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The Physiograph— An Instrument in Teaching Physiology

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Introduction

THE NEGLECT into which the student laboratory of physiology has fallen is almost without counterpart in a century that has seen unprecedented advances in almost every other sphere of human activity and in the face of broad expansion of funds available for medical research. It would not be difficult to comprehend the competitive position of a business that had suffered so complete a lack of capital re-investment over so long a period. It should be no less apparent that medical and graduate students can no longer be taught with the instruments of a century ago. The opportunity and indeed the necessity thus present themselves of devising practical instrumentation to restore the laboratory of physiology to its proper place in medical education. This does not necessarily call for a totally new approach to physiological instrumentation but rather an extraction and modification of modern research techniques which will fit the more modest requirements of the undergraduate yet still retain the essence of accuracy and originality of experience.

The physiology laboratory as it exists today began when Carl Ludwig combined the smoked drum kymograph with the mercury manometer to produce the recording instrument which revolutionized physiological thinking and teaching. Even before Ludwig others had demonstrated how fruitfully the growing technology of physics could be applied to the biological sciences. The discoveries of Oersted and Faraday, for instance, had provided physiologists with practical stimulators which were almost immediately exploited by the brothers Weber in the elucidation of neuromuscular tetanus and in the discovery of vagal inhibition of the heart.

The significant contribution of the kymograph was that it made possible a wholly new approach to physiological studies through the graphic and permanent registration of physiological events as they vary with time. The excellence of the principle was quickly revealed by the broad spectrum of physiological quantities

which could be recorded by means of a series of ingeniously devised mechanical and electrical accessories. The kymograph, in the hands of Ludwig, Marey, Starling, Sherrington and scores of others, became the mediator of the great 19th century renaissance in physiology. It assisted at the birth of the related discipline of pharmacology in the laboratories of Cushny, Abel and Meltzer. Its principles were incorporated into more specialized instruments like the sphygmograph and the basal metabolism machine to inaugurate the extension of quantitative physiological studies into clinical medicine.

Thus, in its day, the kymograph brought physiological advances directly to the student in the fields of physiology, pharmacology and clinical medicine. In laboratories like those of Bowditch at Harvard and Sherrington at Oxford, the student could repeat the classical experiments of physiology and gain direct personal experience with the sources of physiological knowledge. In this respect the student laboratory and the research laboratory were in full and free communication and a wide horizon of physiological investigation opened before each student as he entered the laboratory. The stimulus that this opportunity presented is clearly manifested by the impressive numbers and quality of the students who were attracted to careers in physiology.

Even before the kymograph appeared, events began to transpire which were first to limit and then to eliminate the kymograph as the primary tool of physiological study. From the striking and classical experiments of Galvani, Matteucci, Du Bois Reymond and others, the electrical behavior of irritable tissues appeared on the scene as a new phenomenon. Measurement of these events was far beyond the ability of the kymograph with its mechanical-electrical accessories to sense and record, and a new recording science developed, based on the rheoscopic frog of Matteucci, the d'Arsonval galvanometer as used with the rheotome of Bernstein, and later, the Lippmann-Marey capillary electrometer adapted to photographic recording. The recording of electrical events with these instruments did not enter the student laboratory, nor did the string galvanometer of Einthoven, which supplanted them, ever become a tool for student use.

When the era of widespread electronic instrumentation began in the middle 20's, the opportunity again arose for the introduction of bioelectric phenomena to student teaching and experimentation. However, the student laboratory had already been dissociated from the field of electrophysiology for more than 35 years, and the tradition perforce had to be accepted that student teaching need not and could not deal directly with a main current of day-by-day advance in physiology. Thus, the student laboratory could no longer open its door to the new fields of investigation as it had in Bowditch's day with the kymograph. Students and teachers alike were not long in becoming aware of this situation. To both it meant a loss of the potential value of the laboratory as the place in which understanding of physiology is gained through direct experiential contact. To the student it meant the loss of the only place where nature could speak directly to him without the mediation of the instructor, and where he could join with Harvey and others who saw things that their instructors were unable to see. To the instructor it meant a divorcement of his own research program, almost wholly laboratory

centered, where each day's experiment conditions those of the days to follow, from his teaching program in the student laboratory.

Attempts have indeed been made to correct this situation, either by improving the accessories of the kymograph such as by electrical recording papers, or by supplementing the laboratory equipment with a few examples of each of the more widely used clinical and research instruments such as the electrocardiograph and oscilloscope.

To the best of our knowledge, however, no full scale attempt has yet been made at a fundamental solution to the problem of the complete re-creation of the student laboratory in physiology. Inquiry among many teachers, deans and administrators reveals a defeatist attitude variously expressed, which reflects almost certainly the frustrations each has met in attempting to solve this problem. Many, indeed, consider the problem insoluble and consider the adaptation of modern electronic instrumentation to be not only impractical for student use, but also unimportant, since time spent in the laboratory is largely unproductive and should be given over to what appear to be more successful teaching methods such as good instructional films. Others express the view that adequate instrumentation would be beyond the ability of the student to operate, requiring graduate engineers or physicists as students, and that the apparatus would be excessively costly, prone to failures and would require a staff of physicists to maintain. Another objection often raised is that an adequate instrumentation program is a form of push-button medicine, and is not in the proper tradition of medical education. Some even felt that the trials and tribulations of attempting to operate the old system were good discipline and therefore valuable exercise even if few or no results were obtained, since in fact one is traditionally supposed to learn more from experiments that do not work than from those that do. Pursuing this logic, one should arrange experiments so that failure is guaranteed.

As a matter of fact it is only within very recent years that an attack on the problem of adequate instrumentation for the student laboratory could have been made. Despite the great advances in technological instrumentation in the fields of research and clinical investigation, the instruments available have been almost prohibitively expensive and poorly adapted for student use. Most particularly, each instrument has been made for a specialized purpose with its own recording system, and is usually incompatible with that of other recorders, so that it has been difficult and expensive to assemble the kind of coordinated system achieved by the more primitive kymograph as one of its best attributes.

Any instrumentation program designed to replace the kymograph must not only be able to duplicate the facilities provided by the kymograph recording system but it must in addition possess its own unique properties akin to those which earned the kymograph its central position in the physiological laboratory. Furthermore the system must reflect the main current of physiological advances and be able to record, display and demonstrate an extremely wide range of physiological phenomena. It must be designed to incorporate recognized principles of modern instrumentation utilizing to the fullest degree the resources of present-day engineering and technology. The program must inherently constitute an integrated system of flexible and in-

terchangeable units capable of accepting new components as they are developed. Most importantly, simplicity and obviousness of operation must be a paramount consideration if it is to be of genuine usefulness in the hands of the students. Essentially this demands readiness, convenience and reliability in the graphic recording or visualization of the body of physiological knowledge.

Translated into more specific terms, this means that the instrumentation program must primarily provide adequate coverage of the heart and circulation, muscle and nerve, respiration and the nervous system. Studies of certain aspects of renal physiology, endocrinology, metabolism, digestion, etc., should be possible by an extension of the same techniques and principles underlying the reproduction of the more accessible phenomena such as blood pressure and respiration

A close examination of the principles of measurement embodied in the kymographic system is a logical starting point. In the broadest sense, the recording of a physiological event with the kymograph can be called single-channel data recording. A system capable of performing such a task has an input, an output and an intermediate processing system. The output is the recording device and the processing system is the interconnecting linkage. When recording muscular pull, for example, the input connection is the attachment to the muscle or tendon, the output is the recording stylus reproducing muscular pull by scratching soot from the kymograph paper, the intermediate processing system is the linkage of pulleys, strings and weights which load and connect the muscle to the writing lever.

When the system is transformed from mechanics to electronics, a most universal and practical system evolves. Expressing the principles in the phraseology of electronic engineering, a single data recording channel consists of a *transducer,* a *processor* and a *reproducer.*

The *transducer* or pick-up is sensitive to and discriminates the characteristic property to be studied and converts changes in this property into an equivalent electrical signal. In a very real way the transducer is akin to a sense organ in its selective sensitivity to changes of one particular kind of energy and in its ability to transform this energy into the electrical code of the central processing system. The transducer differs from the sense organ in that it must interpose no alteration of its own in the conversion of changes in the property as described by duration, frequency and intensity. Unlike the sense organ it must *not* adapt or accommodate. The *processor* handles information submitted by the transducer in an appropriate way for ultimate reproduction. Processing techniques such as addition and subtraction as in a bookkeeping machine, multiplication or electronic mathematical computation, are typical operations of the processing device. Processors may be called upon to introduce time lags or scramble information as in communication systems, or integrate widely disparate data as in artillery fire-control systems. In physiology, the appropriate processing is far simpler, for in most instances the main problem is one of multiplication, or more simply stated, amplification. Care must be taken so that no distortion will be introduced between the input and output throughout the whole course of reproduction, (i.e., linear characteristics are to be achieved). Thus, the problem of the processor in physio-

logical studies is largely the provision of amplification with direct coupled characteristics in order to reproduce faithfully slowly changing events. It is of course recognized that the processor in physiology may be called upon to perform other functions. It may filter undesirable frequencies as in phonocardiography, it may integrate air-flow velocity with time to give volume, or it may perform a vector analysis of wave forms in the electrocardiogram. The *reproducer* displays the processed electrical signal in a simplified visual or audible representation. This representation must be faithful to the signal received in terms of intensity and rate of change. The most useful visual and audible reproducers in physiological representation include the recording galvanometer, oscilloscope and loudspeaker. Very frequently the information can be displayed directly in the form of a graphic record produced by direct inking pen.

Some of the more obvious advantages of the employment of this technique of instrumentation reside in the following: (a) Minimal or absent modification of the event observed, i.e., small energy extraction by highly sensitive transducers. (b) Control of sensitivity and selectivity, i.e., discrimination. (c) Wide range of response time for slow and fast events. (d) Simplicity and accuracy of reproduction of single, multiple, similar or dissimilar, continuous or transient events. (e) Conversion of the property studied to an electrical signal permitting remote location of processing and reproducing equipment. (f) Unlimited recording time with the ability to study any event along different time scales.

In contrast with the above, the principles embodied in the kymograph required that: (a) The inherently small signal reproduced had to arise from the event detected. (b) The phenomenon studied was modified by the mechanics of the processing and reproducing systems. (c) The character of the reproduction was largely dependent upon the mechanical properties of the connecting linkage. (d) The field of application was largely restricted to mechanical events. (e) The subject had to be placed in the close and often inconvenient proximity to the recorder. (f) The length of recording time was limited by the length of a loop of smoked paper.

These characteristics not only eliminated the whole field of bioelectricity from kymographic study but made the recording of a large group of low-energy phenomena a trial of ingenuity, delicacy, and patience that restricted these fields to the expert and to occasional rather than routine success. Most of all, variability and the limited energy available made it necessary to employ recorders of different sensitivities and inertias and hence of unequal response times, making it difficult to correlate in time a number of events registered by different recorders. This disability of course is fully eliminated when amplification is available to equalize the output despite the wide differences in energy input from physiological processes which may range from the 50 kilogram pull of a dog quadriceps in full tetanus to the minuscule energy of a single spike potential in an axon. Beyond these limits is the spectrum of events that are detectable without the necessity of drawing energy from the phenomenon studied, such as oximetry, blood flow velocity, etc. These considerations virtually dictate the adoption of an integrated system based on the electronic transduction of the physiological event to an electrical signal. The instrumentation

program described below, incorporating these principles, has resulted in the construction of 20 physiological recorders called *physiographs*. They have been in almost constant service for over two years, each serving a group of four students.

The physiograph

The physiograph is a recording instrument which accepts a variety of inputs from transducers, processes these signals and reproduces simultaneously three physiological events on a time-calibrated record. The recording speed can be varied to suit the data with suitable calibration present at all times. In addition, those tissues that respond to electrical stimuli can be activated appropriately by use of an integrated stimulator which signals its operation on the record. Cause and effect and time relationships are thus recorded, calibrated and presented simultaneously on a single graphic record.

The basic physiograph is shown in Figure 1. Conspicious in the foreground is the recording chart which is the standard 8½ x 11″ folded paper similar to that used so extensively by electroencephalographers. Above it can be seen four light-colored panels. The first three are the channel amplifiers and the fourth is the stimulator. On the upper right hand corner of the top panel can be seen the paper control unit. Its function is to control the chart-drive motor and energize the timer and signal pens.

Below the paper control unit are the recording styli. Reading from top to bottom, the first three pens are connected to channels I, II and III. The fourth pen performs double duty by calibrating the record with time marks and signalling any other important event such as electrical stimulation or drug injection. To the right of the recording styli can be seen the plastic squeeze-bottle ink wells which can be raised or lowered to provide an adequate flow of ink at all recording speeds.

Housed in this single cabinet are three self-contained channel amplifiers, their recorders, a stimulator

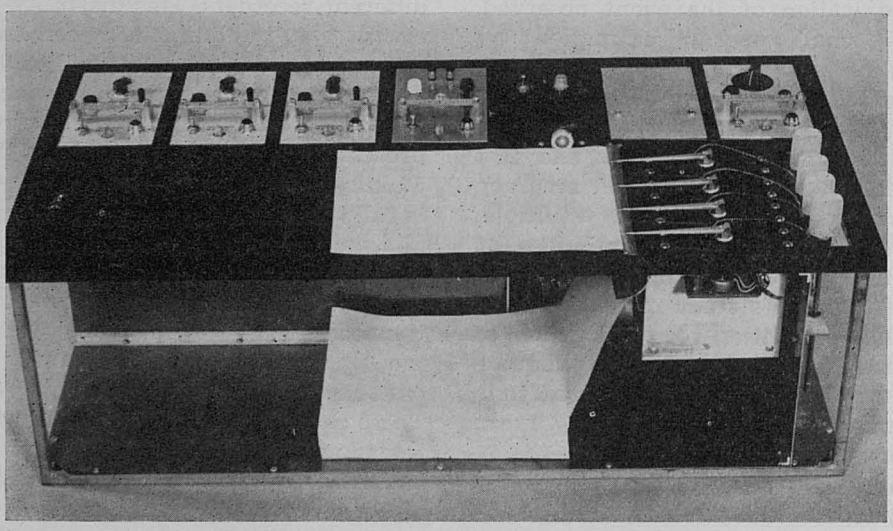


Figure 1—The physiograph.

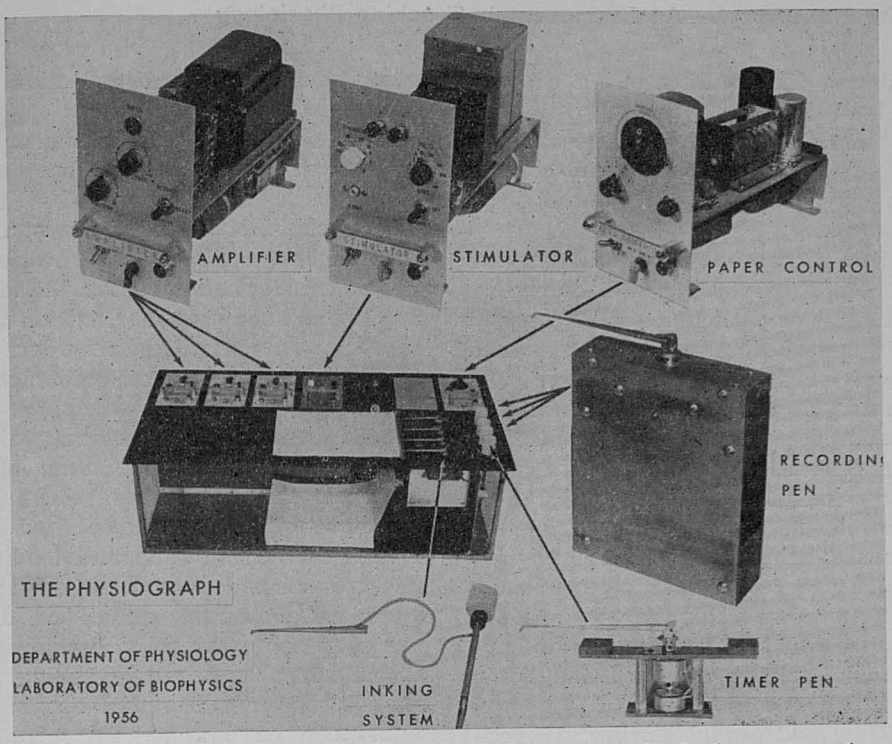


Figure 2—An exploded view of the physiograph showing its basic components.

and a spare opening for any additional experimental unit. In operation, the pick-up, located near the subject, is connected by cable, and recordings of a wide spectrum of physiological events can be made by the student with extreme ease.

The structural skeleton of the physiograph is an open frame chassis, having a black anodized aluminum top panel in which openings for six physiograph units have been provided. The framework is constructed of square steel tubing brazed and protected against rust by heavy cadmium plate. Installed in this cabinet is a universal-connector wiring system which is so extensively standardized that misinstallation of any unit into a wrong opening will permit the particular unit to operate normally or will completely inactivate it. Although the original motivation for inclusion of this system was to provide for service by total interchange of a defective unit, experience has shown that failures have been rare indeed and that this feature now finds its principal use in providing flexibility in recording by selection of appropriate units. An even more desirable characteristic is that an experimental set-up can be easily changed during an experiment as the recordings and events dictate.

There are no other components integral to the basic cabinet. The pens, their styli, the ink wells, and the paper drive motor are easily removed. Each physiograph unit carries a chrome plated handle which identifies its function. Any of the units (3 amplifiers, stimulator and paper control unit) is removable by turning a small lever on its panel one half turn. This unlocks and raises the particular unit approximately one quarter inch, and automatically disconnects it from the power and other circuits. The unit can then be removed by using the handle to slide it upward, free of the

cabinet, like pulling out a drawer. All of the units that fit into the cabinet will function in the cabinet. Figure 2 is an exploded view of the physiograph with its essential components.

The present physiographs provide a recording paper speed extending from faster than EKG or EEG speed (25 and 30 mm. per second) to one sheet (11″) in approximately two hours. Two year's experience has shown that this range is adequate for critical examination of a wide range of physiological variables. It permits the taking of standard electroencephalograms with the physiograph and is adequate to record slow peristaltic waves or the very gradual changes in blood pressure due to hormonal substances or ganglionic blocking agents.

Time and Signal Marker: To register time marks, a timed source of energy is provided to activate a recording stylus. The particular spectrum of time signals used with physiological recording systems extends from second to minute intervals. In this range, experience has shown that the most useful time calibration marks are 1, 5, 30 and 60 seconds. Accordingly, a simple timing unit generating these signals with sufficient energy to operate a recording stylus was incorporated into the paper control unit.

To use a single pen to inscribe time lines is of value but is a waste of resources in view of the other important events requiring signalling. It seemed natural and practical to make the timer pen perform both of these functions by deflection above and below a mid-position. For almost 100 years, timing marks have appeared at the bottom of records as downward "pips." This convention was acknowledged accordingly, and it was decided to signal any other event by an upward deflection of the same pen.

Figure 3 illustrates how the principle of data recording has been applied to a single channel of the physiograph. At the left is a group of transducers or pick-ups for various physiological phenomena. In the center is the basic amplifier and on the right appears the direct recorder.

The transducers were constructed for high conversion efficiency in keeping with Rein's dictum, "Minimum electronics; maximum efficiency in the transducers." A useful principle which is characterized by a high conversion ratio and lending itself directly to the measurement of many physiological quantities depends on photoelectricity. By causing a shade to alter the light falling on a phototube, a substantial electrical signal can be obtained for a relatively small mechanical displacement. This principle has been applied in the construction of a variety of myographs, the pneumograph and the blood pressure transducer. The design of course incorporates linearity of transduction so that the electrical signal duplicates the event itself.

Physiological events occurring naturally as electrical signals require no transduction. They do however require amplification to increase their output to match that of the other transducers. A general-purpose preamplifier has been provided for the bioelectric signals arising in heart, brain, nerve and muscle. The preamplifier can also accept signals from low efficiency transducers such as heart sound microphones, etc.

The processor, a direct coupled balanced power amplifier, enlarges the electrical signals from the transducers and forwards them to the recording pen for graphic reproduction. It also provides appropriate

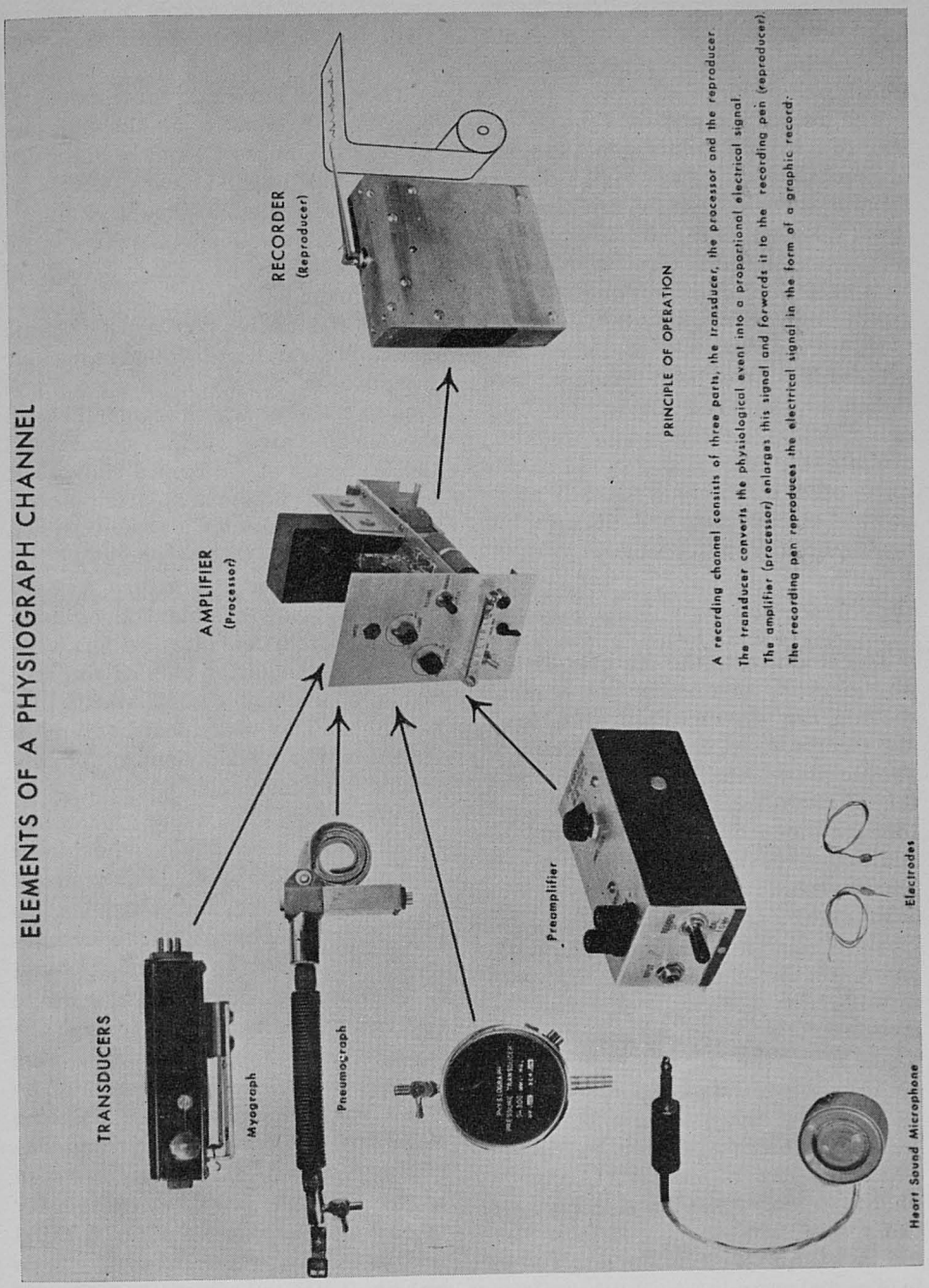

ELEMENTS OF A PHYSIOGRAPH CHANNEL
TRANSDUCERS
Myograph
Pneumograph
Heart Sound Microphone
AMPLIFIER
(Processor)
Preamplifier
Electrodes
RECORDER
(Reproducer)
PRINCIPLE OF OPERATION
A recording channel consists of three parts, the transducer, the processor and the reproducer.
The transducer converts the physiological event into a proportional electrical signal.
The amplifier (processor) enlarges this signal and forwards it to the recording pen (reproducer).
The recording pen reproduces the electrical signal in the form of a graphic record.

FIGURE 3

power for the various transducers and preamplifiers, a single cable making all of the necessary connections.

The recording pen is a large robust d'Arsonval movement capable of producing a maximum pen deflection of four inches. In performance it is closely akin to electroencephalographic and electrocardiographic recorders and combines certain features of both.

Numerous other transducers and accessories have been made or are under development. Devices such as defibrillators, heart sound apparatus, cycling respirators, and oscilloscopes have been completed. All are compatible electrically, and fit into the basic physiograph console.

Typical records

To demonstrate the features of the physiograph, a number of typical records are shown. Figures 4 to 9 are records from various student experiments which serve to illustrate the philosophy of the program and the features of the instrument. In addition they show the manner in which records can be analyzed.

In Figure 4, the effect of load on turtle cardiac muscle is clearly demonstrated. After each beat, the resting load on the ventricle was increased. The response to increased diastolic tension manifests itself by an increase in the force of contraction. The graphic representation of this phenomenon, known to all as Starling's Law of the Heart, appears on the upper right hand corner of the record.

The counterpart of Starling's Law in skeletal muscle is shown in Figure 5. Here, between single twitches, the resting load was increased by increments. The parameters of stimulation and load are noted on the record, and the graph summarizes the effect of force of contraction versus resting tension.

The usual rhythmic contractions of the smooth muscle of the gut are shown in Figures 6a and b. Figure 6a shows the well-known effect of acetylcholine on the tone and amplitude of contractions and Figure 6b illustrates the relaxing effect of epinephrine.

The difference between systemic blood pressure and intraventricular pressure is shown in Figure 7. A plastic catheter was inserted through the aortic valve during systole and the first part of the record shows left ventricular pressure. After a few beats, the catheter was withdrawn into the aorta (between arrows) and the systemic aortic pressure was recorded. During systole the catheter was re-introduced into the left ventricle and the latter part of the record is again that of left ventricular pressure. The electrocardiogram is shown on the second channel for reference purposes.

Practically the whole syndrome of auricular fibrillation is depicted in Figure 8. Channel one is a direct auricular electrogram; channel two is the conventional electrocardiogram from Lead II and channel three shows the blood pressure in the right carotid artery. The typical fibrillating waves of the auricles are emphasized in the first channel. The P waves have disappeared from the EKG and are replaced by rapid fibrillatory waves in channel II, which shows also the complete irregularity of rate and amplitude of R. A rapid and totally irregular pulse is shown by the blood pressure record, and the discrepancy between EKG and pulse rates indicates the existence of a pulse deficit.

The influence of left vagal stimu-

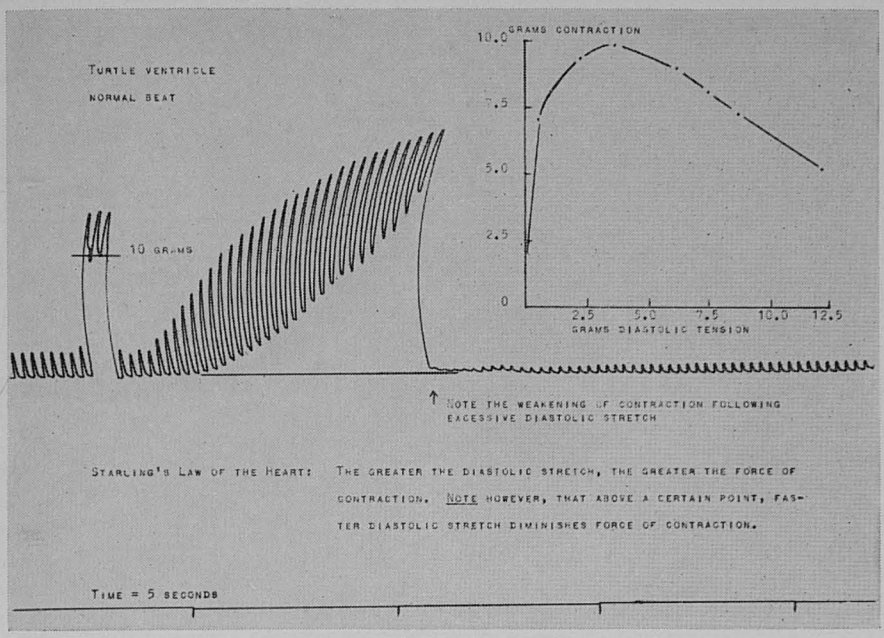


Figure 4—Starling's law of the heart. Legends and the graph, etc. were typed and drawn on the original record sheet.

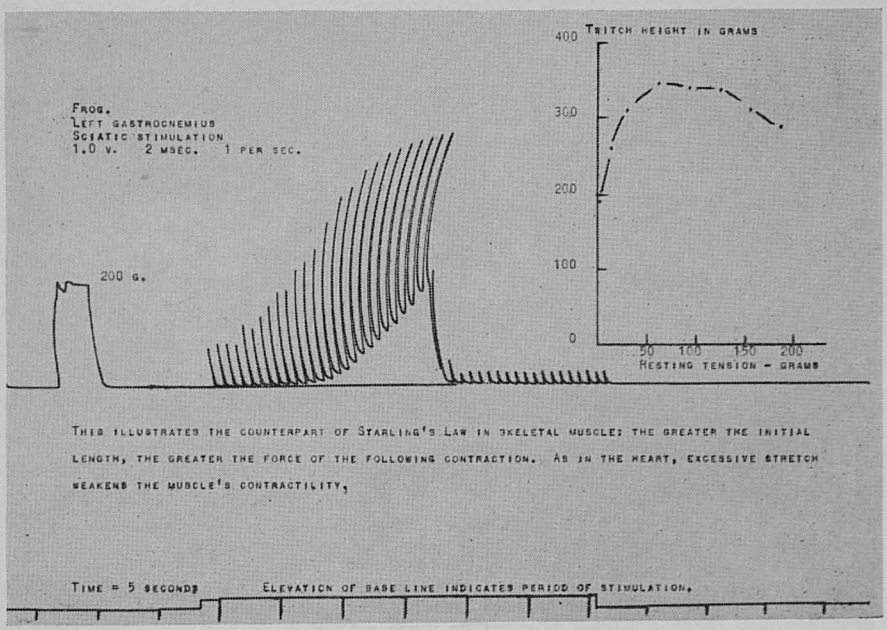
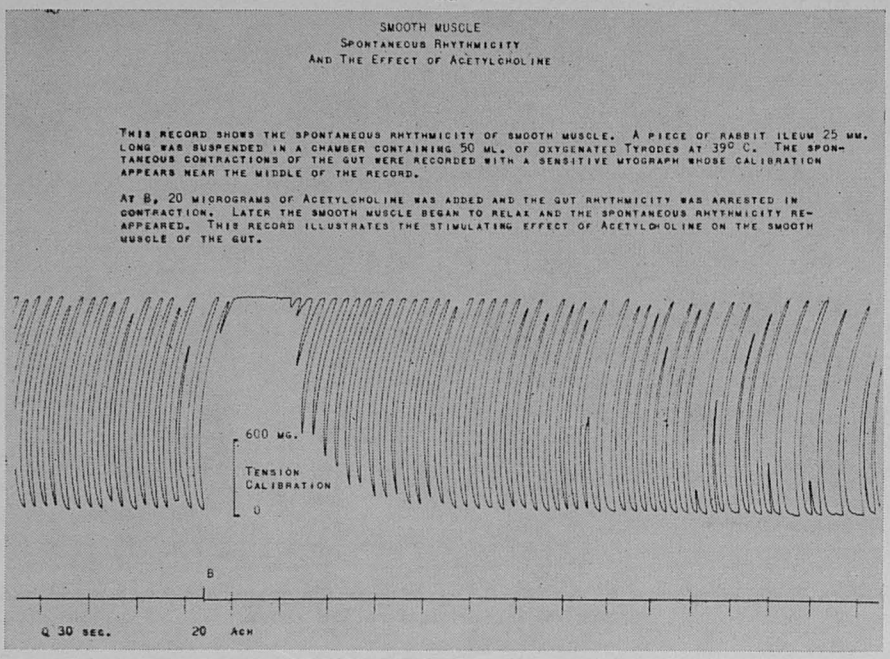


Figure 5—The counterpart of Starling's Law in skeletal muscle. Time and amplification have been changed appropriately to present the data in the same form as Figure 4.

6a



6b

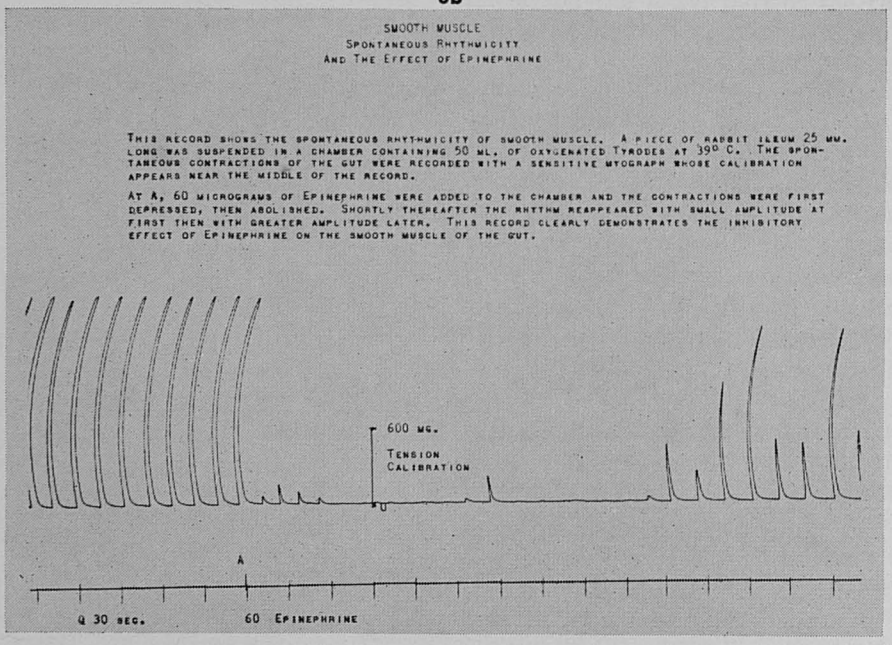


Figure 6—The contraction of smooth muscle. Note again the change in time and amplification. Three different myographs were employed in the three experiments.

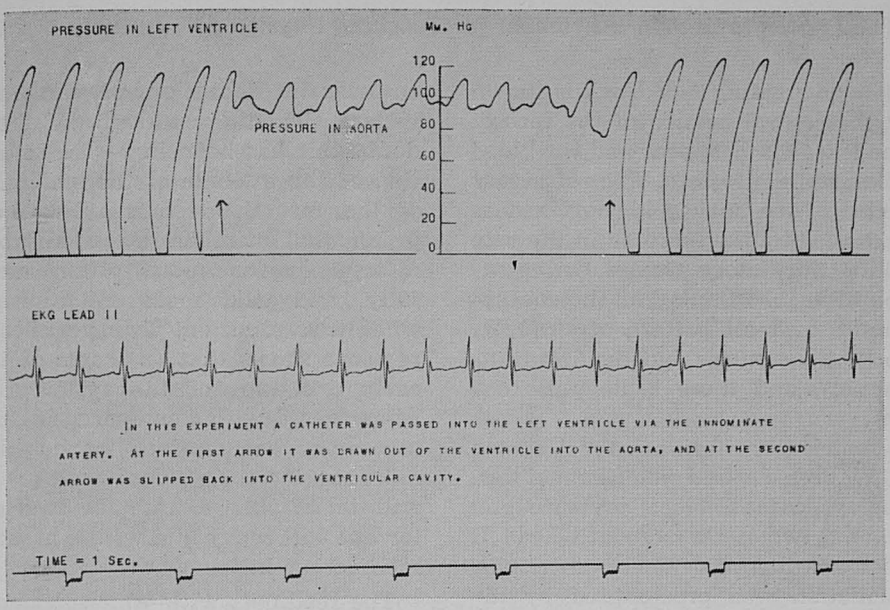


Figure 7—Intraventricular and intra-aortic pressure in the dog.

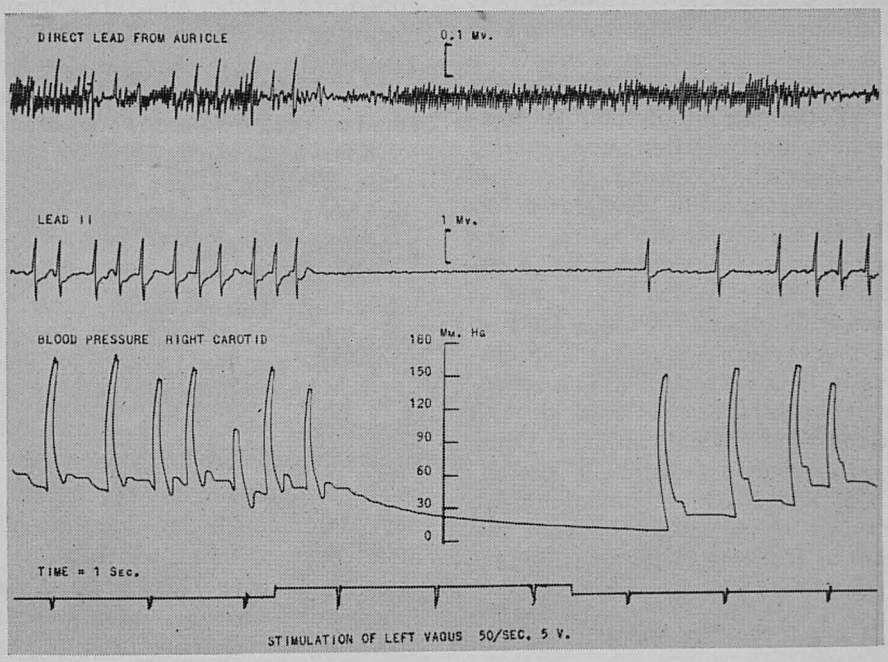


Figure 8—Auricular fibrillation in the dog, produced by application of acetyl-B-methyl choline chloride to the surface of the right atrium.

lation in creating A-V block is shown by the central portion of the record. The R waves disappear and the blood pressure falls to zero. The refractory period of the auricle is shortened as evidenced by the increase in the rate of the fibrillatory waves. On cessation of vagal stimulation, the characteristic over-all pattern of auricular fibrillation returns, but the first beats are slow and there is no pulse deficit.

Ventricular fibrillation is shown in Figures 9a and 9b. Channel one displays carotid blood pressure and channel two is the standard Lead II electrocardiogram. When ventricular fibrillation was precipitated by direct stimulation of the ventricles in Figure 9a, at the time indicated by the signal marker, blood pressure fell to near zero and the normal electrocardiogram was replaced by fibrillating waves. Manual compression, or "massage," of the heart was instituted and the circulation was maintained. A dicrotic wave can be seen after each compression of the heart. In Figure 9b, immediately following the period of manual compression, defibrillation was carried out by passing a strong alternating current through the heart for a few seconds. Following the period of defibrillation, a quiescent period is observed during which the heart is filled with blood. With this load on the myocardium, the first spontaneous beat is very strong. The subsequent beats are smaller and with the return of normal cardiac rhythm, blood pressure is ultimately reestablished. The EKG accompanying the first few beats cannot be seen because of blocking of the preamplifier by the defibrillating current.

Summary of First Two Years' Operation

There can be no question of the enthusiastic reception of the new system by the student. Without doubt this has been in part a reflection of the attitude of the staff, and of the fact that senior as well as junior staff members attended laboratory sessions more often, more fully, and paid more attention to what was going on. Two years' experience shows that (a) some of the early criticisms of the system can be answered with confidence, (b) the laboratory has attained a new significance for the student and (c) it will demand more from the instructor but will repay him with a greater satisfaction in his work.

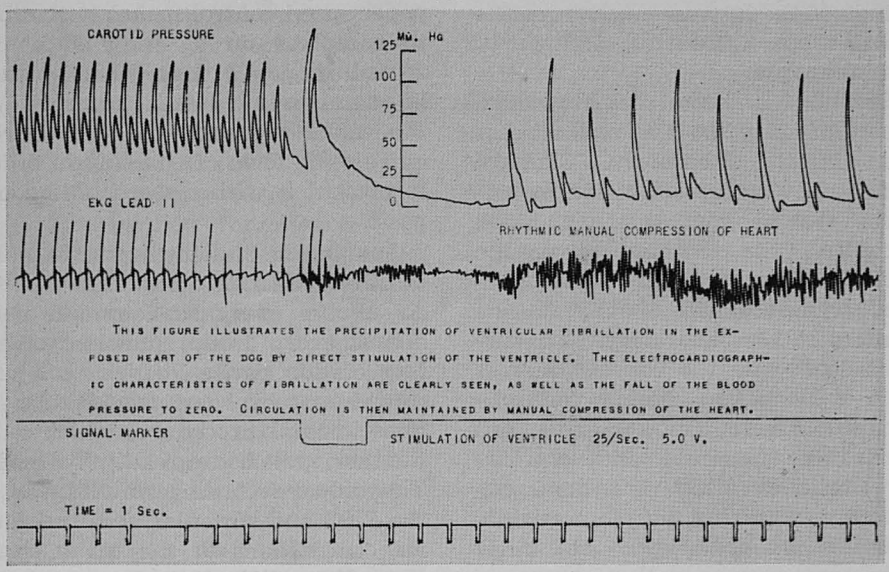
The readiness with which students have gained mastery of the instrument has been surprising. The first day's experiment using a single channel was adequate for most students to familiarize themselves with the equipment and its basic principles. Thereafter channels were added one by one, and three-channel arrangements presented no problems. The location of controls in standardized positions was quickly understood and often students are observed to operate the controls by touch while watching either the record or the animal. It was apparent that this generation of students has become accustomed to radio and television, automatic transmissions, etc., and can operate instrumental controls when the end result of such operation is understandable even though the precise details of intermediate processes are not known.

The instruments have proven to be rugged and capable of operating hour after hour without overheating or altering their performance. A few tubes and fuses have been the only operating casualties. All units were operated for 100 hours before being placed in student use to eliminate

any components prone to early failure, a procedure of proven merit in all electronic instrumentation.

As far as the student is concerned, the prime achievement of the new system is the almost complete reversal of orientation from obtaining results to understanding and interpreting them. Instrumental failures rarely occur, apparatus is ever ready, and in a few minutes the necessary connections are made and records begin to come off in adequate volume for each member of the group to have a full set and for a certain discrimination to be shown in the niceties of recording. The records are instantly usable, so that questions of

9a



9b

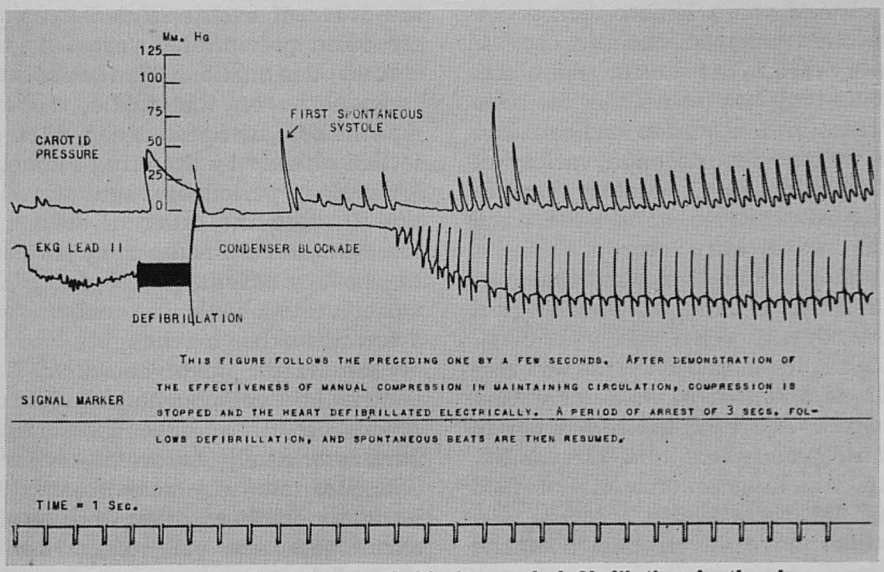


Figure 9—Ventricular fibrillation and defibrillation in the dog.

interpretation arise early in the session. With the de-emphasis on techniques of instrumentation the experimental preparation gets more attention, and its reliability increases; indeed what used to be considered to be the unreliability of the experimental animal probably can be attributed in large part to its neglect at crucial times because of the demands of the instrumentation, or the lethal effect of some requirement of the technique.

Second has been the broadened spectrum of what the student has seen in the laboratory. Classical items of everyday discussion in lecture; systolic and diastolic blood pressures, the dicrotic wave, the electrocardiogram, the electroencephalogram, are now equally routine matters in the laboratory. The student deals with the varying degrees of A-V block, can identify ventricular ectopic beats, and knows the full syndrome of auricular and ventricular fibrillation from first-hand experience, acquiring thus an acquaintance with prototypes of many syndromes that he will encounter in his clinical years. He has seen action potentials, mapped out the cortical sensory areas for touch, sight and sound, and has measured the rate of transmission in nerve fibers. He has written reports on a variety of topics using his laboratory records as the illustrations, and in these and other ways has incorporated his laboratory work as a functional part of his whole body of physiological knowledge.

Third, he has learned to use records as a source of data for future analysis. The ease of calibration in quantity and time and the facility with which large amounts of data may be accumulated, stored, and studied, have given him adequate material for quantitative treatment. Analysis of such fundamental principles as Starling's Law of the Heart and the refractory period of the heart, which in the past have been omitted because of difficulties with calibration or screening enough material on a smoked-drum record, can now be made a part of the most elementary laboratory exercises. On the other hand, the versatility of the paper speed control makes it possible to compress on a single sheet of recording paper data which would be cumbersome when recorded in the usual manner, and would require some form of charting in order to present it within reasonable compass.

Fourth, the student begins to learn to have recourse to experimentation. At almost every session, and with almost every group, questions of interpretation arise which can be solved best by some modification of experimental procedure, which with the new system can readily be made. Thus when recording simultaneously the EKG and auricular and ventricular contractions of the turtle heart it is often difficult to be certain of the order of events, and discussions are often precipitated regarding the correct designation of the several components of the turtle electrogram. These discussions can often be settled quickly by arresting the heart for a short period by vagal stimulation to note the order of events as the beat is resumed, or by slowing the beat sufficiently to separate the various components. To analyse such a record further by changing leads to accentuate in turn auricular and ventricular components is quickly accomplished, and the unchanged parameters help to orient the new data. In this way one observation leads to another, often into useful excursions into the experimental method.

Finally it has been noticed that students have brought problems into the physiological laboratory from other departments and disciplines. This occurs primarily during the project period when the departments of biochemistry and physiology together provide time for a project that may combine the two disciplines or be exclusively in one department. A number of groups carrying out endocrinological projects utilized their physiographs for assay purposes, as did another group utilizing the turtle heart for the bioassay of serum calcium. Another group inspired by pharmacology adapted Handley's method for determining the effectiveness of bronchodilator drugs. In so doing they are not only applying the techniques of physiology to more general use, but are demonstrating that their physiological thinking can be incorporated into their total activity, and that it is proving useful beyond the confines of the laboratory and departmental framework.

The instructor has been no less involved in the changing significance of the laboratory than the student, and in ways that form counterparts to the student's new activities in the laboratory and his attitude toward it. He, like the student, is less occupied with details of technique, and for the same reason. This seeming paradox of a highly developed instrumentation actually reducing time and effort spent on techniques has of course been recognized for some time in industry, and is seen in everyday life in such highly technical devices as the automatic transmission which simplifies driving even though few drivers understand the principles of its operation, much less have the ability to repair one. The instructor is called upon for on-the-spot discussions of the meaning of records obtained in terms of the physiology of the organism studied, and not in terms of the behavior of the apparatus. The laboratory session thus tends to assume the character of bedside teaching where the individuality of a phenomenon found in a particular patient is discussed against the background of the disease in general and its fundamental nature.

The instructor is now in a position to encourage and assist the student in those useful extensions of an experiment which open the door to the experimental method, both because more time is now available, and because the technical problems are more often and more simply surmounted. Thus the chief attribute of a good investigator, the ability to devise simple experimental solutions to problems as they arise, becomes again one of the chief tools of teaching, and aligns the laboratory sessions more closely with the main interests of the intructors. The large variety of unusual physiological occurrences that now present themselves to the student and instructor, in a completely non-scheduled manner, provide ample occasions for this kind of teaching, and, as a matter of fact often serve to start new lines of thinking in the instructor.

It is clear that the new system demands from the instructor, (a) broader interests and knowledge, (b) greater fertility in discussion and suggestions, and, (c) a greater depth of acquaintanceship with the broader subject matter of physiology, than hitherto. It rewards fulfillment of these demands by placing the student laboratory again at the frontier of physiological advances.

El fisiógrafo en la enseñanza de la Fisiología

El descuido que ha sufrido el laboratorio de Fisiología, en un siglo que ha visto tan enormes progresos en casi todas las esferas de

las otras ciencias, y un aumento tan inusitado de los fondos disponibles para la investigación, ha puesto en evidencia lo inadecuado de los instrumentos que aun se usan en esos laboratorios, y la necesidad de inventar otros nuevos que devolvieran al laboratorio de Fisiología su lugar propio en la Educación Médica. Aunque algunos esfuerzos se hicieron para mejorar los accesorios básicos y para introducir algunos nuevos (como el electrocardiógrafo o el osciloscopio) no se ha intentado hasta ahora una solución fundamental del problema mediante una recreación completa del laboratorio de Fisiología para estudiantes. Las encuestas llevadas a cabo sobre el particular entre instructores y administradores de las Escuelas, revelan, además, una actitud derrotista que refleja las frecuentes frustraciones que éstos sufrieron en sus intentos previos de mejorar la situación. Los autores del presente trabajo, profesores del Departamento de Fisiología del *Baylor University College of Medicine* (Houston, Texas), creen que dicho Departamento está en camino de producir una solución del problema con la construcción y uso de un nuevo instrumento, el *fisiógrafo*, el cual, por medios electrónicos, registra acontecimientos fisiológicos. La estructura, funcionamiento y aplicación de ese aparato están descritos detalladamente en este informe, que contiene, además, una serie de descripciones gráficas.

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Separatas de este artículo, en español, podrán obtenerse si son solicitadas por un minimum de 25 lectores.

By His Own Hand

The highest death rates from suicide in both sexes are found in Japan, Denmark, Austria and Switzerland and the lowest are reported in Ireland, Northern Ireland, Chile, Scotland and Spain.

Within the United States the rate for the white population is almost three times that of the non-white population, so states the World Health Organization according to a recent survey. The survey further states that more men are prone to suicide than women.