direction. This can best be accomplished by measuring the force in three constant directions, in practise the three axes of rectangular coordinates.

In order to know the torque with which this force acts on the body, it is necessary, in addition, to know the position of the force. Since the horizontal components are situated in the plane of the platform upon which the subject walks, it is only necessary to determine the position of the vertical component in the horizontal plane to effect a complete determination of the force. This position was determined by Elftman and Manter[1] from cinematic records of the distribution of pressure in the sole of the foot, but it can be more easily achieved with the apparatus here described.

The base of the apparatus is so arranged that it can be suspended between two tables. Resting on this base are four vertical compression springs, supporting the lower of two platforms. When a force is exerted on the platform at any point the total compression in the springs measures the vertical component of the force, The relative distribution of this force between the springs depends on the position of the vertical component with respect to the plane of the platform. The quantities to be measured are three in number; it is most convenient to use the vertical displacement of the platform at points 1, 2 and 3 of the diagram. If the displacement is calibrated in terms of the force required to produce it, the sum of the displacements at points 1 and 3 will give the total vertical force and the position of this force can be obtained by equating moments. Although designed for the investigation of movement, this apparatus can also be used for the more traditional measurement of the position of the center of gravity when the body is stationary.

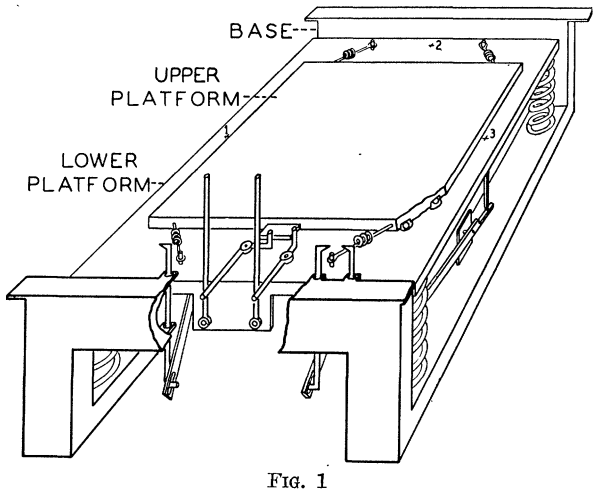


FIG. 1

The horizontal components of force may be measured by means of the displacement of the lower platform in the horizontal plane, since this depends on bending of the springs with respect to their vertical axes. This was proven to be a reliable method by Manter in his investigations on feline locomotion in this laboratory. With the human subject it has been preferable to measure the horizontal components by means of a second platform, parallel to the lower one but separated from it by ball bearings and attached to horizontal springs. From the displacement of the upper platform the components of the force in the direction of movement and lateral to it can be obtained.

The problem of recording the five displacements may be met in various ways. For walking it has been adequately accomplished by lever systems so arranged that the displacements are magnified without distortion and produce movements of indicating levers, all five of which are located in one plane. The indicating levers are photographed with a high-speed cine-camera, the actual speed of which is calculated from the oscillations of a pendulum placed in the photographic field. This camera also provides a record of the position of the foot. For analysis of locomotion another camera is used simultaneously to record the position of the entire individual, walking behind a rectangular grid.

HERBERT ELFTMAN

COLUMBIA UNIVERSITY

[1] H. Elftman and J. Manter, SCIENCE, 80: 484, 1934.

## A PHOTOELECTRIC COLORIMETER

THIS apparatus is the result of an attempt to construct a photoelectric colorimeter which is relatively inexpensive but both highly accurate and sensitive. Many of the colorimeters available measure the current produced by a single photoelectric cell, a procedure which requires a constant light source, the constancy of which is maintained by variable resistances in the lamp circuit,[1,2] by a trickle charger on to a storage battery,[3] or by a diaphragm placed between the lamp and absorption cell.[4] Some of the difficulties with this method of employing a single cell arise from the variations in the current produced by the cell caused by fatigue and changing temperature. These difficulties can be avoided or minimized by using a variable resistance and a galvanometer as a null point indicator to balance the output of two photoelectric cells connected in opposition.[5] Goudsmit and Summerson[6] employed a balanced circuit, but effected the balance by changing the thickness of the layer of solution through which one of the beams of light passed.

[1] A. Weil, SCIENCE, 79: 593, 1934.

[2] K. A. Evelyn and A. J. Cipriani, *Jour. Biol. Chem.*, 117: 365–369, 1937.

[3] I. M. Diller, *Jour. Biol. Chem.*, 115: 315–322, 1936.

[4] C. Sheard and N. H. Sandford, *Jour. Lab. and Clin. Med.*, 14: 558–574, 1929; 15: 483–489, 1930; *Am. Jour. Clin. Path.*, 3: 405–420, 1933.

[5] H. Hartmann, *Ergeb. d. Physiol.*, 39: 412–449, 1937.

[6] A. Goudsmit, Jr., and W. H. Summerson, *Jour. Biol. Chem.*, 111: 421–433, 1935.

The instrument herein described utilizes a balanced circuit, but the balance is achieved by the use of a variable resistance in circuit of one of the photoelectric cells. The apparatus consists of a Leeds and Northrup 2420-c galvanometer, the light of which has been replaced by a 21 c-p. headlight bulb supplied with a 7-volt current from a transformer fed by ordinary house current (110 volts, alternating current). One photoelectric cell (General Electric, Cat. No. 4120833 G 1) is fastened to each side of the galvanometer box after a small window has been cut to allow the passage of light. Interposed between the lamp and the photoelectric cells are 2-inch square light filters, selected from molded filters of Corning Glass Works to transmit only light of the wave-length absorbed by the substance being analyzed, and absorption cells made by drilling a ¾-inch hole in a 1-inch Lucite block (du Pont). The filters, absorption cells and photoelectric cells are shielded to exclude all light save that coming from the lamp. The photoelectric cells are connected in opposition with a decade resistance (Leeds and Northrup, Cat. No. 3976) in the circuit to reduce the output of the left photoelectric cell. The apparatus is illustrated in Fig. 1. The materials and parts cost about one hundred dollars.

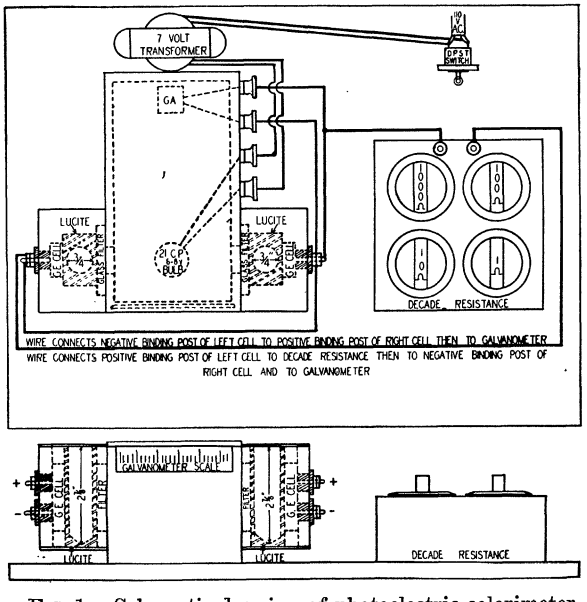


FIG. 1. Schematic drawing of photoelectric colorimeter. Upper drawing—vertical view. Lower drawing—frontal view.

The colorimeter has been employed so far only in the determintion of creatinine concentrations, using the alkaline picrate method. For this Corning filters No. 428 were used. The alkaline picrate diluted 1:2 with water is placed in both the right and left absorption cells and the galvanometer balanced, the reading in ohms representing the blank. After this blank determination the fluid is removed from the right cell by suction. To 20 cc of a creatinine solution 10 cc of alkaline picrate is added and the right absorption cell filled with the mixture. The galvanometer is balanced 12 minutes after the creatinine and alkaline picrate are mixed. The blank is subtracted from this reading. A calibration curve, based on triplicate determinations of dilute creatinine solutions, is shown in Fig. 2. The

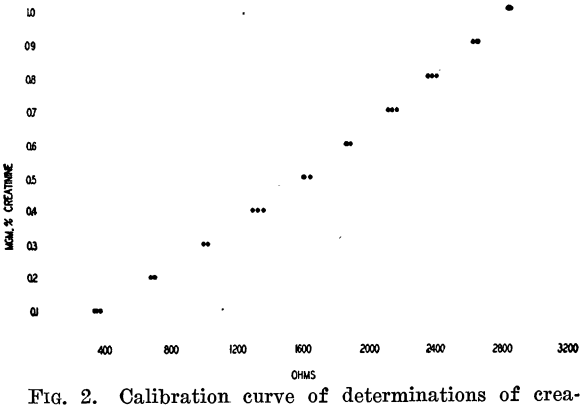


FIG. 2. Calibration curve of determinations of creatinine concentrations with photoelectric colorimeter.

instrument is most accurate in determining low concentrations.

A filter may be substituted for the left absorption cell and a receptacle containing a test-tube used in place of the Lucite cell on the right. The Lucite cells have given more accurate results and, while test-tubes can be used more conveniently, we have preferred to retain the more accurate and slower method.

K. HARE
R. E. PHIPPS
CORNELL UNIVERSITY MEDICAL COLLEGE,
NEW YORK

## BOOKS RECEIVED

LIPPINCOTT, JOSEPH W. *Animal Neighbors of the Countryside.* Pp. 272. Illustrated by LYNN BOGUE HUNT. J. B. Lippincott Company. $2.50.

SAVA, GEORGE. *The Healing Knife; A Surgeon's Destiny.* Pp. x + 310. Harcourt, Brace. $2.50.

STROUD, JAMES B. *Introduction to General Psychology.* Pp. xv + 681. 110 figures. Prentice-Hall. $3.25.

SUTTON, RICHARD M., Editor. *Demonstration Experiments in Physics.* Pp. viii + 545. 408 figures. McGraw-Hill. $4.50.

VOSBURGH, WARREN C. *Introductory Qualitative Analysis.* Second edition, revised. Pp. vii + 222. 11 figures. Macmillan. $2.25.

WALKER, A. EARL. *The Primate Thalamus.* Pp. xxiii + 321. 95 figures. University of Chicago Press. $3.00.

WELLS, A. K. *Outline of Historical Geology.* Pp. xiv + 266. 99 figures. George Allen and Unwin, Ltd., London, and Nordemann Publishing Company, New York. $3.50.