal muscle of frog, Experiment 3, p. 233.

Fatigue of human skeletal muscle, Experiment 2, p. 234.

SPINAL CORD AND BRAIN¹

The spinal cord a seat of simple reflexes, Experiments 1 and 2, p. 1. Influence of afferent impulses on reflex action, p. 2. Threshold value lower in end organ than in nerve trunk, Experiments 1 and 2, pp. 2 and 3. Summation of afferent impulses, p. 3. Segmental arrangement of reflex apparatus, Experiments 1 and 2, p. 4. Reflexes in man; from the skin, p. 5. Cornea reflex, p. 5. Throat reflex, p. 6. Pupil light-reflex, p. 6. Consensual reflex, p. 6. Accommodation reflex, p. 6. Knee jerk, p. 6. Ankle jerk, p. 7. Gower's experiment, p. 7. Effect of strychnine on reflex action, p. 8. Removal of cerebral hemispheres, p. 8. Posture, "brainless" frog, p. 9. Balancing experiment, p. 10. Retinal reflex, p. 10. Croak reflex, p. 10. Apparent purpose in reflex action, Experiments 1, 2, and 3, p. 12. Reflex time, p. 13. Reaction time, p. 13. Reaction time with choice, p. 14. Inhibition of reflexes through peripheral afferent nerves, p. 15. Inhibition through central afferent paths; the optic lobes, Experiments 1 and 2, p. 16. The roots of spinal nerves, p. 17. Localization of movements at different levels of the spinal cord, p. 18. Distribution of sensory spinal nerves, p. 19. Muscular tonus; Brondgeests's experiment, p. 20.

¹ Experiments for Harvard Medical Students. Third edition, 1903.

SYMPATHETIC

[Experiments will be announced later.]

CUTANEOUS SENSATIONS¹

Sensations of Temperature. — Mapping of hot and cold spots, p. 21. Outline, p. 21. Mechanical stimulation, Experiments 1 and 2, p. 21. Chemical stimulation, p. 21. Electrical stimulation, p. 22. Temperature after-sensation, p. 22. Balance between loss and gain of heat, p. 22. Fatigue, p. 22. Relation of stimulated area to sensation, p. 23. Perception of difference, p. 23. Relatively insensitive regions, Experiments 1 and 2, pp. 23 and 24.

Sensations of Pressure. — Pressure spots, p. 24. Threshold value, p. 24. Touch discrimination, Experiments 1 and 2, p. 26. After-sensation of pressure, p. 27. Temperature and pressure, p. 27. Touch illusion; Aristotle's experiment, p. 28.

GENERAL SENSATIONS²

Tickle. — 1. Irradiation. 2. After image. 3. Topography. 4. Summation. 5. Fatigue.

Pain. — 1. Threshold value. 2. Latent period. 3. Summation. 4. Topography. 5. Individual variation. 6. Temperature stimuli.

Motor Sensations. — 1. Judgment of weight. 2. Sensation of effort. 3. Sensation of motion.

¹ Experiments for Harvard Medical Students. Third edition, 1903.

² *Ibid.*

TASTE¹

1. Threshold value. 2. Topography. 3. Relation of taste to area stimulated. 4. Electrical stimulation.

SMELL, HEARING

[Experiments will be announced later.]

PHYSIOLOGICAL OPTICS²

Introduction. — Construction of the path of a ray passing through a prism, p. 11. Refraction by convex lenses: principal focus, Experiments 1 and 2, p. 14. Estimation of principal focal distance, p. 15. Conjugate foci, p. 16. Virtual image, p. 17. Construction of image obtained with convex lens, p. 17. Refraction by concave lenses, p. 20. Refraction by segments of cylinders, Experiments 1 and 2, pp. 20–21. Refraction through combined convex and cylindrical lenses, Experiments 1 and 2, pp. 22–23. Spherical aberration by reflection, p. 24. Spherical aberration by refraction, Experiments 1, 2, and 3, pp. 25–26. Dispersion circles, Experiments 1 and 2, p. 27. Myopia, p. 28. Hypermetropia, p. 29. Chromatic aberration, p. 30. Aberration avoided by a diaphragm, p. 32. Numbering of prisms, p. 33. Numbering of lenses, p. 33.

¹ Experiments for Harvard Medical Students. Third edition, 1903.

² An Introduction to Physiology, Part IV, Physiological Optics, pp. 1–99.

Refraction in the Eye. — The eye as a camera obscura, Experiments 1 and 2, p. 35.

The Schematic Eye. — *Cardinal points of the cornea (System A).* Construction drawing of System A, p. 38. Principal focal distances, p. 39. Determination of principal foci by construction, 2, p. 41. Construction of image, p. 41. *Cardinal points of the crystalline lens (System B).* Construction drawing of System B, p. 43. Optical centre, p. 44. Nodal points, p. 45. Principal surfaces, p. 46. The point *s*, p. 47. Principal points, p. 48. Principal focal distances, p. 48. *The cardinal points of the eye (System C).* Principal surfaces, p. 49. Nodal points, p. 51. Principal foci, p. 52. Calculation of the situation and size of dioptric images, Constructions 1 and 2, pp. 54–56. Reduced eye, p. 56. *Relations of the visual axis*, p. 61. Visual angle, p. 62. Apparent size, p. 62. Size of retinal image, p. 63. Acuteness of vision, p. 63. Smallest perceptible image, p. 64. Measurement of visual acuteness, p. 64.

Accommodation, p. 67. Scheiner's experiment, p. 67. Dispersion circles, p. 68. Diameter of circles of dispersion, Experiments 1, 2, and 3, pp. 68–70. Accommodation line, p. 70. *Mechanism of accommodation.* Narrowing of pupil, p. 71. Relation of iris to lens, Experiments 1 and 2, pp. 72–73. Changes in the lens, Experiments 1 and 2, pp. 73–75. *Measurement of accommodation.* Far point, p. 77. Determination of far point, p. 77. Near point, p. 78. Determination of near point, p. 78. Range of accommodation, p. 79.

Ophthalmoscopy. — Reflection from retina, Experiments 1, 2, 3, and 4, pp. 82–84. Influence of

angle between light and visual axis, Experiments 1, 2, and 3, pp. 85-86. Influence of size of pupil, p. 86. Influence of nearness to pupil, p. 86. Ophthalmoscope, Experiments 1 and 2, p. 87. *Direct method.* Emmetropia, Experiments 1 and 2, pp. 88-90. Ametropia; qualitative determination, p. 91. Measurement of myopia, p. 91. Measurement of hypermetropia, p. 93. Measurement of astigmatism, p. 93. *Indirect method,* Experiments 1 and 2, pp. 94-96.

VISION¹

1. Diagnosis of color-blindness. 2. Mapping the field of vision. 3. Mapping the blind spot. 4. The yellow spot. (Additional experiments will be announced later.)

FERMENTATION

1. Isolation of unorganized from organized ferments (*torula ureae*). 2. Hydrolytic action. 3. Rate of zymolysis affected by (*a*) temperature, (*b*) chemical reaction, (*c*) accumulation of product, (*d*) concentration of enzyme, (*e*) condition of material, (*f*) presence of salts. 4. Specific action (*a*) ptyalin, (*b*) pepsin, (*c*) trypsin, (*d*) rennin, (*e*) steapsin, (*f*) fibrin ferment, (*g*) amylolytic ferment of liver. 5. Zymogens. 6. Reversible actions.

¹ The experiments on vision, fermentation, digestion, blood, respiration, and metabolism are at present described in "Experiments for Harvard Medical Students." Third edition, 1903.

DIGESTION

1. Expression of stomach contents. 2. Length of time food remains in the stomach. (Additional experiments will be announced later.)

ABSORPTION. LYMPH

[Experiments will be announced later.]

BLOOD

1. Specific gravity. 2. Separation of morphological constituents from plasma: (*a*) sugar filtration, (*b*) salted plasma, (*c*) cooled horse-blood. 3. Relative volume of corpuscles and plasma. 4. Hydraemia. 5. Counting red and white corpuscles. 6. Estimation of haemoglobin: (*a*) anaemia, (*b*) haemorrhage, (*c*) regeneration. 7. Freezing-point. 8. Alkalinity. 9. Permeability (resistance) of corpuscles. 10. Haemolysis: (*a*) bloods of different species, (*b*) peptone, (*c*) snake venom. 11. Visible changes in coagulation.

SECRETION

[Experiments will be announced later.]

RESPIRATION

Mechanics of Respiration. — 1. Measurement in millimetres of mercury (with artificial scheme) of the intra-thoracic and intra-pulmonary pressure in (*a*) inspiration, (*b*) expiration, (*c*) normal

respiration, (*d*) forced respiration, (*e*) obstructed air passages, (*f*) asphyxia, (*g*) coughing and sneezing, (*h*) hiccough, and (*i*) perforation of the pleura.

Chemistry of Respiration. — Estimation of oxygen, carbon dioxide, and water.

METABOLISM

1. Estimation of respiratory oxygen, carbon dioxide, and water: (*a*) in quiet respiration, (*b*) during muscular exertion. 2. Nitrogenous equilibrium. 3. Effect of exercise upon nitrogenous metabolism. (Additional experiments will be announced later.)

THE CIRCULATION OF THE BLOOD¹

Conversion of an intermittent into a continuous flow, Experiments 1, 2, and 3, pp. 244-248. The relation between rate of flow and width of bed, p. 248. The relation of peripheral resistance to blood-pressure, p. 250. The curve of arterial pressure in the frog, p. 251. The effect on blood-pressure of increasing the peripheral resistance in the frog, p. 253. Changes in the stroke of the pump; inhibition of the ventricle, p. 253. The effect of inhibition of the heart on blood-pressure in the frog, p. 254. The opening and closing of the valves, p. 255. The period of outflow from the ventricle, p. 256. The visible change in form,

¹ An Introduction to Physiology, Part II, pp. 239-314.

p. 257. Graphic record of ventricular contraction, p. 258. All contractions maximal, p. 258. Staircase contractions, p. 259. The isolated apex; Bernstein's experiment, p. 259. Rhythmic contractility of heart muscle, p. 260. Constant stimulus may cause periodic contraction, p. 260. The inactive heart muscle still irritable, p. 261. Refractory period; extra-contraction; compensatory pause, p. 261. The transmission of the contraction wave in the ventricle; Engelmann's incisions, p. 262. The transmission of the cardiac excitation from auricle to ventricle; Gaskell's block, Experiments 1, 2, and 3, pp. 263 and 264. Tonus, p. 265. The influence of "load" on ventricular contraction, p. 265. The influence of temperature on frequency of contraction, p. 266. The action of sodium, calcium, potassium in heart muscle, pp. 266-268. The heart sounds, Experiments 1, 2, 3, and 4, pp. 269-271.

The Pressure-Pulse. — Frequency, p. 271. Hardness, p. 272. Form, p. 272. Volume, p. 273. The pressure-pulse in the artificial scheme, p. 273. The human pressure-pulse curve, Experiments 1 and 2, pp. 274-275. Low tension pressure-pulse, Experiments 1 and 2, p. 277. Pressure-pulse in aortic regurgitation, p. 278. Stenosis of the aortic valve, p. 279. Incompetence of the mitral valve, p. 280. The volume pulse, p. 280.

The Innervation of the Heart and Blood-Vessels. — Preparation of the sympathetic, p. 283. Action of the sympathetic on the heart, p. 284. The preparation of the vagus nerve, p. 286. Stimulation of cardiac inhibitory fibres in vagus trunk, p. 287. Effect of vagus stimulation on the auriculo-

ventricular contraction interval, p. 289. Irritability of the inhibited heart, p. 289. Intracardiac inhibitory mechanism, p. 290. Inhibition by Stannius ligature, p. 290. Action of nicotine, p. 291. Atropine, p. 292. Muscarine, p. 292. Antagonistic action of muscarine and atropine, p. 292. Inhibitory centre of the heart nerves, p. 292. Augmentor centre, p. 294. Reflex inhibition of the heart; Goltz's experiment, p. 295. Reflex augmentation, p. 296. The bulbar vasomotor centre, Experiments 1 and 2, pp. 296 and 297. The vasomotor functions of the spinal cord, Experiments 1, 2, and 3, p. 298. Effect of destruction of the spinal cord on the distribution of the blood, p. 299. The vasomotor fibres leave the cord in the anterior roots of spinal nerves, Experiments 1 and 2, p. 300. Vasoconstrictor fibres in the sciatic nerve, p. 302. Vasodilator nerves, Experiments 1 and 2, p. 303. Reflex vasomotor actions, p. 304.

APPARATUS

A complete list of the articles used in the first-year course, including the additional experiments, page 20, will be found in the Appendix, pages 81-90.

The desk assigned each pair of students is 155 cm. long and 61 cm. wide. A ledge 7 cm. high guards the farther side. At one end are placed a locker 35 cm. wide, and two drawers; a single lock secures the three. Not all the apparatus used in the course can be placed in the locker and drawers at one time. That used in

the earlier chapters is issued first (see Appendix, Form G, page 91). From time to time, articles of the first issue no longer in use are returned to the instructors (see Appendix, Form I, page 94).

The department finds it advisable to maintain a stock of apparatus large enough to enable broken articles to be replaced at once from the reserve. Thus the student is not delayed while repairs are making; moreover, the repairing for the entire course can then be done in the summer, after the instruction is finished. The expense, per instrument, is thereby diminished.

LABORATORY NOTE-BOOK

Each student is required to keep in a laboratory note-book an account of his own experiments and observations. The details of the experiment given in the laboratory publications should of course be omitted. Where the experiment includes a graphic record, such as a muscle curve or a curve constructed upon coördinate paper, the record should be fastened in the laboratory note-book with gummed paper. Diagrams should be employed whenever necessary, but time should not be spent in needlessly detailed drawing of apparatus. The note-books will be collected every Friday and examined by the instructors.

CONFERENCE

The conferences are held in Room A for half an hour five times a week during fifteen weeks. They are devoted to questions and explanations

concerning the work of the course, and are in fact a combination of recitation and lecture. The matters discussed are suggested by the written tests and by the questions placed by the students in question boxes, one of which is set in each laboratory.

WRITTEN TESTS

The written tests are exercises of twenty minutes' duration, held daily during sixteen weeks. On Mondays there is an additional written test, an hour in length. In all cases the student is required to cite the experimental evidence for his statement. The answers are written upon ruled paper of uniform size, 24.5×19.5 cm., printed as follows:

Form B.

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY.

Name.....Date..... 190.....

Desk..... Room.....

Each day's papers are filed in a case, in which a pigeon-hole is provided for each student. In the same pigeon-hole are placed in their turn the student's thesis, laboratory note-book, and final examination papers, constituting a complete record of his work.

The written tests form a most valuable method of instruction. They teach the student to state with precision and brevity the experimental evidence for many of the fundamental conclusions

in physiology. At the close of the first month of instruction men whose work the written tests show to be poor are personally consulted regarding their difficulties, often to their great benefit.

The following questions illustrate the written tests :

State experiments to prove where stimulation begins on closure of the galvanic current. Explain the difference between the stimulating electrodes and the physiological anode and cathode in stimulation of human nerves. What is the reaction of degeneration? What chemical changes take place in dying muscle? Draw the curve expressing the absolute force of muscle from the beginning to the end of the phase of rising energy and state how it is obtained. Mark on the intra-ventricular pressure-curve the moment of opening and closing of the mitral and aortic valves. Give the experimental basis for an explanation of the auriculo-ventricular interval. Describe the action of the vagus nerve upon the heart. Give evidence to show that afferent impulses are transmitted by the posterior roots of spinal nerves. What evidence is there that the fibres passing through the white ramus communicans arborize about a sympathetic cell? Cite experiments to prove that the crystalline lens changes its shape in accommodation. Give evidence that the semi-circular canals are concerned in equilibrium. State the evidence for the existence of hot and cold "spots" on the skin. State the difference between voice and tone. Give a brief account of the digestion of fat. Give proof of the existence of internal secretion. What proof exists

that hæmoglobin and oxygen are in loose chemical combination in the blood? How may a nitrogen equilibrium be established?

SPECIAL DEMONSTRATIONS

A special demonstration is given every Saturday during sixteen weeks. The subjects during 1903 will be as follows:

- Feb. 7. (1) Surface tension altered by energy.
 (2) Extra currents at the opening and closing of the primary current.
- “ 14. Reaction of degeneration in man.
 “ 21. Action current of the human heart.
 “ 28. Electromotive properties of an “artificial nerve.”
- March 7. (1) The muscle sound; experiments of Helmholtz.
 (2) Total work done by muscle; the work-adder.
- “ 14. Stimulation of the cerebral cortex.
 “ 21. (1) The action of the sympathetic on the smooth muscle of the hairs.
 (2) The pigeon deprived of cerebral hemispheres.
 “ 28. The pigeon with severed external semicircular canals.
- April 4. The innervation of the sphincter of the iris.

- April 11. Movements of the stomach and intestines.
- “ 18. The flow of lymph from the thoracic duct.
- May 2. The action of the chorda tympani and the sympathetic nerves on secretion by the submaxillary gland.
- “ 9. The action of the vagus and the superior laryngeal nerves upon the respiratory movements.
- “ 16. (1) The action of the valves in the ox heart.
(2) The inhibition of the mammalian heart.
- “ 23. (1) The action of the depressor nerve upon the vasomotor centre.
(2) The vasomotor fibres in the cervical sympathetic.
- “ 30. A holiday.

The demonstrations are made to not more than ten students at one time. Care is taken that every student shall see the experiments clearly.

RECITATION

A recitation is given weekly during fifteen weeks. The recitation is not an examination; its only purpose is instruction. The questions are asked in an order that will systematically develop the subject treated.

THESES AND THE READING OF INVESTIGATIONS

Each student is required to write a physiological thesis, the material for which must be taken directly from the report of the original investigators. The subjects chosen are as a rule such as will supplement the instruction given in other ways. In 1903 fifty theses will be discussed by the class.

Each student is also required to prepare from the original sources the bibliography of one other subject, and to verify his references, so far as the literature is accessible to him.

Students chosen to read their theses are further required to acquaint themselves with the literature of three other subjects in the list to be discussed by the class. These students will open the discussion upon the subjects which they have thus especially studied.

Before the beginning of the course the following letter of instructions is addressed to each student:

Form C.

INSTRUCTIONS FOR THESIS

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY,
BOSTON, February 2, 1903.

DEAR SIR: —

In the first-year course in physiology, each student is required to write a physiological thesis, the material for which must be taken directly from the original investigations. As many of the investigations are in German or French, you are

requested to state upon the enclosed card (Form D) whether you can read one or both of these languages. On pages 40-45 of the pamphlet entitled "Physiology at Harvard" you will find a list of subjects for theses which will be discussed by the class in 1903, and a second list of subjects for theses to be written but not discussed during the present year. Your record during your first term in the Medical School assigns you to the $\left\{ \begin{smallmatrix} \text{first} \\ \text{second} \end{smallmatrix} \right\}$ list. Your subject will be given you five weeks before your thesis is due. If in the first list, you will find references to the original literature of your subject on pages 40-42 of the pamphlet "Physiology at Harvard." If in the second list, you will receive an envelope bearing the subject of the thesis and the references to original sources. The names of the Boston and Cambridge libraries which contain the physiological journals and other sources may be had from the "List of periodicals, etc. currently received, in the principal libraries of Boston and vicinity," published by the Trustees of the Boston Public Library. Your receipt for the reference card will be taken (Form E). The card must be returned when the thesis is handed in. Your assistance in the correction of errors and omissions in the references will be much appreciated.

The thesis should not exceed two thousand words. It should be written with ink in a Physiological Thesis Book. Every statement not the writer's own must be accompanied by a reference to the original source, giving author's name, name of journal or title of book, year of publication, number of volume, and the page upon which the statement appears. The thesis should begin with a brief outline of the problem and the way in which investigators have attacked it, and should end with a summary of the results attained.

You are also required to write upon Form B a bibliography which you yourself will prepare from the "Centralblatt für Physiologie," the "Jahresbericht für Physiologie," the reviews in the "Journal de physiologie et de pathologie générale," and the original sources. The subject for your bibliography will be placed upon Form E.

Students whose rank entitles them to read theses will further be required to acquaint themselves with the literature of three other subjects in the list to be discussed by the class. References to this literature are given on pages 45-63 of the pamphlet "Physiology at Harvard." The subjects assigned to you will be found upon Form E. Each thesis subject, therefore, will be studied in full by the author of the thesis, and by three disputants. When the thesis is read, the three students who have each prepared that subject will open the discussion.

Very truly yours,

W. T. PORTER.

Form D.

HARVARD MEDICAL SCHOOL,
BOSTON,.....

DEAR SIR: —

I ^{cannot}_{can} read French and German. My preference of subjects for a thesis is as follows:

1.
2.
3.

Very truly yours,

.....

Form E.

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY,
BOSTON,

I have received this day the ^{notice} _{references} for the thesis on

This thesis, together with the reference card, is to be delivered to Professor W. T. Porter not later than

I have also been notified to prepare a bibliography upon the subject

This bibliography, written upon Form B, is to be delivered to Professor W. T. Porter not later than June 1.

I have further been notified to prepare for discussion the original literatures of the three subjects the theses upon which are to be read upon the following days

(See "Physiology at Harvard," pages 45-63)

(Signed)

This form is issued in duplicate. The student will retain one copy.

THESES TO BE DISCUSSED IN 1903

- March 10. The physical nature of protoplasm.
- " 11. The functions of the cell nucleus.
- " 12. Influence of light on protoplasm.
- " 13. Chemotaxis.
- " 14. Phagocytosis.
- " 17. Bacteria in health.
- " 18. Nature of the nerve impulse.
- " 19. Nature of muscular contractility.

- March 20. Ciliary activity.
" 21. The neuron theory.
" 24. Nerve cells in rest and activity.
" 25. Trophic nerves.
" 26. Cross-suturing of nerves.
" 27. Sensory areas in the cortex of the brain.
" 28. Aphasia.
" 31. Reflexes from sympathetic ganglia.
- April 1. Effects of mental states on visceral functions.
" 2. Theories of sleep.
" 3. Accommodation of the eye.
" 4. Color blindness.
" 7. Function of the semicircular canals.
" 8. Functions of the upper respiratory tract.
" 9. Vowel sounds.
" 10. Locomotion.
" 11. Effect of food on the nature of the digestive secretions.
" 14. Movements of the alimentary canal.
" 15. Autodigestion of the stomach.
" 16. Absorption of fat.
" 17. Absorption from the peritoneal cavity.
" 18. Œdema.
" 28. Hæmorrhage and the regeneration of the blood.
" 29. Hæmolysis.
" 30. Physiological effects of high altitudes.
- May 1. Gland cells in rest and activity.
" 2. Elimination of poisons.
" 5. Excretion of urea.
" 6. Internal secretion of the pancreas.

- May 7. Adaptation of organs to new conditions.
- “ 8. Alcohol as food and as stimulant.
- “ 9. Respiratory exchange in the lungs.
- “ 12. Origin of the heart-beat.
- “ 13. Nutrition of the heart.
- “ 14. Origin of glycogen.
- “ 15. Origin of urea.
- “ 16. Fever.
- “ 19. Hibernation.
- “ 20. Cerebral activity and the circulation.
- “ 21. Massage.
- “ 22. Artificial parthenogenesis.
- “ 23. Natural defences of the organism.

THESES TO BE WRITTEN BUT NOT DISCUSSED
IN 1903.

Nature of voluntary muscle contraction.
 Muscle twitch and tetanus.
 Muscle tonicity.
 Smooth muscle.
 Muscle work.
 Influence of heat on muscle.
 Muscle fatigue.
 Heat production in nerves.
 Rate of nerve impulse.
 Chemical stimulation of nerve.
 Nerve degeneration and regeneration.
 Neuromuscular spindles.
 Efferent nerve fibres in posterior roots.
 Localization of neurons.
 Nerve-cell connections of the splanchnic nerves.
 Functions of the bile.

- Cause of death by electric currents.
- Knee jerk.
- Muscle leverage.
- Functions of the epiglottis.
- Inhibition.
- Absorption of proteids.
- Skin absorption.
- Influence of nerves on intestinal absorption.
- Digestion of enemata.
- Phenomena of agglutination.
- Transfusion of blood.
- Origin and fate of the red blood corpuscles.
- Estimation of hæmoglobin in blood.
- Fibrin ferment.
- Specific gravity of blood.
- Origin of lymph.
- Secretion of foreign substances in milk.
- Relation of diuresis to the circulation in the kidney.
- Relations between the functions of the spleen and the pancreas.
- Internal secretion of the thyroid gland.
- Heat production in glands.
- Mode of action of diuretics.
- Water excretion by the skin.
- Internal secretion of the kidney.
- Secretion of bile.
- Diuretic action of sodium chloride.
- Innervation of salivary glands.
- Physiological albuminuria.
- Function of the supra-renal capsules.
- Tea and coffee.
- Male and female respiratory movements.
- Cause of the first respiration.

- Carbon dioxide excretion by skin.
- The relation between high temperature and rapid respiration.
- Cause of death after vagus section.
- Poisoning by carbon monoxide.
- Effects of compression of one lung on respiratory exchange.
- Seat of respiration in the body.
- First heart sound.
- Relation between the heart-beat and the constituents of the blood.
- Coördination of the heart-beat.
- The action of the auriculo-ventricular valves.
- Venous pulse.
- Fibrillary contractions of heart.
- Effects of closure of the coronary arteries.
- Intra-auricular pressure.
- Semilunar valves.
- Pulse curve.
- Voluntary control of heart.
- Negative pressure in the ventricles.
- Physiology of the embryonic heart.
- Influence of gravity on the circulation.
- Action of the vagus nerve on heart.
- Depressor nerve.
- Vasodilator nerves.
- Vasomotor nerves of the lungs.
- Vasomotor nerves of the brain.
- Accelerator nerve of heart.
- Vasomotor nerves of intestine.
- Cerebral circulation and intra-cranial pressure.
- Vascular conditions during sleep.
- Vasomotor nerves of muscle.
- Venomotor nerves.

Income and outgo of iron.
Coloring matters of the body.
Relation between the activity of muscle and its metabolism.
Phosphorescence.
Origin of uric acid.
Origin of the oxalic acid of the urine.
Metabolism in nerve cells.
The effect of varnishing the skin.
Compressed air.
The effect of increase in the oxygen tension.
Effect of meals on nitrogen content of urine.
Nitrogen equilibrium.
Syntheses in animal body.
Relation of urea excretion to muscle work.
Mechanism and innervation of the spleen.
Nitrogen excretion by the skin.
Nature of sugar in blood.
Heat coagulation.
Regeneration of organs.
Relation between foetal pulse and sex.

BIBLIOGRAPHIES FOR THE THESES TO BE
DISCUSSED IN 1903¹

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¹ These bibliographies were prepared by my colleague Professor Cannon.

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CALENDAR

DATE. 1903.	SYSTEMATIC LECTURES.	LABORATORY EXPERIMENTS.	DATE. 1903.
Feb. 3-	(General physiology. Daily	Gen. physiology, includ-	Feb. 3-
Mar. 9	conference.)	ing muscle and nerve.	Mar. 8
" 10	Spinal cord and brain.	Spinal cord and brain.	" 9
" 11	" "	" "	" 10
" 12	" "	" "	" 11
" 13	" "	" "	" 12
" 16	" "	" "	" 13
" 17	" "	" "	" 16
" 18	" "	" "	" 17
" 19	" "	Cutaneous sensations.	" 18
" 20	" "	" "	" 19
" 23	" "	Taste, smell, hearing.	" 20
" 24	Sympathetic.	" "	" 23
" 25	Cutaneous sensations.	" "	" 24
" 26	Taste and smell.	Physiological optics.	" 25
" 27	Hearing.	" "	" 26
" 30	" "	" "	" 27
" 31	" "	" "	" 30
Apr. 1	Vision.	Vision.	" 31
" 2	" "	" "	Apr. 1
" 3	" "	" "	" 2
" 6	" "	Fermentation, diges-	
" 7	Voice.	tion, absorption, lymph,	
" 8	Speech.	blood, secretion, respi-	
" 9	Locomotion.	ration, metabolism.	" 3
" 10	Digestion and absorption.	" "	" 6
" 13	" "	" "	" 7
" 14	" "	" "	" 8
" 15	" "	" "	" 9
" 16	Lymph and blood.	" "	" 10
" 17	" "	" "	" 13
Recess.	" "	" "	" 14
Apr. 27	" "	" "	" 15
" 28	Secretion.	" "	" 16
" 29	" "	" "	" 17
" 30	" "	" "	Recess.
May 1	" "	" "	Apr. 27
" 4	" "	" "	" 28
" 5	Nutrition, diet.	" "	" 29
" 6	" "	" "	" 30
" 7	Respiration.	" "	May 1
" 8	" "	Circulation.	" 4
" 11	" "	" "	" 5
" 12	" "	" "	" 6
" 13	Metabolism and animal heat.	" "	" 7
" 14	" "	" "	" 8
" 15	" "	" "	" 11
" 18	" "	" "	" 12
" 19	Reproduction.	" "	" 13
" 20	" "	" "	" 14
" 21	" "	" "	" 15
" 22	" "	" "	" 18
" 25	" "	" "	" 19
" 26	" "	" "	" 20
" 27	" "	" "	" 21
" 28	" "	" "	" 22
" 29	" "	" "	" 25
" 30	Holiday.	" "	" 26
June 1	" "	" "	" 27
" 2	" "	" "	" 28
" 3	" "	" "	" 29
" 4	" "	Holiday.	" 30
" 5	" "	Circulation.	June 1
		Practical examination.	" 2
		" "	" 3
		" "	" 4
		" "	" 5

LECTURES

The accessory data not already provided in the laboratory work upon muscle and nerve, the circulation, and physiological optics will be given in the conferences held during the experiments upon those subjects. The distribution of the remaining didactic exercises is shown in the accompanying calendar.

The calendar shows that the lectures are delivered after the subject of the lecture has been studied in the laboratory. The lectures accordingly are not elementary. The elements the student has already learned from his own experiments and their accessory data. It is the function of the lecturer to discuss the student's observations and to collate them with the work of other observers. The lectures are held at nine o'clock, the hour most favorable for this purpose. They are of thirty minutes' duration. Experience shows that a carefully planned lecture of thirty minutes may be as effective as one of forty-five or sixty minutes.

OPTIONAL LECTURES

The optional lectures are discussions of original investigations which the lecturer himself has made. The list for 1903 is as follows:

AT 8.30 A.M.

May 12	Prof. Cannon.	Movement of the food in the œsophagus.
" 13	" "	Movement of the food in the stomach.

May 14	“	“	Movement of the food in the intestines.
“ 15	“	“	Directive influence of light on organisms.
“ 18	“	“	Cerebral pressure.
“ 19	Dr. Maxwell.		Voluntary control of the muscles of the hairs.
“ 20	Prof. Porter.		Path of respiratory impulse.
“ 21	“	“	Relation of physical development to success in public school life.
“ 22	“	“	Result of closure of the coronary arteries.
“ 25	“	“	Filling of the heart.
“ 26	“	“	New method for study of intracardiac pressure.
“ 27	“	“	Cause of the heart-beat.
“ 28	“	“	Influence of the heart-beat on the flow of blood through the walls of the heart.
“ 29	“	“	The pulse.

SPECIAL EXPERIMENTAL WORK

During the last two weeks of the course students who have performed the regular laboratory work with distinction may elect to perform special experimental work. Each student is provided

with a sufficiently circumscribed subject, the original sources, a method, and the necessary apparatus. With this careful preparation, many of the fundamental discoveries in the subject chosen may be repeated and the general plan of work pursued by all students of biological science may be acquired.

EXAMINATIONS

In order to receive the degree of Doctor of Medicine the student must have demonstrated to the Department of Physiology that his training in this subject is satisfactory. The character of the student's work during the four months of his instruction counts materially toward his final grade. At the end of the term two formal examinations are held, one of which is practical, while the second is written. Candidates failing in the June examination may be re-examined in September. The practical examination, as is natural in an experimental science, grows in importance each year. The student is required to perform four out of six experiments assigned him by lot. He is examined during two half-days, receiving each day three experiments, from which he must choose two. The character of this test will be understood from the following instructions to students and the list of experiments assigned in June, 1901.

DEPARTMENT OF PHYSIOLOGY, PRACTICAL
EXAMINATION, JUNE 3, 4, 5, 6, 1901

NOTICE

Each student will perform four of the six experiments bearing his number. In each case he will write on one of the blank forms furnished herewith the problem selected and an account of his results. Necessary apparatus not already in the locker may be obtained by presenting a signed requisition. Where the results of the experiment are not expressed in a graphic record, they must be demonstrated to one of the instructors, who will then countersign the student's account of the experiment. Graphic records must be marked plainly with the student's name, placed in a shellacking-frame, and, at the close of the student's work, handed to one of the Staff, together with all three of the problems suggested. No student may leave his desk until his examination is finished.

PRACTICAL EXAMINATION IN PHYSIOLOGY

[Each student is required to make four of the six experiments bearing his number, and to write an account of his observations on the blank furnished herewith. Where the results of the experiments are not expressed in a graphic record they must be demonstrated to the instructor.]

1. Demonstrate polar stimulation by the galvanic current. Show the vasomotor functions of the spinal cord. Demonstrate the inhibition of reflex action in the frog. Furnish experimental evidence for an explanation of the auriculo-ventricular interval. Prove that the galvanic current stimulates during the whole time of its passage through an irritable tissue. Demonstrate the influence of load on ventricular contraction.

2. Show by diagram the method of determining the size of a retinal image. Demonstrate that the nervous impulse must pass to the central nervous system before it can produce a reflex action. Demonstrate the difference in the physiology of smooth and striated muscles. Prove the existence of tonic contraction of muscle. Demonstrate the current of action in muscle or nerve. Give experimental evidence that the vagus connects with the nerve cells in the heart.

3. Show the function of the anterior spinal nerve-roots. Record with the artificial scheme pulse curves of low arterial tension and high arterial tension, and discuss their method of production. Construct a diagram showing the formation of the image in myopia. Prove that the extensibility of muscle is increased in tetanus. Demonstrate the limits of the refractory period and the existence of the compensatory pause. Prove that the demarcation current (current of injury) may act as a stimulus.

4. Show the effect of inhibition of the heart on arterial pressure in the frog. Demonstrate on muscle the different effect of sudden and of gradual increase in intensity of stimulus. Prove the discontinuous nature of tetanic contraction. Show the influence of temperature on the form of the contraction wave of skeletal muscle. Produce evidence that irritability is separable from conductivity. Show that the control of movements is localized at different levels of the spinal cord.

5. Determine the effect of stimulation of the vagus on the beat of the ventricle. Show that all contractions of heart muscle are maximal. Give experimental evidence that a nerve fibre may conduct impulses in both directions. Show that a constant stimulus may cause periodic contraction. Show the influence of fatigue on muscular contraction. Draw a construction showing the formation of the image in the indirect method of observing the retina.

6. Show the action of the sympathetic on the heart. Demonstrate the spreading of impulses in the central nervous system. Record curves showing the influence of changes in the aortic pressure on the interval between the beginning of ventricular contraction and the opening of the semilunar valves (in the artificial scheme). Show the segmental arrangement of the reflex apparatus. Construct a diagram showing the formation of the image in hypermetropia. Show the influence of an increase in peripheral resistance on the blood pressure in the frog.

7. Demonstrate that the cardiac systole is a simple contraction. Show the influence of load on the work done by skeletal muscle. Show where the more complicated coördinated reflex acts have their centres. Prove the independent irritability

of muscle. Show experimental proof of the law of contraction with weak, medium, and strong ascending currents. Make a record of minimal and maximal stimulation and show the effect of summation.

8. Show evidence that the ventricular contraction wave may be transmitted by muscular tissue. Prove that the excitability of a nerve is altered in the neighborhood of the anode and the cathode during the passage of the galvanic current. Secure a record of the effect of duration of stimulus on smooth muscle. Compare an isometric contraction with an isotonic contraction. Obtain from the artificial scheme of the circulation a characteristic pulse curve of aortic regurgitation and explain its production. Demonstrate and discuss the apparent purpose in reflex action.

The character of the written examination will be evident upon reading the following papers :

SEPTEMBER, 1900

[Answer any four questions, but not more than four.]

1. Describe the coagulation of either blood or milk, stating both the physical and chemical phenomena.

2. Describe and draw an artificial scheme upon which the physical phenomena of the circulation of the blood can be demonstrated.

3. Give experimental evidence to show how the tetanic contraction of muscle is produced.

4. Describe fully the interchange between the air in the alveoli and the gases in the blood.

5. Give the complete course of any one of the ascending or descending tracts in the central nervous system.

6. Give experiments establishing the importance of any one of the internal secretions.

JUNE, 1901

[Answer any four questions, but not more than four. The answer to any one question should not exceed three hundred words.]

1. Draw curves showing the changes of pressure in the auricle, ventricle, and aorta from the beginning of one auricular contraction to the beginning of the next. Add brief explanatory notes.

2. Give an account of the physiology of smooth muscle.

3. Discuss the chemistry of respiration.

4. Draw the motor area of the cortex and give evidence in support of the theory of cortical localization.

5. Write a sketch of the physiology of absorption.

SEPTEMBER, 1901

[Answer any three questions, but not more than three. The answer to any one question must not exceed three hundred words. Mention, where possible, experimental evidence in support of your opinion. Matter not bearing directly on the question asked will count against the writer.]

1. Give an account of the physiology of ferments.

2. Describe the principal conducting paths in the spinal cord.

3. Give a general description of the vasomotor nervous system.

4. State experiments in support of a theory of accommodation in the eye.

JUNE, 1902

[Answer any three questions, but not more than three. The answer to any one question must not exceed three hundred words. Mention, where possible, experimental evidence in support of your opinion. Matter not bearing directly on the question asked will count against the writer.]

1. Give an account of the innervation of the heart.
2. Describe the digestion of proteids.
3. Discuss the sensory functions of the skin.
4. Sketch the metabolism of carbohydrates.

SEPTEMBER, 1902

[Answer any three questions, but not more than three. The answer to any one question must not exceed three hundred words. Mention, where possible, experimental evidence in support of your opinion. Matter not bearing directly on the question asked will count against the writer.]

1. Give a brief account of the electrical properties of muscle.
2. Sketch the metabolism of proteids.
3. Discuss the functions of the glomeruli of the kidney.
4. State the principal facts regarding the physiology of the sympathetic nerves.

III

THE ADVANCED COURSE

STUDENTS in the fourth year of the Medical School may elect advanced instruction, at present consisting of one hundred and sixty hours of laboratory study, in any field of physiology. It is to be presumed that such students desire additional work in physiology to fit them for some special field of medicine, for example the diseases of the nervous system; or they may wish to pursue physiology, pathology, or some other biological science as a profession. They will be received into the research laboratories of the department, and will carry on their studies side by side with the members of the Staff. The work will consist of fundamental experiments, the study of accessory data, and the reading of selected original investigations. The student will be guided by personal conferences with the professor in charge, and, if desirable, by informal lectures. He may also attend the optional lectures given in May (see page 39), in which each member of the Staff discusses the subjects which he has himself investigated.

This course counts toward the degree of Doctor of Medicine, and an examination, largely practical, will be required.

IV

PHYSIOLOGICAL RESEARCH

THE laboratories are open at all times to students qualified to undertake research. The following investigations have been published during the past six years:

1896

- PORTER, W. T.: The vasomotor nerves of the heart. Boston medical and surgical journal, 1896, cxxxiv, pp. 39, 40.
- PORTER, W. T.: Weiteres über den Verschluss der Coronararterien ohne mechanische Verletzung. Centralblatt für Physiologie, 1896, ix, pp. 641-647.
- PORTER, W. T.: The use of anthropometrical measurements in schools. Educational review, 1896, pp. 126-133.
- PORTER, W. T.: Further researches on the closure of the coronary arteries. Journal of experimental medicine, 1896, i, pp. 46-70.
- PORTER, W. T.: A new method for the study of the intracardiac pressure curve. Journal of experimental medicine, 1896, i, pp. 296-303.

1897

- MAGRATH, J. B., and H. KENNEDY: On the relation of the volume of the coronary circulation to the frequency and force of the ventricular con-

traction in the isolated heart of the cat. *Journal of experimental medicine*, 1897, ii, pp. 13-34.

PORTER, W. T.: 1. On the cause of the heart-beat. 2. The recovery of the heart from fibrillary contractions. 3. Note on the relation between the beat of the ventricle and the flow of blood through the coronary arteries. *Journal of the Boston Society of the Medical Sciences*, 1897, i, pp. 15-21.

PORTER, W. T.: On the cause of the heart-beat. *Journal of experimental medicine*, 1897, ii, pp. 391-404.

1898

PORTER, W. T.: The recovery of the heart from fibrillary contractions. *American journal of physiology*, 1898, i, pp. 71-82.

PRATT, F. H.: The nutrition of the heart through the vessels of Thebesius and the coronary veins. *American journal of physiology*, 1898, i, pp. 86-103.

PORTER, W. T.: The influence of the heart-beat on the flow of blood through the walls of the heart. *American journal of physiology*, 1898, i, pp. 145-163.

HYDE, I. H.: The effect of distention of the ventricle on the flow of blood through the walls of the heart. *American journal of physiology*, 1898, i, pp. 215-224.

CLEGHORN, A.: The reinforcement of voluntary muscular contractions. *American journal of physiology*, 1898, i, pp. 336-345.

CANNON, W. B.: The movements of the stomach studied by means of the Röntgen rays. *American journal of physiology*, 1898, i, pp. 359-382.

- CANNON, W. B., and A. MOSER: The movements of the food in the œsophagus. *American journal of physiology*, 1898, i, pp. 435-444.
- BANCROFT, F. W.: The venomotor nerves of the hind limb. *American journal of physiology*, 1898, i, pp. 477-485.
- MUSKENS, L. J. J.: An analysis of the action of the vagus nerve on the heart. *American journal of physiology*, 1898, i, pp. 486-510.
- PORTER, W. T.: A new method for the study of the isolated mammalian heart. *American journal of physiology*, 1898, i, pp. 511-518.

1899

- PORTER, W. T.: The coördination of the ventricles. *American journal of physiology*, 1899, ii, pp. 127-136.
- STEWART, C. C.: On the course of impulses to and from the cat's bladder. *American journal of physiology*, 1899, ii, pp. 182-202.
- BAUMGARTEN, W.: Infarction in the heart. *American journal of physiology*, 1899, ii, pp. 243-265.
- CLEGHORN, A.: The action of animal extracts, bacterial cultures, and culture filtrates on the mammalian heart muscle. *American journal of physiology*, 1899, ii, pp. 273-290.
- CLEGHORN, A.: The physiological action of extracts of the sympathetic ganglia. *American journal of physiology*, 1899, ii, pp. 471-482.
- WOODWORTH, R. S.: Studies in the contraction of smooth muscle. *American journal of physiology*, 1899, iii, pp. 26-44.
- MATHEWS, A. P.: The origin of fibrinogen. *American journal of physiology*, 1899, iii, pp. 53-85.

1900

- DEARBORN, G. V. N.: Notes on the individual psycho-physiology of the crayfish. *American journal of physiology*, 1900, iii, pp. 404-433.
- PORTER, W. T., and H. G. BEYER: The relation of the depressor nerve to the vasomotor centre. *American journal of physiology*, 1900, iv, pp. 283-299.
- PORTER, W. T., and W. MUHLBERG: Experiments concerning the prolonged inhibition said to follow injury of the spinal cord. *American journal of physiology*, 1900, iv, pp. 334-342.
- FRANZ, S. I.: On the methods of estimating the force of voluntary contractions and on fatigue. *American journal of physiology*, 1900, iv, pp. 348-372.
- CLEGHORN, A.: The physiological effects and the nature of extracts of sympathetic ganglia. *Journal of the Boston Society of the Medical Sciences*, 1900, iv, pp. 239-242.

1901

- MATHEWS, A. P.: The spontaneous secretion of saliva and the action of atropine. *American journal of physiology*, 1901, iv, pp. 482-499.
- MCCURDY, J. H.: The effect of maximum muscular effort on blood-pressure. *American journal of physiology*, 1901, v, pp. 95-103.
- CLEGHORN, A., and C. C. STEWART: The inhibition time of a voluntary muscular contraction. *American journal of physiology*, 1901, v, pp. 281-286.
- CANNON, W. B.: Cerebral pressure following trauma. *American journal of physiology*, 1901, vi, pp. 91-121.

1902

- CANNON, W. B.: The movements of the intestines studied by means of the Röntgen rays. *American journal of physiology*, 1902, vi, pp. 251-277.
- OPITZ, R. B.: A comparative study in the viscosity of the blood. *American journal of physiology*, 1902, vii, pp. 243-260.
- LILLIE, R. S.: On the oxidative properties of the cell-nucleus. *American journal of physiology*, 1902, vii, pp. 412-421.
- OPITZ, R. B.: The flow of the blood in the external jugular vein. *American journal of physiology*, 1902, vii, pp. 435-459.
- FRANZ, S. I.: On the functions of the cerebrum: I. The frontal lobes in relation to the production and retention of simple sensory-motor habits. *American journal of physiology*, 1902, viii, pp. 1-22.
- WOODWORTH, R. S.: Maximal contraction, "staircase" contraction, refractory period, and compensatory pause, of the heart. *American journal of physiology*, 1902, viii, pp. 213-249.

V

THE SUMMER COURSE

THE summer course in physiology will be given daily during the five weeks from June 29 to August 1, 1903, inclusive. This course will be found to be valuable to instructors of schools and colleges who seek experience in the teaching of physiology by laboratory methods. Students who wish to prepare themselves for the courses in the Medical School, or who may desire to recover ground lost by illness or other misfortune, will also find an opportunity here. The instruction will consist of fundamental experiments performed by the students themselves, and the study of accessory data. An informal lecture or conference will be given daily.

The fee for these thirty days of laboratory instruction, including the necessary material, will be forty dollars.

APPENDIX

APPARATUS

The following articles are required for the experiments upon muscle and nerve, the circulation, spinal cord and brain, physiological optics, and cutaneous sensations (pages 13-24). Additional lists for the subjects in preparation will be issued when the experiments are ready.

Adjustable plate, or nerve holder.¹

Artificial scheme, see circulation scheme.

Balancing board, see board, balancing.

*Band, rubber, diameter 9 cm., for the head.

Beakers, 3, 7 × 6 cm.

Block, 8.6 × 8.6 × 1.6 cm., for +10 D lens, in artificial eye box.

—, 8.6 × 8.6 × 1.6 cm., for cylindrical +7 D lens, in artificial eye box.

—, 8.6 × 8.6 × 1.6 cm., for mirror, in artificial eye box.

—, 8.6 × 8.6 × 1.6 cm., for retina, in artificial eye box.

Board, balancing, 38.5 × 20.5 × 4.5 cm.

—, mesentery, with 6 fine pins.

¹ Articles marked * will be placed in the small wooden boxes.

Book, for laboratory notes, 21×17.5 cm., 180 pages.

—, for thesis, 21×17.2 cm., 32 pages.

Bottle, glass stopper, 9×3.7 cm., 45 c.c. curare ;
2 drops should paralyze a frog in about 10
minutes.

—, 5×3 cm. 20 c.c., with 100 grams of mercury.

—, glass stopper, 13×5.3 cm., 135 c.c. normal
saline.

—, glass stopper, 13×5.3 cm., 135 c.c. saturated
solution zinc sulphate.

—, round, 9.5×4 cm., 72 c.c. distilled water,
cork flush with neck, in artificial eye box.

—, square, $7.5 \times 4.3 \times 4.3$ cm., filled with 68 c.c.
of 75 per cent glycerine tinged with eosin ; cork
flush with neck ; in artificial eye box.

—, flat, $11.5 \times 4.5 \times 2.2$ cm., 60 c.c. chrome alum
solution.

Bottles, 3, glass stoppers, 10×4.2 cm., 70 c.c., for
solutions.

Bowl, earthenware, 18×5.5 cm., 1200 c.c.

Box, black, to cover retina.

—, $43.5 \times 20.4 \times 24$ cm., to mount electrometer.

Boxes, 2, wooden, $12 \times 8.7 \times 5$ cm.

*Brush, camel's-hair, for handling nerves.

Burner, Bunsen, with 150 cm. rubber tubing.

—, fish-tail, with perfect tip.

*Cannula, metal, for aorta, with 10 cm. rubber
tube, and 3.5 cm. glass rod to fit tube.

Carbon dioxide generator, with wash bottle, marble,
20 per cent HCl in beaker, and connecting tubes.

Card, with no. 20 copper wire.

Cell, Daniell, amalgamated zinc, copper, porous cup,
saturated solution copper sulphate, 5 per cent
sulphuric acid.

Cells, 2 dry.

*Cement, colophonium 1 part, beeswax 4 parts,
piece $2 \times 2 \times 2.5$ cm.

Circulation scheme.

Clamp, curved iron.

—, 4 double iron.

Clamp, femur, or muscle clamp.

Clay, potter's kaolin in dish, 5.5×3.7 cm., moistened with 0.6 per cent NaCl solution.

Cloth, cotton, 30×40 cm.

*Collar button.

*Compressor, or cork clamp, or Gaskell clamp.

Cork, diameter 2 cm.

Cotton; fill beaker loosely.

Cylinder, cardboard, 20.5×5.5 cm., for kymograph paper.

—, cardboard box, 26×4 cm., for straws.

—, tin, cork plug, incense, in artificial eye box.

Diaphragm, 0.2 mm. aperture, in artificial eye box.

—, L aperture, in artificial eye box.

—, vertical and horizontal slit, in artificial eye box.

Dish, evaporating, diameter 8 cm.

—, paper, diameter 16 cm., for rocking key.

Dissecting case, with scissors, one large and one small forceps, and a seeker.

*Electrodes, brass, 1 flat, and 1 wire.

—, for inductorium.

*—, needle, 2 pair, each pair passed through a cork, diameter 1 cm.

—, 4 unpolarizable boots, with 4 spring clips, 4 zincs, and 4 no. 27 wires, 10 cm. long, in moist chamber.

—, 2 platinum, 2×0.5 cm.

—, 1 zinc, 7×0.5 cm.

Electromagnetic signal, see signal magnet.

Electrometer, capillary, 20 per cent sulphuric acid, with box, and curved iron clamp.

Ergograph, iron stand with spring, with adjustable rod, hand rest, and curved iron clamp.

Eye, artificial, see optical box.

—, artificial ophthalmoscopic, in artificial eye box.

Frog, sciatic nerve cut 4 days before use.

Frogs, medium size, average number for each student, 45.

—, large, average number for each student, 4.

Frog board, 4 clips.

Frog-heart manometer, see manometer, small mercury.

Funnel ring.

Galvanometer.

*Gas chamber, cork with 2 tubes and 2 electrodes, normal saline clay.

*Handles, 4 wooden, for pressure-hairs.

Heart-holder, wooden stand.

Holmgren's Worsteds, for testing color vision.

*Hooks, 2 S-shaped, one end sharp.

*—, 2 double.

Ice.

Incense, 4 pieces, 3 cm. long, in artificial eye box.

Inductorium.

Ink, black and red.

Interrupter wheel.

*Iron filings, 2 grams.

Jar, glass, battery, 20 × 17 cm., to hold frog.

Key, rocking, with paper dish.

—, simple.

Kymograph.

Lantern, 2 draw tubes.

Lens, convex, +2 D, in small envelope, in artificial eye box.

—, convex, +10 D, in wooden block, in artificial eye box.

—, concave, -2 D, in small envelope, in artificial eye box.

—, cylindrical, +2 D, in small envelope, in artificial eye box.

Lens, cylindrical, +7 D, in wooden block, in artificial eye box.

Lever, light muscle, with small scale pan and vertical pin.

Lever, heavy muscle, with large scale pan.

Ligature, linen thread, 100-yard spool.

—, silk, 2 yards, on spool.

*Magnet, bar.

Manometer, small mercury, with glass float and rubber tube.

Marble, for carbon dioxide generator.

Membrane, finest rubber, diameter 2 cm., for sphygmograph tambour.

*—, rubber dam, diameter 5 cm., for sphygmograph thistle tube.

*Menthol pencil.

Mercury cup, for vibrating reed.

Mesentery board, see board, mesentery.

Metronome, one in each room.

*Micrometer ocular.

Microscope, with jointed stand for horizontal adjustment.

*Millimetre paper, strip 15 × 1.5 cm.

Mirror, concavo-convex, in wooden block, in artificial eye box.

—, plane, glass, 5 × 5 cm., in artificial eye box.

Moist chamber, with 4 unpolarizable boots, 4 clips, 1 femur clamp, and glass shade.

Mounting rod, for boot electrodes.

Muscle clamp, see clamp, femur.

—, lever, heavy, see lever, heavy muscle.

—, lever, light, see lever, light muscle.

—, warmer, with thermometer, lead shot, and ice.

Nerve holder, see adjustable plate.

Optical box, see also

block, holding +10 D lens.

— holding cylindrical +7 D lens.

Optical box, *continued*

- , block, holding concavo-convex mirror.
- , holding retina.
- bottle, round, 9.5×4 cm., 72 c.c. of distilled water, cork flush with neck.
- , square, filled with 75 per cent glycerine tinged with eosin; cork flush with neck.
- cover, plate glass.
- cylinder, tin, with cork plug.
- diaphragm, 0.2 mm. aperture.
- , L aperture.
- , vertical and horizontal slit.
- , black paper, 8.6×8.6 cm., aperture 4 mm.
- incense, 4 pieces 3 cm. long.
- lens, convex, +2 D, in small envelope, in artificial eye box.
- , convex, +10 D, in wooden block, in artificial eye box.
- , concave, -2 D, in small envelope, in artificial eye box.
- , cylindrical, +2 D, in small envelope, in artificial eye box.
- , cylindrical, +7 D, in wooden block, in artificial eye box.
- mirror, plane, silvered glass.
- ophthalmoscopic eye, with rod.
- screen, 1 cm. diameter.
- slide, glass, to cover window.
- , ground glass.
- *Paper, black, 1×1 cm., stroboscopic method.
- , coördinate, 10×10 cm.
- , filter, 1 sheet, 50×50 cm.
- *—, filter, 5×5 cm., soaked in starch paste with potassium iodide.
- , glazed on one side, in cardboard case, 25 sheets, 54.8×18.5 cm. gummed 0.8 cm. at one end.

Paper, *continued*

—, paraffin, 10×7 cm.

—, black, red, green, blue, 1 cm. square.

—, white, 50×60 cm.

—, for written tests, 24.5×19.5 cm., printed.

* —, for writing-points, 5×5 cm.

Paramecia.

*Pins, 6, for mesentery.

Pipette, glass tube, 20 cm. long, diameter 0.6 cm., drawn out.

—, fine glass.

—, rubber bulb.

Plate, glass, 12.8×10.3 cm.

—, glass cover, for artificial eye box.

Plethysmograph tube, with rubber collar 4 cm. long, rubber tubing, and T-tube.

Pole changer, see key, rocking.

Rabbit, uninjured, in rabbit holder, for heart reflex.

Reed, vibrating, 20 cm.

Respiration apparatus, for estimation of O, CO₂, and H₂O:

2 aspirator bottles 36×14 cm., 4000 c.c.

wooden tray containing seven bottles, 18×7.3 cm., 500 c.c.; 1 and 4, filled with soda-lime; 2, 3, and 5 filled with pumice stone soaked in sulphuric acid; 6, a Müller's mercury valve; 7, a quart glass jar, with metal screw top and rubber ring.

12 small velvet corks to stop tubes when not in use.

2 rubber tubes 17×1.1 cm.

4 rubber tubes 5×1 cm.

2 rubber tubes, 40×1.1 cm.

Rheochord.

*Ring, brass, 0.1 gram.

- *Ring, 2 straw fasteners.
- *Rod, glass, 3.5 cm., for aortic cannula tube.
- , glass, L-shaped, Exp. salts on heart-muscle.
- , stirring, 20 cm. long, end drawn out.
- , wooden, 8.5 × 0.6 cm.
- Scale pan, large.
- pan, small.
- Shellac dissolved in 96 per cent alcohol.
- *Shot, lead, 1 gram, split.
- Signal magnet.
- *Slide, glass, 7.6 × 2.6 cm.
- , glass, 7.6 × 3.9 cm., in artificial eye box.
- , ground glass, 7.6 × 3.9 cm., in artificial eye box.
- Sodium chloride, crystals in salt mouth, 30 c.c., bottle.
- Solutions,¹
 - amyl nitrite.
 - acetic acid (strong).
 - alcohol.
 - ammonia, NH₃.
 - atropine, 0.5 per cent.
 - Biedermann's fluid,
 - sodium chloride, NaCl, 5 grams.
 - disodium hydrogen phosphate, Na₂HPO₄, 2 grams.
 - sodium carbonate, Na₂CO₃, 0.4 gram.
 - water, H₂O, 1000 c.c.

¹ The composition of each solution is written upon as many tags as there are pairs of students. The writing is coated with shellac dissolved in alcohol. Experience has shown that not more than three solutions are needed at any one laboratory exercise. The necessary quantity of the liquids is transferred from large stock bottles to three small bottles, upon which the corresponding tags are placed. Each tag has a metal ring which slips readily over the neck of the bottle. At the close of the exercise the tags are stored away, and the bottles carefully washed.

Solutions (*continued*) —

calcium chloride, CaCl_2 , 1 per cent.

copper sulphate, CuSO_4 , saturated solution.

distilled water, H_2O .

ether.

hydrochloric acid, HCl , 20 per cent.

muscarine (trace).

nicotine, 0.2 per cent.

potassium chloride, KCl , 5 per cent.

— chloride, KCl , 0.9 per cent.

Ringer's fluid,

calcium chloride, CaCl_2 , 0.0026 gram.

potassium chloride, KCl , 0.035 gram.

sodium chloride, NaCl , 0.7 gram.

water, H_2O , to make 100 c.c.

sodium carbonate, Na_2CO_3 , 1 per cent.

— chloride, NaCl , saturated solution.

— chloride, NaCl , 0.6 per cent, "normal saline."

— chloride, NaCl , 0.75 per cent.

strychnine sulphate, 0.5 per cent.

sulphuric acid, H_2SO_4 , 5 per cent.

— acid, H_2SO_4 , 0.2 per cent.

veratrine acetate, 1 per cent.

Sphygmograph tambour, with rubber tubing, T-tube, fine straw, finest rubber membrane, thistle tube, rubber dam, and collar button.

Stand, two iron, with 4 clamps.

—, wooden.

Straw, fine, for sphygmograph tambour.

—, large, 36 cm. long, with platinum wire soldered to thin copper wire.

Straws, large, 20 cm. long, 3 in cardboard case.

Tags, written and shellacked, one for each solution except curare, normal saline, and saturated solution zinc sulphate.

Thermometer, diameter not over 0.8 cm.

- *Thread, silk, 50 cm.
- Tin foil, see paper.
- Tortoise, average number for each student, 1.
- Towel, small.
- Tracing holders, 3.
- Tuning fork.
- Vertebral saw.
- Volume tube, 2 corks with hook electrode.
- Wash bottle, for carbon dioxide generator.
- Web board; may use mesentery board.
- *Weights, 10 one-gram in box.
- , 100 ten-gram in large scale pan.
- Wire gauze, 10 × 10 cm.
- Wire, 300 cm., fine copper, no. 33, on spool.
- , copper, 10 cm.
- , iron, 10 cm.
- , zinc, 10 cm.
- Wires, copper, 13 no. 25, 60 cm. long, on spool.
- , copper, 2 no. 25, 150 cm. long, coiled.
- , connecting, for lantern, with plug.
- Work adder.

Form F.

[Requisition blank.]

HARVARD MEDICAL SCHOOL,
 DEPARTMENT OF PHYSIOLOGY,
, 190.....

The undersigned desires the following supplies:

.....

Room.....

(Signed).....

Number.....

¹ Articles used in the experiments on fermentation, digestion, and blood will be included in this list in the third edition, to be issued in 1904.

Form G.

[First issue of apparatus.]

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY,
February 3, 1903.

The undersigned students have received this first issue of apparatus, for experiments upon the methods of electrical stimulation of muscle and nerve, chemical and mechanical stimulation.¹

Adjustable plate.

Beakers, 3.

Bottle, with curare.

—, with 0.6 per cent NaCl.

—, with saturated ZnSO₄.

—, with Hg.

Boxes, 2 small wooden.

Bowl.

*Brush, camel's-hair, for handling nerves.

Burner, Bunsen, and tubing.

—, fish-tail with perfect tip.

Cells, 2 dry.

*Cement, colophonium.

Clamp, curved iron.

—, 4 double iron.

—, femur.

Clay, in glass dish.

*Compressor (Gaskell clamp).

Cork.

Cylinder, cardboard, with 25 sheets kymograph paper.

—, cardboard box, with 3 straws.

Dish, paper, for rocking key.

*Electrodes, brass, one flat and one wire.

—, for inductorium.

¹ Articles marked * will be found in the small wooden boxes.

- *Electrodes, 4 needle, with 2 small corks.
- , 4 unpolarizable (4 boots, 4 spring clips, 4 zincs, in moist chamber).
- Frog board with 4 clips.
- Funnel ring.
- *Hooks, S-shaped, 2.
- *—, double, 2.
- Inductorium.
- Jar, battery.
- Key, rocking, with paper dish.
- , simple.
- Kymograph.
- Lever, light muscle, with vertical pin.
- Ligatures, thread, on spool.
- Millimetre paper.
- Moist chamber, glass cover.
- Mounting rod for unpolarizable electrodes.
- Paper, coördinate.
- , filter.
- *—, for writing points.
- , glazed, 25 sheets in cardboard case.
- Pipette.
- , fine glass.
- , with rubber bulb.
- Plate, glass.
- Porcelain dish.
- Rheochord.
- *Ring, wire straw fastener, 2.
- Rod, glass.
- Scale pan, small.
- Signal magnet.
- Stand, wooden.
- Stands, 2 iron, and 4 clamps.
- Straws, 3 in case.
- Tracing holders, 3.
- Tuning fork.
- *Weights, 10 ten-gram.

Wire, 300 cm. fine copper, on spool.
 —, copper, 10 cm.
 —, zinc, 10 cm.
 Wires, copper, 13, each 60 cm., one, 150 cm.
 (Signed).....

.....
 Desk..... Room.....

Form H.

[Second issue of apparatus.¹]

HARVARD MEDICAL SCHOOL,
 DEPARTMENT OF PHYSIOLOGY,
1903.

The undersigned students have received this second issue of apparatus, comprising the additional pieces necessary for experiments upon irritability and conductivity, electromotive phenomena of muscle and nerve, change in form, nervous system, cutaneous sensations, general sensations, and taste.

Balancing board.

Cork clamp.

Cotton.

Electrodes, 2 platinum, 2×0.5 cm.

Ergograph, with adjustable rod, and hand rest.

Funnel ring.

Heart holder.

Interrupter wheel.

Lever, heavy muscle (rigid muscle lever).

Menthol pencil.

Micrometer ocular.

¹ The electrometer, mounted on box, with curved iron clamp will be separately issued upon the days it is to be used.

Muscle warmer, with mounting rod.

Rod, pointed wooden.

Rubber band.

Scale pan, large, with 90 ten-gram weights.

Shot, lead, split.

Volume tube; rubber stopper with capillary tube,
glass rod, and electrode; cork stopper, with
electrode.

Weights, 10 one-gram, in box.

—, 90 ten-gram, in scale pan.

Wire gauze.

(Signed).....

.....

Desk.....Room

Form I.

HARVARD MEDICAL SCHOOL,

DEPARTMENT OF PHYSIOLOGY,

March....., 1903.

The following apparatus has been returned by
students.....and.....

Room.....Desk.....

[First return list.]

Adjustable plate.

Bottle, with saturated $ZnSO_4$.

Cork clamp.

Dish with clay (kaolin).

Electrodes, 2 platinum, 2×0.5 cm.

—, 4 unpolarizable (4 boots, 4 spring clips, 4
zincs).

Ergograph, with adjustable rod, and hand rest.

Interrupter wheel.

Micrometer ocular.

Moist chamber, glass cover.

Mounting rod for unpolarizable electrodes.

Lever, heavy muscle.

Muscle warmer, with mounting rod.

Nerve holder, see adjustable plate.

Rheochord.

Wire, copper, 10 cm.

—, zinc, 10 cm.

(Signed).....

For Department of Physiology.

Form J.

[Third issue of apparatus.]

HARVARD MEDICAL SCHOOL,

DEPARTMENT OF PHYSIOLOGY,

....., 1903.

The undersigned students have received the following apparatus for the experiments on physiological optics and on vision.

Artificial eye, with rod.

Optical lantern, two draw-tubes.

Optical box, containing

block, holding +10 D lens.

—, holding cylindrical +7 D lens.

—, holding concavo-convex mirror.

—, holding retina.

bottle, round, 9.5 × 4 cm., 72 c.c. of distilled water, cork flush with neck.

bottle, square, filled with 75 per cent glycerine tinged with eosin; cork flush with neck.

cover, plate glass.

cylinder, tin, with cork plug.

diaphragm, 0.2 mm. aperture.

—, L aperture.

—, vertical and horizontal slit.

Optical box, *continued*

— Diaphragm, black paper, 8.6×8.6 cm.,
aperture 4 mm.

Incense, 4 pieces 3 cm. long.

Lens, convex, +2 D, in small envelope.

—, convex, +10 D, in wooden block.

—, concave, -2 D, in small envelope.

—, cylindrical, +2 D, in small envelope.

—, cylindrical, +7 D, in wooden block.

Mirror, plane, silvered glass.

Ophthalmoscopic eye, with rod.

Screen, 1 cm. diameter.

Slide, glass, to cover window.

—, ground glass.

(Signed).....

.....

Desk..... Room.....

[*Form K*, a receipt for apparatus used in the experiments upon fermentation, digestion, absorption, lymph, blood, secretion, respiration, and metabolism, will be printed in the next edition of this pamphlet.]

Form L.

[Fifth issue of apparatus.]

HARVARD MEDICAL SCHOOL,

DEPARTMENT OF PHYSIOLOGY,

....., 1903.

The undersigned students have received the following issue of apparatus, comprising the additional pieces necessary for experiments on the circulation.

Beaker, small.

Board, mesentery.

- Cannula, brass.
 Circulation scheme.
 Collar button.
 Manometer, small mercury, with glass float, glass rod, and rubber tube.
 Membrane, rubber dam, diameter 5 cm.
 Plethysmograph tube with rubber collar 4 cm. long.
 Sphygmograph thistle tube with rubber tubing and T-tube.
 Stand, wooden.
 Tambour, with finest rubber membrane.
 (Signed).....

 Desk.....Room.....

Form M.

HARVARD MEDICAL SCHOOL,
 DEPARTMENT OF PHYSIOLOGY,
, 1903.

The following apparatus has been returned by
 students.....and.....
 Room.....Desk.....

[Second return list.]

- Dish, paper, for rocking key.
 Electrodes, brass, one flat and one wire.
 Key, rocking, with paper dish.
 Lantern, two draw-tubes.
 Mounting rod for unpolarizable electrodes.
 Optical box, containing
 block, holding +10 D lens.
 —, holding cylindrical +7 D lens.
 —, holding concavo-convex mirror.
 —, holding retina.

bottle, round, 9.5×4 cm., 72 c.c. of distilled water, cork flush with neck.

bottle, square, filled with 75 per cent glycerine tinged with eosin; cork flush with neck.

cover, plate glass.

cylinder, tin, with cork plug.

diaphragm, 0.2 mm. aperture.

—, L aperture.

—, vertical and horizontal slit.

—, black paper, 8.6×8.6 cm., aperture 4 mm.

incense, 4 pieces 3 cm. long.

lens, convex, +2 D, in small envelope.

—, convex, +10 D, in wooden block.

—, concave, -2 D, in small envelope.

—, cylindrical, +2 D, in small envelope.

—, cylindrical, +7 D, in wooden block.

mirror, plane, silvered.

ophthalmoscopic eye, with rod.

screen, 1 cm. diameter.

slide, glass, to cover window.

—, ground glass.

Pole changer, see key, rocking.

Rubber band.

Scale pan, large, with 90 ten-gram weights.

Slide, glass.

Tuning fork.

Weights, 90 ten-gram, in scale pan.

(Signed).....

For Department of Physiology.

Form N.

HARVARD MEDICAL SCHOOL,
DEPARTMENT OF PHYSIOLOGY,
....., 1903.

The locker keys must be returned to the mechanic in the gallery of the Physiological Labora-

tory between and
 The deposit
 for the key will be refunded only at this time.
 You are reminded that the cost of replacing lost
 apparatus, the repair of broken parts, and the
 cleaning of apparatus and lockers left dirty will
 be charged against your account.

In Rooms B and H, at o'clock
 morning, receipts will be issued for the following
 apparatus.

[Third return list.]

....., 1903.

The following apparatus has been returned by
 students and
 Room Desk

Beakers, 4, one small.
 Board, mesentery.
 Bottle, with curare.
 —, with chrome alum.
 —, with 0.6 per cent NaCl.
 —, with Hg.
 —, 2, with CaCl_2 and KCl solutions.
 Boxes, 2 small wooden.
 Bowl.
 Brush, camel's-hair.
 Burner, Bunsen, with tubing.
 —, fish-tail with perfect tip.
 Cannula, brass.
 Cells, 2 dry.
 Cement, colophonium.
 Circulation scheme.
 Clamp, curved iron.
 —, 4 double iron.
 —, femur, see muscle clamp.
 Collar button.

- Compressor (Gaskell clamp).
Cylinder, cardboard, with kymograph paper.
—, cardboard box, with 3 straws.
Electrodes, for inductorium.
—, 4 needle, with 2 small corks.
Electromagnetic signal, see signal magnet.
Frog board with 4 clips.
Funnel ring.
Heart holder.
Hooks, S-shaped, 2.
—, double, 2.
Inductorium.
Jar, battery.
Key, simple.
Kymograph.
Lever, light muscle, with vertical pin.
Ligatures, thread, on spool.
Manometer, small mercury, with glass float, glass rod, and rubber dam.
Membrane, rubber dam, 5 cm. square.
Millimetre paper.
Muscle clamp.
Paper filter.
—, for writing points.
—, glazed, with cardboard case.
Pipette, large glass.
—, fine glass.
—, with rubber bulb.
Plate, glass.
Plethysmograph tube with rubber collar 4 cm. long.
Porcelain dish.
Ring, wire straw fastener, 2.
Rod, glass.
—, glass, L-shaped.
Saw, vertebral.
Scale pan, small.
Signal magnet.

Sphygmograph thistle tube with rubber tubing and T-tube.

Stands, 2 iron, and 4 clamps.

—, wooden.

Straws, 3 in case.

Tambour, with finest rubber membrane.

Tracing holders, 3.

Weights, 10 ten-gram.

Wire, fine copper, on spool.

Wires, copper, 13, 60 cm. each, one 150 cm.

Wire gauze.

(Signed).....

For Department of Physiology.

Form O.

[List of apparatus liable to be broken.]

Beakers	20 cents
Boat electrodes	10 "
Capillary tube on electrometer	25 "
Cover to moist chamber	20 "
Gas chamber	10 "
Glass plate	2 "
Jar of Daniell cell	25 "
Pipettes	3 "
Stirring rod	2 "
Tip to gas burner	2 "



