Cassegrain secondary mirror. This would minimize the size of the telescope—and hence the expense—as well as make it easier to handle. Such a design is already in existence. The optics, mounting, and driving mechanism should all be of the finest construction so that very small diaphragms might be safely used.

If such an observatory were to be established, there is no question but that it would make a very substantial contribution to our astrophysical knowledge at a fraction of the initial cost of a very large reflector. It would also provide a real opportunity for guest investigators from the Middle West and the East, who are seriously handicapped at present by their climate and often by city lights. "Home" researches in objective-prism spectroscopy and photographic photometry would be greatly strengthened by additional photoelectric observations. Serious photoelectric work is being accomplished or contemplated at many observatories in the eastern half of this country, including Harvard, Princeton, Pennsylvania, U. S. Naval Observatory, Virginia, Case, Ohio State, Michigan, Vanderbilt, Wisconsin, and Indiana. Such work is invaluable both in the training of graduate students and in the development of photoelectric equipment and experience. All these observatories—and others—should be intensely interested in the establishment of a permanent desert observatory devoted to photoelectric research. Here, then, is a superb opportunity which, if brought to fruition, would make possible an ever-continuing series of important investigations pursued under optimum conditions.

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Application of Echo-Ranging Techniques to the Determination of Structure of Biological Tissues[1]

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THE RESULTS OF PRELIMINARY STUDIES on the use of a narrow beam of 15 megacycle pulsed ultrasonic energy for the examination of the histological structure of tissues have been sufficiently encouraging to warrant the development of the apparatus that is the subject of this report.

Whereas the initial method of examination of tissues gave records of histological structure in one dimension analogous to a needle biopsy, the method to be described was designed to give a two-dimensional picture such as would be obtained by adding up the information from a series of needle biopsies taken in one plane across a given piece of tissue. Such differentiation of soft tissue structure is without precedent in the biological field. Theoretically it was thought possible to record soft tissue structure by tracing the information obtained from a sound beam sweeping through the tissues onto a fluorescent television screen. Thus, a tumor could be detected in soft tissues, provided the echoes returning from the tumor differed from the echoes returning from the tissue of origin of the tumor. Differences of sufficient magnitude obtained from the needle biopsy method of examination have already been demonstrated in the pilot studies reported elsewhere (*1–4*). The initial studies covered a variety of common tumors arising in the human stomach, brain, and breast. Work subsequent to these studies has confirmed the findings on a larger and wider scale.

Definition of terms. It is necessary to introduce some new words in order to make it possible to describe the

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[2] We wish to thank Maurice B. Visscher, head of the Department of Physiology, and Henry E. Hartig, head of the Department of Electrical Engineering, University of Minnesota, for their help and suggestions in the preparation of this communication, particularly in regard to the section on terminology.

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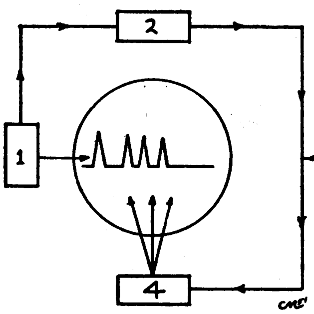

FIG. 1. Arrangement of the basic echographic system.

following material. Accordingly, the whole subject of examination of biological tissues by means of ultrasonic echo returns will be referred to as "Echography," corresponding with the term "electrocardiography." Similarly, the apparatus associated with production of the records will be referred to as an "Echograph." It is the basic machine used for both unidimensional and two-dimensional echography. The applicator units will be referred to as unidimensional "Echoscopes" and two-dimensional echoscopes. The records obtained will be referred to as unidimensional "Echograms" and two-dimensional echograms.

Unidimensional echography. To understand two-dimensional echography, or the moving sound beam method of tracing out the histological structure of biological tissues, it is necessary to review briefly unidimensional echography, or the stationary beam method of examination.

The basic principle of the echograph is the driving of bursts of sound energy into tissues. Sound travels through tissues as pressure waves, so that the effects are entirely mechanical. If the power of the pressure waves and the period of application are kept low, no damage results (*5*). In between the bursts of sound energy, which are generated by a piezoelectric crystal, or transducer, echoes returning from the tissues strike the same crystal, and electric charges are generated. These charges are amplified greatly and are made to modify a beam of electrons sweeping back and forth on the face of a television screen at such a rate as to take advantage of persistence of vision. A static trace is thus produced that can be observed with the naked eye and photographed for permanent recording.

The echograph. The arrangement of the components of the electronic system is shown in Fig. 1. An electronic clock (1) times the bursts of sound energy and starts the trace on the face of the television screen (cathode-ray tube). The transmitter (2), upon receipt of the pulse from (1), creates the electrical impulses necessary to cause the piezoelectric crystal (3) to vibrate. The sound leaves the crystal in a narrow beam and penetrates the tissues. Echoes returning from the tissues are received by the same crystal (3), now quiescent, and are amplified by unit (4) to deflect the trace as shown. The process is repeated often enough to give a stable trace that can be observed and photographed.

In practice it has been found possible to use a self-contained instrument, called a unidimensional echoscope (Fig. 2, top), which provides hydraulic coup-

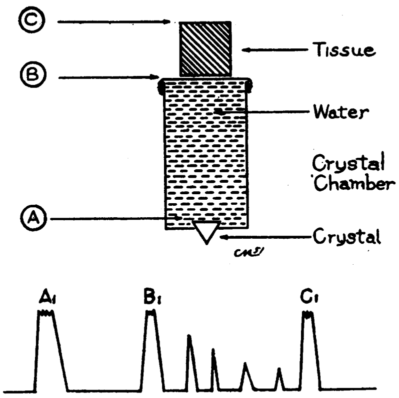

FIG. 2. Cross section of crystal chamber and tissue under examination (top) and a typical unidimensional echogram obtained from the arrangement (bottom).

ling between the crystal, or transducer, and the pieces of tissue under examination. A column of water is placed between the transducer and a wetted rubber membrane, which seals the unit. The sound energy passes in a narrow beam through the water, the wetted rubber membrane, and the tissue, and the echoes are returned. The unidimensional echogram obtained is also shown in Fig. 2 (bottom). A_1 is the transmitted pulse sent out by unit (2) in Fig. 1, which is amplified by unit (4) in the same manner as an echo. B_1 is the echo returned from the rubber-membrane-tissue interface B. C_1 is the corresponding echo returned from the tissue-air interface C. In between B_1 and C_1 can be seen echoes arising from within the tissue.

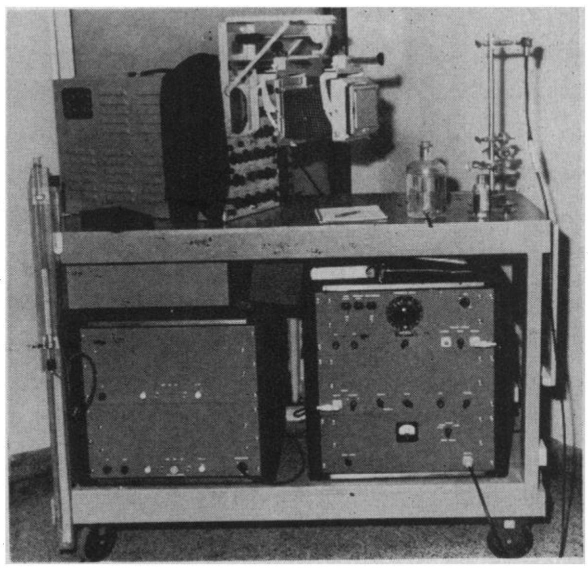

FIG. 3. The complete echographic apparatus as used in hospital. The unidimensional echoscope can be seen clamped to a stand on the right, connected to the transmitter-receiver unit. The cathode-ray screen with the camera in the recording position is to the left on the table.

It should be noted that the strength (loudness) of the echoes is recorded vertically, and the time of occurrence, or depth, of propagation of the echoes in the tissue is recorded horizontally. The part of the trace between A_1 and B_1 is constant and is deleted from the actual presentations in order to use the available space on the television screen to the fullest advantage. (Reference to D in Fig. 7 will show a photographic record of the trace obtained from a piece of normal beef kidney cortex in the manner described here. X and Y correspond to B_1 and C_1 in Fig. 2.)

A photograph of the echograph as used in hospital for cancer detection studies is shown in Fig. 3. The unidimensional echoscope shown in Fig. 2 can be held in the hand and applied to the tissues under examination.

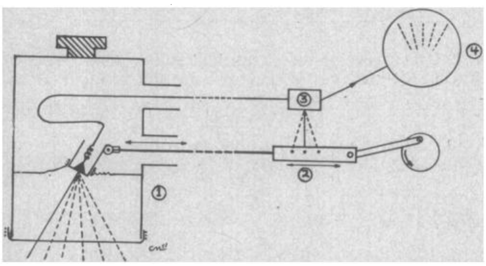

FIG. 4. Diagram illustrating the principle of operation of the two-dimensional echographic modification. The pivoted crystal mounted in the two-dimensional echoscope (1) is driven by the oscillating ram (2), which is connected mechanically to the electronic unit (3), which synchronizes the position of the sweep on the cathode-ray screen (4) with the path of the sound beam in the tissues.

Clinical studies on the living, intact subject indicated that a two-dimensional method of presentation would give additional information, greatly facilitating the interpretation of the unidimensional echograms. The type of record described in Fig. 2 is, in effect, the equivalent of a needle biopsy in that the path of the narrow beam of sound penetrating the tissues does not move for a given record. If a series of such unidimensional echograms could be taken in one plane over an area of skin, a graph could theoretically be made from the echograms, and a structure such as a tumor could be delineated and located in depth, or detected in two dimensions. Practically, such a procedure would be extremely difficult. Fortunately, the same result can be obtained automatically by applying the principles of echo-ranging. A pilot model was fabricated for attachment to the basic echograph so that a rapid change-over could be effected when necessary.

Two-dimensional echography. A functional diagram of the mechanism is shown in Fig. 4. The two-dimensional echoscope (1) containing the crystal mounted on pivots can be seen. (The actual instrument is shown in Fig. 5.) The pivoted crystal is mounted in a water chamber closed by a rubber membrane. As the crystal is moved through an angle of 45 degrees, an area of skin together with the underlying tissue is swept by the sound beam in one plane. The movement of the

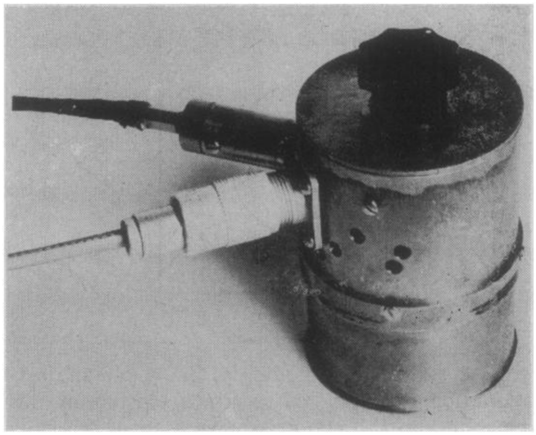

FIG. 5. The two-dimensional echoscope as used in the experiments. The flexible mechanical and electrical connections can be seen.

crystal is synchronized by means of an oscillating ram (2) connected flexibly and mechanically to the crystal and electronically through unit (3) to the television or cathode-ray screen (4). The complete two-dimensional echographic conversion unit is shown in Fig. 6.[4]

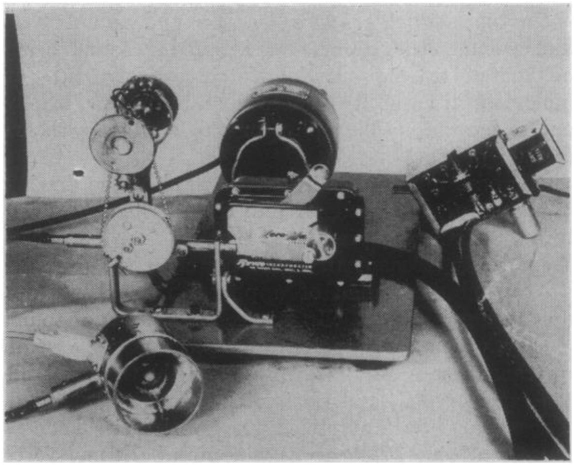

FIG. 6. The units for two-dimensional echographic conversion. Grouped about the oscillating ram, which is driven by a variable speed drive, are the echoscope (left foreground) and the plug-in electronic conversion box (right).

Experiments. To orientate two-dimensional echography with unidimensional echography, a piece of beef kidney cortex approximately 1 cm thick was cut. This specimen was laid upon the wetted rubber membrane of the two-dimensional echoscope at C (Fig. 7), in the same manner as in Fig. 2. It will be noted that the specimen was thinner in the center than at the end of the range of travel of the sound beam, indicated by the broken lines. It will also be noted that the specimen was placed upon the membrane in such a manner that at one extreme of travel of the crystal the sound beam would pass into air. The crystal was

[4] We wish to thank Revco, Incorporated, 405 Thorpe Building, Minneapolis, for supplying the widely variable gearbox shown in Fig. 6.

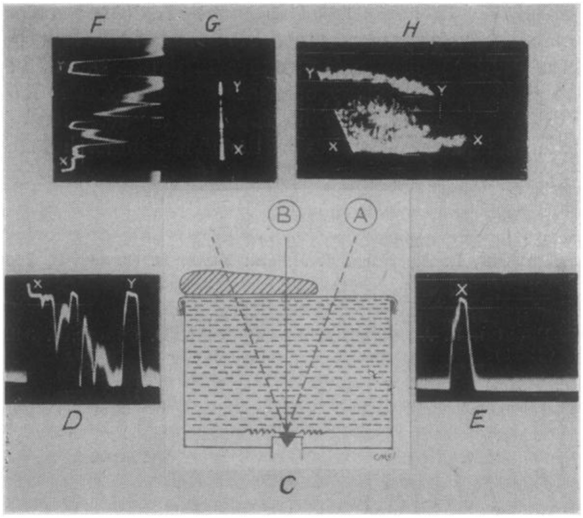

FIG. 7. At C, a cross section of two-dimensional echoscope set up for kidney cortex experiment. (Cf. Fig. 2, top.) At E, the unidimensional echogram of the membrane-air interface X; at D, echoes returned from the kidney cortex tissue between the rubber membrane signal X and the tissue-air leaving interface Y; at F, the echogram D oriented vertically; at G, an alternative method of presentation of echogram D obtained by variation of intensity. The time axis is vertical in both traces. Variations in the strength of echoes can be seen between X and Y as deflections of the baseline in trace F and as areas of differing intensity in the trace G. At H, the two-dimensional echogram obtained by sweeping the unidimensional echogram G. The outline of the tissue can be seen "painted out" by the tissue-air leaving interface Y. The membrane signal X can be discerned at the bottom of the record. It can be seen from H that the kidney did not extend completely across the applicator.

locked in position pointing in the direction A so that the sound beam passed into air after leaving the rubber membrane. The unidimensional echogram E was obtained. It will be observed that the rubber-membrane-air interface returned a strong echo X and that no echoes returned from the air beyond the rubber membrane in the path of the sound beam.

Next the crystal was rotated so that the sound beam traveled in the direction B through the tissue, in a manner analogous to the arrangement shown in Fig. 2. The crystal was locked in this position, and the unidimensional echogram shown at D was obtained. Again the rubber-membrane-tissue interface returned a strong echo X, as did the tissue-air interface Y. In between X and Y can be seen echoes arising from within the kidney substance. In the echogram D the time base for the returning echoes runs from left to right horizontally. This means that the echoes returning from the rubber-membrane-tissue interface X appear sooner on the record than the echoes returning from beyond the rubber-membrane-air interface, because of the delay of sound in the tissue as greater depth of tissue is penetrated. The strength of the returning echoes is shown by the vertical deflections from the base line.

To facilitate understanding the next step, the unidimensional echogram D is turned 90 degrees, and the time base is now oriented from below up, as shown at F.

The next step is to present the echoes shown on the unidimensional echogram F (and D) as spots of varying intensity on the face of the television screen. Thus, the strong rubber-membrane-tissue interface echo X can be seen at the lower part of the unidimensional echogram G, and the strong tissue-air interface Y, at the top. In between are spots of light the brightness of which varies according to the strength of the echoes returning from the kidney tissue with the crystal locked in position B of Fig. 7, at C.

The echogram shown at G was then caused to move in synchronism with the pivoted crystal, as shown in Fig. 4 (1 and 4). As the unidimensional echogram G moved in its sector, lines were traced out by the spots of light on the cathode-ray screen. A photographic plate was exposed during this process. The internal structure of the kidney based on echoes from within the kidney substance was traced out as the sound beam swept in and out of the tissue.

The record shown at H is believed to be the first two-dimensional echogram of biological tissue to be recorded. The varying thickness of the specimen can be seen as the tissue-air interface Y–Y was traced out on the photographic film. The rubber-membrane-tissue

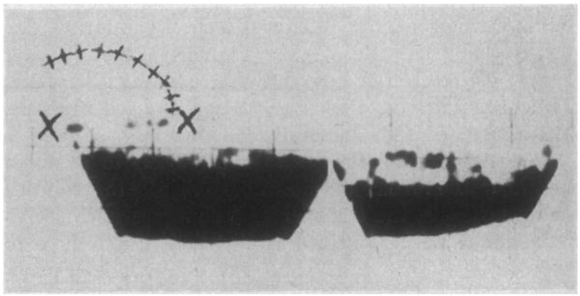

FIG. 8. The two-dimensional echogram obtained from a patient with a tumor of the adductor muscles of the left thigh above the knee. The right-hand picture was taken from the normal right thigh. The left-hand picture was taken with the sound beam sweeping from normal into tumor tissue. The deep signals X were believed to arise from the tumor. (The line X–X was almost continuous in the negative.) Had the machine been more powerful the tumor would probably have been outlined by an echo pattern within the area enclosed by the crosses, which were added to the record as shown.

and the rubber-membrane-air interfaces X–X were also traced out. The absence of signals beyond the rubber membrane when the sound beam swept out of the tissue into air (position A) was clearly recorded. Theoretically such a picture could be observed with the naked eye by moving the echogram G rapidly enough to obtain visual persistence on the face of the cathode-ray tube, but the apparatus was not sufficiently well developed at the time.

A limited clinical trial of two-dimensional echography was decided upon. A patient (Case No. 782,109) was hospitalized for a recurrence of a tumor on the inside of the left thigh above the knee. The tumor, which had been previously diagnosed as a myoblastoma by biopsy, could be palpated in the adductor muscles, but no swelling of the skin was observed over it. Two two-dimensional echograms obtained from this patient are shown collectively in Fig. 8. The echogram of the normal right thigh is shown to the right. The two-dimensional echoscope (Fig. 5) was positioned in a comparable site on the left thigh in such a way that the sound beam swept from normal into tumor tissue. The two-dimensional echogram shown to the left in Fig. 8 was obtained. The signals *X–X* were believed to arise from the growth as the sound beam swept into it. These signals were almost continuous in the negative. Had the apparatus reached a greater state of perfection, the tumor might have been revealed by echo patterns within the area enclosed by the cross-lines inserted on the record.

Further development of the methods described for examination of living, intact, biological tissue in such a manner as to reveal structure in depth should be of great value in many branches of biology. The immediate application of echography to the detection of tumors in accessible sites in the living intact human organism is envisaged.

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News and Notes

The Wenner-Gren Summer Seminar in Physical Anthropology

FOR the past six summers a changing group of physical anthropologists and allied specialists has met by invitation at the Wenner-Gren Foundation for Anthropological Research (formerly the Viking Fund) through the foundation's generous support. These seminars have been organized and led by S. L. Washburn, of the University of Chicago.

The purpose of the sessions has been to examine the theoretical bases of the whole subject, the validity of its methods, the transfer of techniques and results from other fields, and the application of all these to specific data. The goal is to outline both key problems of the field and the most fruitful approaches to their solution. The first few sessions were designed to clarify aims and terminology and to analyze some of the assumptions, techniques, and methods of investigation and interpretation, using concrete examples. Foreign as well as American specialists have attended to demonstrate new fossil material and new methods.

The concurrent *Yearbook of Physical Anthropology,* edited by Gabriel W. Lasker, describes each session. The work of the first four seminars was theoretical in aim: evaluation of process and critical scrutiny of various classificatory, experimental, and genetic concepts, and of assumptions both long-accepted and novel; the first three concentrated on human evolution, race, constitution, and growth. The fourth seminar, more specific, was divided into two main topics: the Australopithecinae of South Africa, and methods used in study of the American Indian. The fifth differed in being exclusively concerned with techniques and materials, which were considered under three main heads: (1) new ways of dating fossil and archaeological material, including C^{14}, fluorine salt concentration, and spectrographic analysis; (2) improvements on, and additions to, existing techniques in anthropometry; (3) statistical handling of data and problem planning.

The sixth seminar was a synthesis of the work of the first five. Its aim was to reach agreement on what would make a reasonably balanced program for graduate students in physical anthropology, covering the field in terms of its subdivisions. The 1951 meetings did much to shape the philosophy of a more unified physical anthropology. Among tangible results are a series of brief statements representing prevailing points of view, an outline of areas needing further research to reach agreement, and minimal reading lists, which were amended through suggestions sent in by nonattending members of the American Association of Physical Anthropologists. These are published in the *Yearbook of Physical Anthropology, 1950.*

A summary of major topics at this seminar follows:

1) *Human genetics* is basic in understanding human evolution (process of interaction between mutation, changing population size, genic loss, mixture, selection, and isolation) and race differentiation as an evolutionary product. Analyses of the same populations by phenotypic and genetic methods should give the same results, but until genes and growth processes involved in functional trait constellations are better understood, further race classification means little, although blood group analyses already give a partial check. Since genetic analysis has to use specific anatomical characters, and since the phenotypic concept of race is a constellation of overlapping trait groups held together in unstable combinations in breeding isolates of widely varying size, the two approaches are less antithetical than they seem, and phenotypic similarity may continue to suggest biological relationship. It is now essential to learn more of breeding patterns and to multiply our knowledge of specific human characters.

2) *Primate studies,* comparative and experimental, bear on the development, ecology, and physiological functioning of man and can apply to medical and growth problems involving relation of form to function.

3) *Fossil primates and fossil man* have prompted new studies in which emphasis has shifted from comparative description to the evolutionary processes involved. A grasp of the history of evolutionary theory is also neces-