Animal acupuncture: Mapping and anesthesia

by

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INTRODUCTION

Acupuncture is a system of therapeutic medicine, which has recently been popularized. This form of medicine originated in China about 2600 B.C., although other cultures developed similar forms of medicine at approximately the same time. Acupuncture therapy involves the insertion of needles into specific points of the body to primarily prevent and to secondarily cure illness. In the late 1950's the Chinese expanded the use of acupuncture to anesthesia. The new technique has proven effective, even in major surgery. Research on the mechanism of acupuncture is in its early stages, and most of what is known about these techniques is based only on human experience.

After the introduction of acupuncture to the United States, many physicians and controlling agencies called for the strict control of its practice until proper research could be conducted to determine its safety and effectiveness. This work was designed to deal with two questions. Firstly, are the effects observed with acupuncture treatment and anesthesia the result of auto-suggestion and pre-operative indoctrination or rather the physical manipulation of metabolic processes? Secondly, can the techniques of acupuncture be translated into animal systems for both research and therapeutic use? The first question has been raised by many people in the medical sciences, because these procedures generally have been used only on humans. The use of animals to test the effectiveness of acupuncture techniques can provide evidence from which conclusions can be drawn as to the involvement of hypnotism or other similar factors in acupuncture.

There are two basic objectives in this research. The first is to adapt certain techniques which are designed to locate and characterize acupuncture points in humans to animals. By locating these points on animals, maps can be developed which will enable workers to relate the human system to animal systems for other animal studies. A second objective is to use a simple procedure to test the functionality of certain points determined in the first part of the study. Anesthesia trials will be used for the purpose.

The study was designed in this manner for three reasons. Firstly, by using animals, the effects of autosuggestion and hypnotism could be reduced or even eliminated. These factors must always be considered in human work when testing the effectiveness of a procedure. Secondly, the maps developed could be used to test many procedures in animal therapy and expand the scope of acupuncture research on animals. Finally, the development of a procedure for animal acupuncture anesthesia could provide an alternative to the conventional anesthetics in use which are quite variable in their safety and effectiveness.

LITERATURE SURVEY

Acupuncture has become a recent interest of western science. In China, research into the mechanism of acupuncture only has developed within the last 15 years, and very few results have become available to western scientists. Also, a language barrier has prevented the spread of information concerning acupuncture. The research described in this thesis represents one of the few projects on acupuncture in the United States and the first and only study of acupuncture at Iowa State University. For these reasons, this survey will describe acupuncture in a general manner to give an understanding of acupuncture medicine and of the types of problems and research methods being considered and used and will review the proposed explanations of the effects of acupuncture.

The survey will be divided into three sections. The first will be a history of acupuncture as it began in the Orient and spread to the Occident. The second section will give a brief introduction to the principles and techniques of acupuncture therapy and acupuncture anesthesia. The third part will cover the research on acupuncture and review the most popular theories on mechanism. Areas of related work will be mentioned as alternative approaches to studying acupuncture.

History

The first record of acupuncture medicine dates to 2600 B.C. during the reign of the Emperor Huang Ti in China. This record is a text called Huang Ti Nei Ching Su Wên (The Yellow Emperor's Classic of Internal Medicine (Veith, 1949)). The text outlines the basic principles upon which acupuncture is based. These principles are explained in metaphysical terms intertwining medicine, philosophy and religion in such a way as to develop a very sophisticated and complicated concept of the human body and those actions necessary to maintain health. This text is the basis upon which classical acupuncture is taught and practiced today.

As each dynasty passed, certain minor revisions were made in the Nei Ching. Chinese medicine might have developed along the same lines as western medicine had not certain religious developments halted its progress. The Confucian tenets of the sacredness of the body ended the investigations of anatomical structure of the body and of surgical procedures. These developments forced the adoption of a medical system which could operate by only treating the surface of the body. This requirement was met by acupuncture.

It was not until the early 17th century that western medicine was introduced to China (Vieth, 1949). Traditional medicine was practiced on the poor and eventually was ignored completely by the government of Chiang Kai-shek in the 1940's. When chairman Mao Tse-tung came to power, he directed that the two forms of medicine (traditional and western) be combined to treat the people of China. With this support, acupuncture anesthesia was developed in 1956, and research programs have expanded its use in China (China Pictorial, 1972).

Although at a later time, forms of folk medicine similar to acupuncture developed in other cultures. Papyrus Ebers, dating 1550 B.C., indicate that the Egyptian culture had formulated a concept of the body similar to that of the Chinese. Other cultures, such as the Bantu of South Africa, an isolated tribe of Indians in Brazil and Eskimos in North America, still practice crude forms of acupuncture (Mann, 1971).

Acupuncture was introduced to the western world in the 17th century by Jesuit priests sent to China. Monks returning from China brought acupuncture to Europe, and since then many countries in Europe have established societies of acupuncture (Manaka and Urquhart, 1972). The recent interest in acupuncture in the United States was stimulated by a Presidential trip to China in 1972.

Review of Principles and Techniques

Principles

Presented here is a short review of the principles that form the foundation of classical acupuncture. It is important to understand that when this system of medicine was developed, science and medicine were considered a subdivision of religion and philosophy. Because of this, many of the concepts are metaphysical in nature and foreign to western scientific thinking. The review is included because it provides a perspective on acupuncture that lends organization to the methods and provides a different perspective by which to evaluate the human body. These basic principles should not be ignored even in the development of research ideas.

A number of texts (Austin, 1972, Duke, 1968 and Mann, 1971) outline the theoretical base from a practitioner's viewpoint. The original and most complete source of information remains the Yellow Emperor's Classic of Internal Medicine. This text is closely related to the philosophy of Taoism (Vieth, 1949) and deals with three basic principles.

The first principle states that man and nature exist as dependent forces and that man's health is dictated by the manner in which he interacts with nature and obeys its laws. The vital force of nature is Ch'i. Ch'i must be maintained and controlled in man's body to maintain health. Acupuncture is the method by which Ch'i is controlled.

The second concept is that Ch'i is the combined forces of Yin and Yang. Yin and Yang are primogenial elements from which all existence is formed. All major binary forces, earth and heaven, woman and man, fire and water, are viewed as Yin or Yang. Under normal conditions these forces are in balance or equilibrium. These forces are in operation in the human body and when they become imbalanced, illness is the result. Acupuncture is the technique by which the forces are rebalanced.

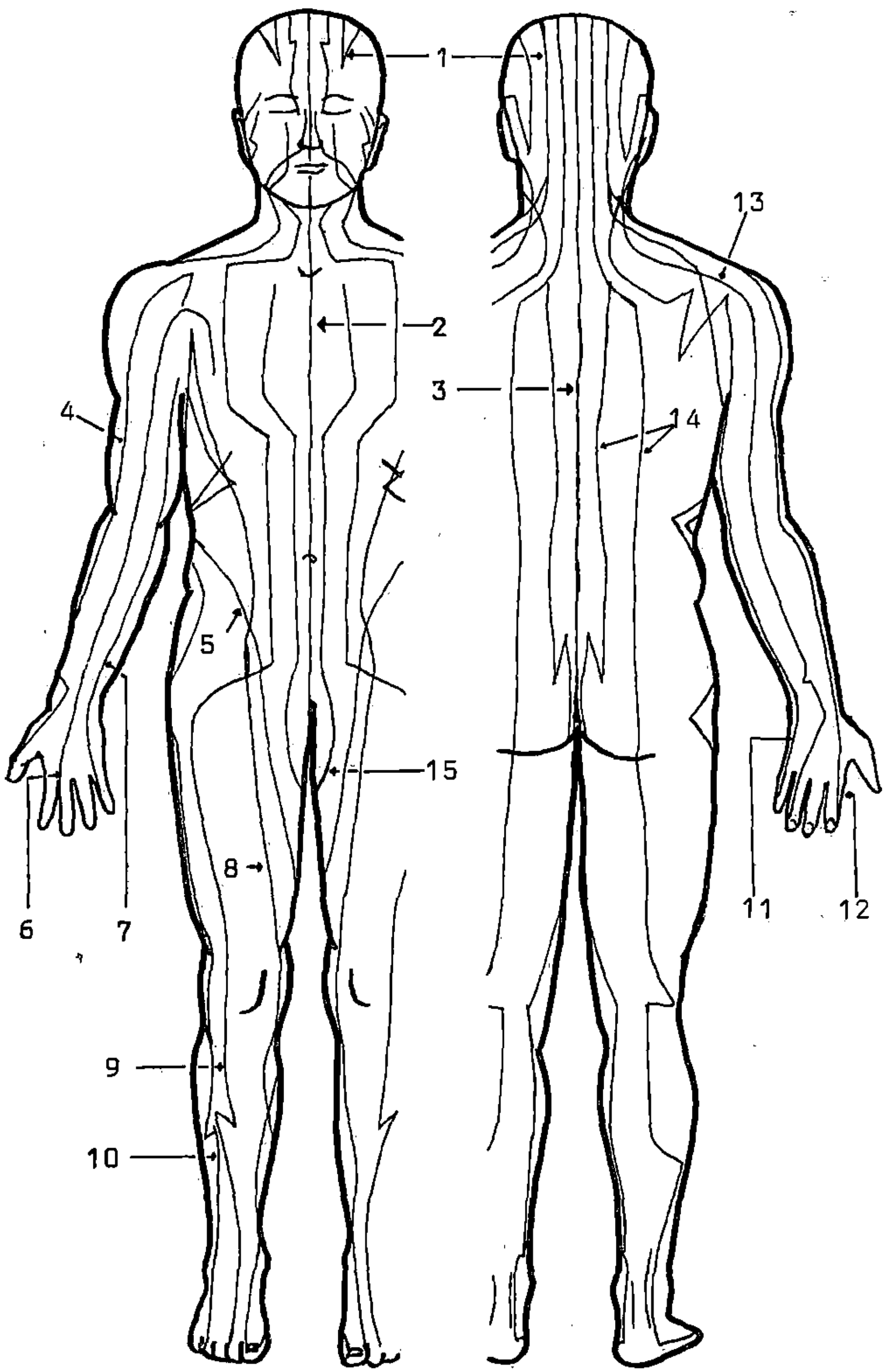
The third concept is that of the five elements. The five elements are a further subdivision of Ch'i and the Yin and Yang concept. Because man is a product of the interaction of Yin and Yang, he exists under laws which govern the interaction of the five elements. The five elements are metal, water, fire, wood and earth. Any process that involves movement through a series of changes or rhythms is under the influence of the changing dominances of the five elements. The four seasons represent the effects of the four elements on the fifth, earth. In terms of the human body, this concept of the five elements is translated into a system by which disease is diagnosed and treatment applied. The physician notes physical indications and ascribes elemental qualities to a disorder. Treatment, then, involves manipulation of the life forces to change the physical symptoms to a normal elemental balance.

Control of the life forces is exerted through a series of points on the body that are unique and related to specific organs. These points are organized into 12 meridians which are associated with specific organs by the control that they exert over the organs. The meridians are channels along which Ch'i travels. Each meridian is located bilaterally on the body and is ascribed the properties of Yin or Yang. Figure 1 illustrates the meridian pattern of the human body. The functional relationship between the organs is very complicated; thus, an illness may require the treatment of more than one organ and, therefore, more than one point on different meridians. This, then, is the general classical theory for the action of acupuncture. Most practicing acupuncturists do not have a working knowledge of these principles but rely on set treatment patterns for a wide variety of diseases. A current movement by acupuncturists is to ignore classical concepts in an attempt to popularize the techniques.

Techniques

Acupuncture anesthesia is a modification of acupuncture therapy techniques. There are three basic therapy techniques. The most popular is the insertion of very fine

Figure 1. Human acupuncture map showing meridians and vessels. 1. Bladder meridian. 2. Conception vessel. 3. Governing vessel. 4. Lung meridian. 5. Liver meridian. 6. Pericardium meridian. 7. Heart meridian. 8. Spleen meridian. 9. Stomach meridian. 10. Gall bladder meridian. 11. Small intestine meridia n. 12. Large intestine meridian. 13. Triple warmer merdian. 14. Bladder meridian. 15. Kidney meridian. All meridians are bilateral.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needles into acupuncture points. The points are located by reference to classical maps or by electrical measurements (Mann, 1971). The classical maps of the human body show a total of 365 points, but by electrical measurements over 900 points have been found . The needles are inserted at various depths depending on the location of the point to be needled. Once inserted, the needle may be twirled, connected to an electrical stimulator or merely left in place. The number of needles used, the length of time of insertion and the number of treatments depend on the illness and the practitioner's judgement. When the treatment has ended, the needle is quickly removed. Sterile technique is used to avoid the contraction of, especially, hepatitis. After successive treatments at the same point, skin discoloration may occur.

The second technique, used mainly in the Orient, is moxibustion. This involves the slow burning of a substance called mugwort (**Artemsia vulgaris**) on the point to be treated. The technique effects a stimulation of the area as does needling, and the material is removed before any damage is done to the tissue. Mugwort also may be wrapped around the needle and burned after insertion, heating the needle without causing excess pain.

The third technique, which was developed in Japan, is the massage at acupuncture points. This can be effective in minor disorders; however, needling is the most effective therapy.

Another technique is auricular acupuncture which involves acupuncture of the ear. This technique is popular in France and has been found effective in the treatment of nerve deafness and in reducing the effects of heroin withdrawal (Wen and Cheung, 1973).

Acupuncture anesthesia is a simple modification of acupuncture therapy technique. The term anesthesia does not accurately describe the effects of the procedure. The effects are rather a state of analgesia that is induced in specific areas of the body. These areas maintain sensitivity to temperature and touch, but pain responses are eliminated when acupuncture is applied (Bresler, 1973). The Chinese have studied a series of points and have determined a limited number (45 points) most effective for anesthesia in particular areas (Lowe, 1973). A needle is inserted at the point used in relation to a specific area (i.e. Large Intestine 4 is used for analgesia in the lower jaw and abdomen), and then an electrical stimulator is connected to the needle. The points, in most situations, are well removed from the area where analgesia is observed. A second paste electrode can be used to complete the circuit, or a second point on the opposite side of the body can be used. A small potential of 6-9 volts is gradually applied until the resulting sensation becomes uncomfortable. The current is in the form of pulses, usually monophasic, generated at a frequency of 15-600 Hertz. An induction period of 30-40 minutes usually is required, although it may be as short as 20 minutes, depending on the individual. The analgesic effect can be maintained indefinitely as long as the frequency and voltage are varied occasionally. Once stimulation is removed, the analgesic effect remains for about the same length of time as was required for induction. If postoperative pain is discomforting, the stimulation can be reinduced and maintained, although this generally is not needed.

Applied and Basic Research and Related Studies

Once the United States public expressed an interest in acupuncture and began to request this form of medicine, a number of people in the American medical profession began to investigate acupuncture. A number of physicians travelled to China and reported the success of acupuncture anesthesia (Diamond, 1971). Other physicians maintained that acupuncture anesthesia was the result of indoctrination or was not sufficiently successful to warrant its use (DeBakey and Schanke, 1973). This stimulated research studies in the United States and the retrieval of research information from China. A basic problem of language has slowed the exchange of information between western scientists and Chinese researchers. Preliminary studies have been initiated at many institutions, and many of the results have not been reported yet.

Therapy

Research in acupuncture therapeutics for humans basically has involved clinical trials of disorders known to be affected by this type of therapy. Pain disorders as involved in arthritis and phantom-limb pains have been the major areas of study. The techniques have been expanded for control of drug addiction (Wen and Cheung, 1973). Reports indicate a high degree of success in the control of the physical side effects of heroin withdrawal. Acupuncture also decreases the time in labor of pregnant women (Tsuei et al., 1974).

The expansion of acupuncture for animals was begun in China and is now being studied in the United States. The techniques are the same as used in humans. A text called Veterinary Acupuncture (Chiang-hsi Provincial Veterinary Preventive Medicine Station, 1972), printed in China, has been translated at Iowa State University. The text outlines acupuncture treatment patterns for the cow, pig and poultry. A wide variety of disorders are discussed, and animal maps are provided. These maps will be described later in the results section. Treatment for shock in cats has shown that acupuncture shortens and enhances recovery markedly (Anhwei Medical College, 1973a and 1973b). Acupuncture has been used to help horses relieve intestinal obstructions (Satory, 1972) and to aid mares in foaling (Taylor, 1974). Research in the United States has been conducted on horses and dogs for arthritis and a series of other disorders (Cotterman, 1974; Modern Veterinary Practice, 1973) and has been successful in the limited number of cases treated.

Anesthesia

Much of the research in China has been devoted to expanding the use of acupuncture anesthesia. United States physicians have travelled to China and been permitted to view many procedures on which they have reported (Diamond, 1971; Brown, 1972). Acupuncture anesthesia has been used successfully in laryngectomies (Shanghai First Medical College, 1973b), thyroidectomies (Shanghai First People's Hospital, 1973), pulmonary resections (Shanghai First Tuberculosis Hospital, 1973) and splenectomies (Ch'angshan County People's Hospital, 1973). In these four procedures, preoperative sedatives (luminal, dolantin or scopolamine) were administered to control various reflex problems. All dosages were sufficiently low to insure that the patient was completely conscious.

The procedures were conducted from 47–700 times, with an average success rate of 95%. Other major forms of surgery also have been conducted with great success. Thoracic surgery was done on 818 human cases with a success rate of 88.5% (Peking Acupuncture Anesthesia Co-ordinating Group, 1973). Cardiac surgery was done with acupuncture on 144 cases, and a success rate of 94.4% was reported by Hunan Medical College (1973a). In these procedures, dolantin was given preoperatively and procaine was used for initial skin incisions. Over a thousand cases of neurosurgery have been done with acupuncture anesthesia with a success rate of 96.3% (Hsüan Wu Hospital, 1973; Hua Shan Hospital, 1973). Acupuncture anesthesia for a variety of pediatric surgical procedures has been successful in 88.0% of 1,308 cases (Peking's Children's Hospital, 1973). The lower success rate among children was attributed to children's tendency towards apprehension due to the surgery.

Acupuncture anesthesia has been used on horses for Caesarean sections (Hsinghua Selected News, 1972), but no further information was available. Other surgical procedures done on domestic animals with acupuncture anesthesia included enterotomies, hysterectomies, rumenotomies on domestic ruminants, dental and orthopedic procedures, with an average success rate of 95% (Taylor, 1974).

Basic Research

Much of the basic research in acupuncture has been directed towards explaining the analgesic effects experienced during acupuncture anesthesia. Neural systems have been studied to evaluate the degree of analgesia and the location of inhibitory actions. Peking Medical College (1973) conducted pain trials by using the modified potassium iontophoresis method to check elevation of skin pain threshold during acupuncture anesthesia. By using Large Intestine-4 and Stomach-36 points, increases of 66-95% elevation in pain threshold were observed during acupuncture. Morphine (10 mg) increased pain thresholds 80-90%. Upon injection of 2.0% procaine before treatment at the acupuncture point, any elevation of the threshold was eliminated. Trials using placebos were conducted as controls. Clark and Yang (1974) have evaluated elevation of pain thresholds during acupuncture anesthesia by the Signal Detection Theory. The test is designed to separate actual elevation of pain threshold from a subject's tendency to raise his criterion for reporting pain upon suggestion. The test failed to explain the origin of the rise in the pain threshold with acupuncture. Bresler (1973) has induced anesthesia in a human patient for oral surgery by using two points, Large Intestine-4 and Stomach-36 with electrical stimulation. The analgesia did not extend to the lips and unattached gingiva. The patient remained sensitive to heat, cold and pressure during the analgesia.

Coincident with effective acupuncture is the "heavy" sensation experienced by the patient in the area of the point being needled. Shanghai Institute of Physiology (1973) reports that this sensation is associated with muscular activity as detected by electromyography. Experiments with patients with different disorders indicate that when normal neural function is impaired in a limb, the "heavy" sensation is eliminated and acupuncture anesthesia is less effective, indicating that the anesthesia is mediated by sensory nerve fibers (Shanghai First Medical College, 1973a).

The role of the spinal cord in mediating the analgesic effects of acupuncture has been studied by two techniques. When analgesia is induced in the spinal area, Hoffmann's reflex, resulting from electrical stimulation of peripheral nerves, disappears when full analgesia is achieved (Hsü Yi County People's Hospital, 1973). This indicates that large fiber activities produced by acupuncture may inhibit small fiber activities involved in pain recognition. Other studies by the degeneration method confirm that small fiber impulses supplying the tract of Lissauer are inhibited by large fibers originating in the limbs (Shenyang Medical College, 1973). This partially explains why needling a point in the arm could cause analgesia in the chest.

A number of groups have studied the role of the thalamus in mediating acupuncture anesthesia. Linzer and VanAtta (1973) used cats to study the response of different thalamic nuclei to acupuncture. They resolved that pain impulses recorded in the thalamus were reduced by acupuncture, but the site of inhibition could not be determined. Jacobs _et al_. (1972) obtained similar results on experiments with monkeys. Chang (1974) studied the parafascicularis and centralis lateralis in rats and rabbits and observed reductions in response to pain stimuli with acupuncture but could not define the location of inhibition. The role of the midbrain reticular formation has been studied in a similar way in guinea pigs, and similar conclusions were drawn (Shanghai College of Traditional Medicine, 1973).

Biochemical studies of the brain have shown that after acupuncture analgesia has been induced, an increase in 5-hydroxytryptamine concentration in the medulla and thalamus and reduced glutamic acid in the thalamus can be detected (Hunan Medical College, 1973b). No significant changes were found in norepinephrine or gamma-aminobutyric acid concentration in the brain regions after acupuncture. This experiment indicates that 5-hydroxytryptamine plays some role in acupuncture anesthesia, but the role is unclear. Research on the changes of free amino acid composition of the brain during acupuncture anesthesia is being conducted, but no results are available (Daniels, 1973).

Studies characterizing the electrical properties of acupuncture points have revealed certain electrical characteristics unique to these points. When resistance measurements are made at the surface of the skin, acupuncture point values are 100K–200K ohms whereas normal skin resistance is much higher, at least 1 megohm (Krippner and Rubin, 1973). This property has lead to the design of a number of point finders based on the detection of large changes in resistance. This property has been used to diagnose neural disorders in humans (Ionescu-Tirgoviste et al., 1974). A second approach has been used by Bergsman and Wooley-Hart (1973) to characterize the functional state of acupuncture points. They have determined that a threshold current can be measured at an acupuncture point when ohmic conditions prevail. When increases in applied voltage lead to disproportionate increases in observed current, a threshold current has been reached. These thresholds were measured at points associated with lung function in tuberculoid patients. Patients with tuberculoid cavities had significantly lower threshold values than those with only lesions. They concluded that this technique can be used to determine the functional state of an organ. Orkin and Frost (1973) have conducted similar experiments by studying only resistance and could not correlate the functional state of an organ with this electrical property. Acupuncture points also have higher millivolt potentials than adjacent skin. Brown et al. (1974) have used this characteristic to locate and study points. Their work indicates that potentials of 2-42 millivolts can be measured on the human body and that these values are stable over short periods of time (1-4 hours).

Other types of research have involved characterization of changes in body function during acupuncture. Bresler and Levin (1973) have recorded changes in electroencephalograms (EEG) and galvanic skin potentials at acupuncture points and have found significant changes in EEG's when the needle was inserted. Also, galvanic skin potentials changed markedly when the functional state of the subject was changed. Studies of gastrointestinal motility in dogs have shown that acupuncture of points related to these organs can greatly stimulate or inhibit motility depending on which points are used (Matsumoto et al., 1973; Numoto et al., 1973). Lee (1974) has studied the effect of acupuncture on controlling blood flow to the intestines. He found that acupuncture caused marked decreases in red blood cell velocities in the mesenteric vessels and a fall in carotid arterial pressure during stimulation.

Theories

Most theories on the mechanism of acupuncture attempt to explain only the analgesic effects of acupuncture anesthesia. As yet, no one has proposed any mechanisms for the many therapeutic effects with acupuncture. This is partly because of the lack of clinical data available from controlled therapeutic trials and because of the variety of illnesses. Most theories discuss the transmission of pain stimuli by neural pathways and how acupuncture might inhibit these stimuli. These theories are closely associated with current information on the perception of pain by vertebrates. As a result, the mechanisms of action proposed for acupuncture are based on older theories of neural and brain function.

The early attempts to explain the acupuncture effect were based on the "Gate Theory" proposed by Melzack and Wall (1965). The theory states that large myelinated fibers (A-beta fibers) carry a small constant stimulus which would block the transmission of major pain stimuli carried by small (C) unmyelinated fibers. Both types of fibers are located in the substantia gelatinosa of the spinal cord. Man and Chen (1972) are among those who have proposed a second gate located in the thalamus. Pain impulses are received in the paraventricular and centralateral nuclei of the thalamus. Acupuncture stimulation establishes a rythmic pattern in these areas that inhibits the transmission of pain impulse (Small, 1974). The medial reticular formation of the midbrain also may be involved in mediation of the inhibitory responses (Shanghai College of Traditional Medicine and Shanghai Normal College, 1973). Most of the other neural theories differ only as to the location of inhibition.

Chaing (1974) has proposed a variation on neural theories. He proposed that the stimulation of the imbedded needle causes pressure waves to propagate from the needle producing the "heavy" sensation. These waves then change the hydrostatic pressure around local nerves by affecting the rate of signal transmission of the nerves with resulting inhibition. In addition, an electrostatic effect induced by electrical stimulation may cause migration of certain chemicals to or from nerves, thus modifying their function. He also proposed that a piezoelectric effect caused by needling might modify normal neural function.

Mann (1971) lists other neural theories that discuss different neural reflexes, but all theories fail to fully explain the effects of acupuncture anesthesia or therapy.

Other scientists have considered the problem from a more basic point of view. Smith and Kenyon (1973) have proposed that the life energy Ch'i may be related to adenosine triphosphate (ATP). They theorized that acupuncture changes ATP concentrations in a variety of tissues. The autonomic nervous system is most affected by stimulation of its nerve endings. Stimulation of the nerves causes changes in the utilization of ATP in the nerve that changes its activity. The change in ATP utilization is transmitted along the nerve tracks and causes reduced pain response.

Kirlian Photography

The concept of biological energy in other than chemical forms such as ATP has been proposed and studied. The Russians have developed a procedure called Kirlian Photography by which electrical phenomena emanating from living tissue can be recorded. The "aura" effect has been studied in relation to acupuncture points on the human body. High energy emanations flow from the surface of the skin at acupuncture points. These emanations can be altered if the points are treated by acupuncture (Krippner and Rubin, 1973). Attempts have been made to correlate specific human physical disorders with changes in the "aura" photograph around the hands and feet of sick patients. Reproducible results, however, have been difficult to collect (Kightlinger, 1974). These techniques may provide, however, a new approach to the study of acupuncture.

Bong Han Studies

Kim Bong Han (1964) has presented evidence for the existence of a system of ducts and corpuscles that may relate to acupuncture. He describes a series of interconnecting vessels that are independent of the circulatory and lymphatic systems. These vessels make contact with all the organs and extend to the reticular layer of the skin. These vessels connect a series of corpuscles in the skin and deep in the body. Contained in the vessels and corpuscles is a liquor that has high concentrations of hyaluronic acid, amino acids, nucleotides and a variety of steroids. There is a constant movement of material through this vessel system. The evidence for these observations is poorly documented, and the work was discounted as artifactural when first presented. The work now is being re-evaluated in light of recent research into acupuncture (Krippner and Rubin, 1973).

METHODS AND INSTRUMENTATION

Mapping

Three species of animals were studied to determine or confirm acupuncture point patterns. Six Sanaan goats were used as the primary test animals. These goats were 2–8 months of age and weighed between 10–25 Kg. Both males (3) and females (3) were used. A single dog was used to develop a second animal map. The dog was a male mongrel, weighing approximately 11 Kg, and was 4 months of age. The third animal was a Jersey calf that weighed approximately 185 Kg, and was 4 months of age.

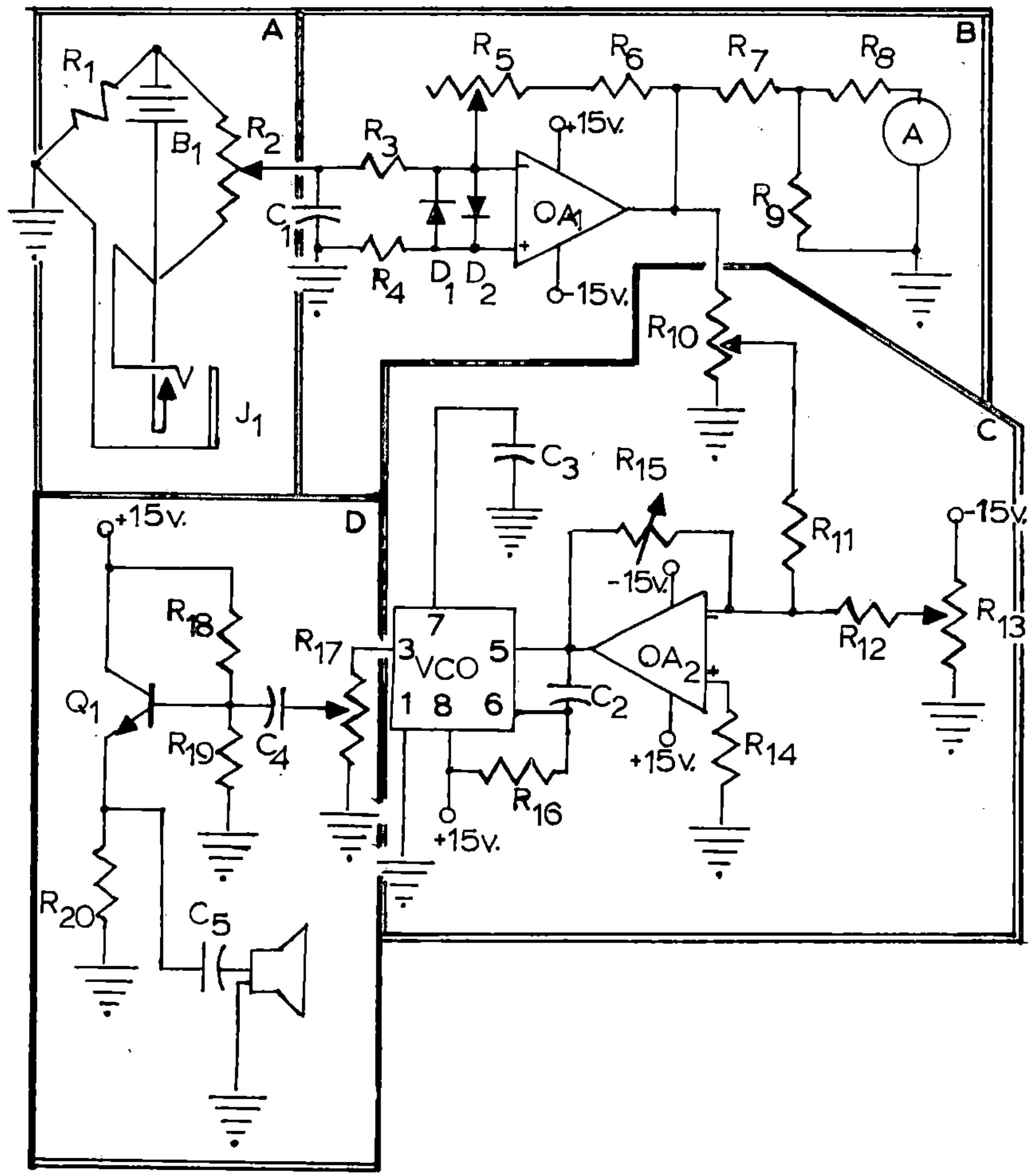
All animals were clipped with no. 40 gauge clippers in the skin areas to be studied. At the beginning of the study, the goats were sedated with Sparine (gamma-dimethylamino-n-propyl phenothiazine hydrochloride)(1.4 mg/kg body weight). Eventually, the animals became acclimated to the procedure, and no sedation was required. An EKG paste electrode was placed on the rear lower leg as a reference electrode. The hair also was clipped from this area. During the mapping trials, the goats were restricted in stanchions which maintained the animals standing with heads restrained. No sedation or restraint was used on the dog. The calf was restrained in a stanchion.

Earlier attempts to use rats and cats failed because of the fragility of the skin.

Recordings of the point patterns were made by marking each point on the skin with ink and photographing the entire area studied. Later, with the millivolt potential studies, the point patterns were recorded on animal illustrations. The photographs and illustrations were compiled visually into final maps for each animal. The millivolt potentials were recorded on a strip chart recorder.

Two techniques were used to locate points. The Low Skin-Contact Resistance (L.S.C.R.) method is outlined by Krippner and Rubin (1973). Acupuncture points exhibit a drop in skin resistance from that of nonacupuncture point areas. This drop is from 1 megohm to 100K-200K ohms. An instrument designed by Devine (1970) and modified by Swift at Iowa State University was used in the L.S.C.R. method. The schematic is illustrated in Figure 2. Section A of the figure is a resistance bridge that is connected to the animal through connector J1. Completion of the circuit is through the paste electrode and a movable search electrode. The search electrode is composed of a rounded and polished copper bead 2 millimeters in diameter embedded at the end of a hollow glass tube encased in tygon tubing. The bead is attached to a wire running through the center of the tube and is subsequently connected to J1 through a shielded

Figure 2. Low Skin-Contact Resistance detector (L.S.C.R.) schematic. Parts: A. – Resistance bridge; B. – Amplifier; C. – Voltage-controlled oscillator; D. – Output stage. Functional potentiometers: R_2 – Bridge balance; R_5 – Calibration; R_{10} – Sensitivity; R_{17} – Volume control. For parts list see Appendix A.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C4
Q1
+15v.
R20
C5

cable. The bridge is balanced with potentiometer R2, with the resulting current amplified in section B. Potentiometer R5 sets the calibration, and meter A provides visual output. The current from section B is regulated through R10 to section C, a voltage-controlled oscillator. The oscillator drives the audio output stage, section D. The unit is designed to generate an audio signal when the resistance across J1 drops from 1 megohm to 100K-200K ohms. A parts list for the unit is given in Appendix A.

A second method for mapping has been outlined by Brown et al. (1974). Acupuncture points exhibit millivolt potentials of 10-60 millivolts above nonacupuncture points. A flow diagram of the instrumentation is shown in Figure 3. The pre-amplifier and amplifier were a Grass Low-level D.C. PreAmplifier, model 5P1, and a D.C. Linear Amplifier, model 5E. The voltage potentials were recorded on a Bausch & Lomb VOM-5 Strip Chart Recorder, no. 37-01-06-31. For the anesthesia traces, a Hewlett-Packard 7402A Dual Chart Recorder was used to record both stimulus and response. The same electrode system in the L.S.C.R. method was used in this method.

Anesthesia

Goats were used for the anesthesia trials. They were

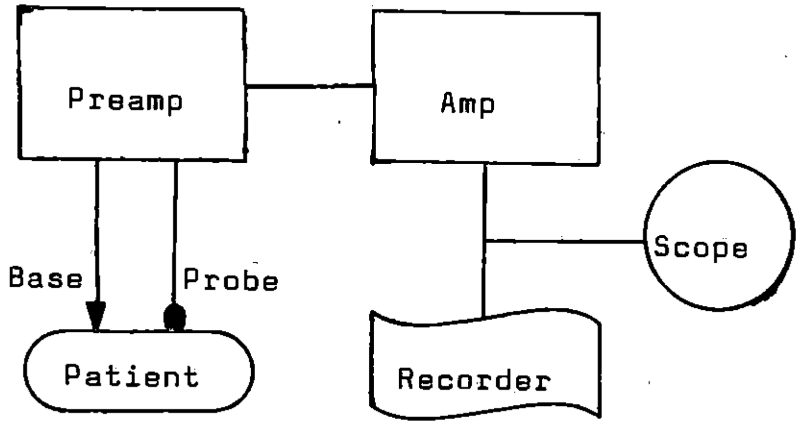


Figure 3. Flow diagram of millivolt potential apparatus.

of the same group used in the mapping experiments. The goats were given no pre-experimental sedation. The goats were restrained in a stanchion. Skin areas were shaved where millivolt recordings were made. A paste electrode was located on the rear leg and served as a reference electrode for both the stimulator and the millivolt recorder. A single needle electrode was inserted at point 1 as marked on the goat illustration in Figure 4. This point was located by the L.S.C.R. method. The needle was inserted along the bone approximately one centimeter deep. This point correlates to Large Intestine-4 in the human system and is used in human anesthesia procedures to induce analgesia in the lower jaw and lower abdomen (Lowe, 1973). The needle and reference electrodes were connected to a stimulator which will be described later. During the anesthesia experiments, recordings of skin potentials were made at acupuncture points. The recordings were made with the equipment described previously. The recordings were made at point 5 as marked in Figure 4. Analgesia was tested by piercing tissue with an 18-guage hypodermic needle and noting flinch response.

The electronic stimulator was designed by Logan at Iowa State University and constructed there. The unit contains six channels each with separate voltage, frequency and pulse width control. Figure 5 shows the waveform generated by each channel. Each channel is capable of producing a pulse of

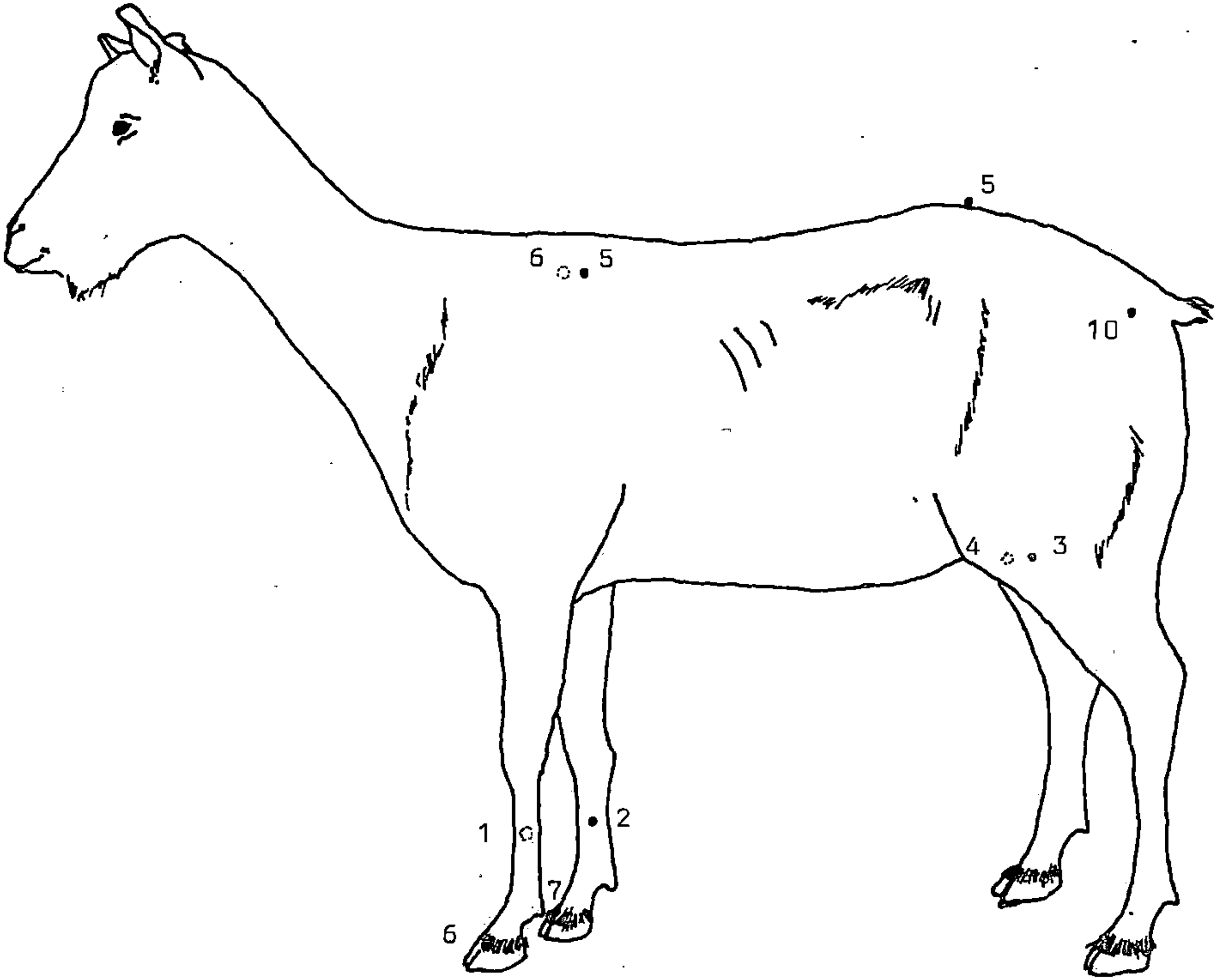
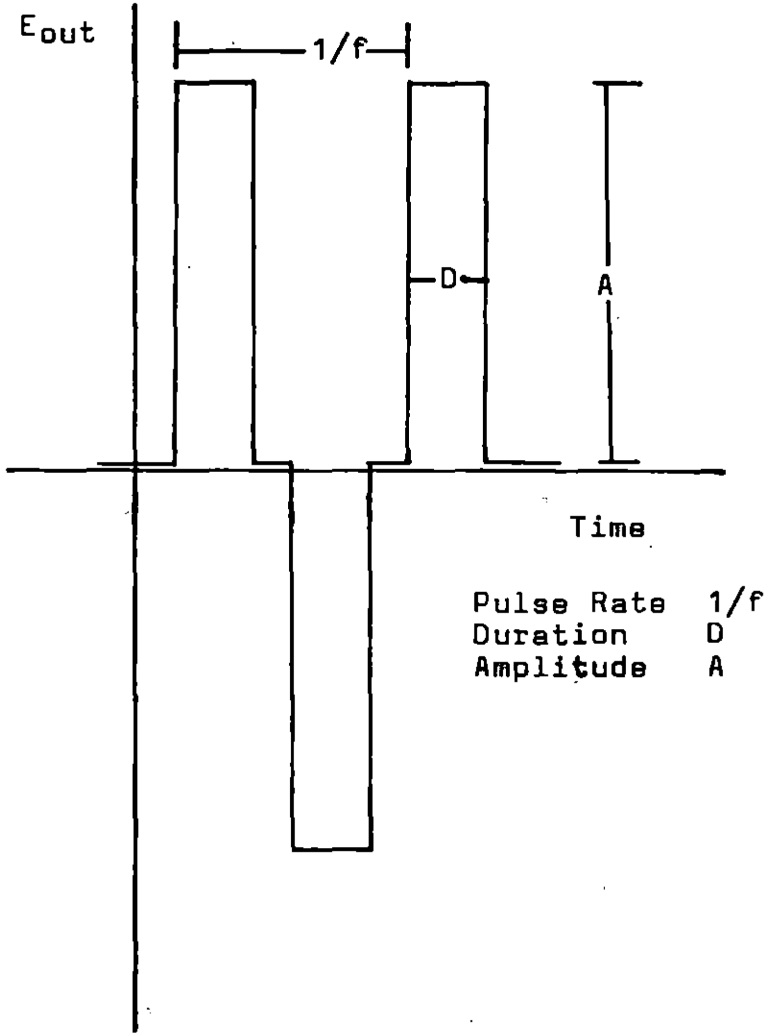


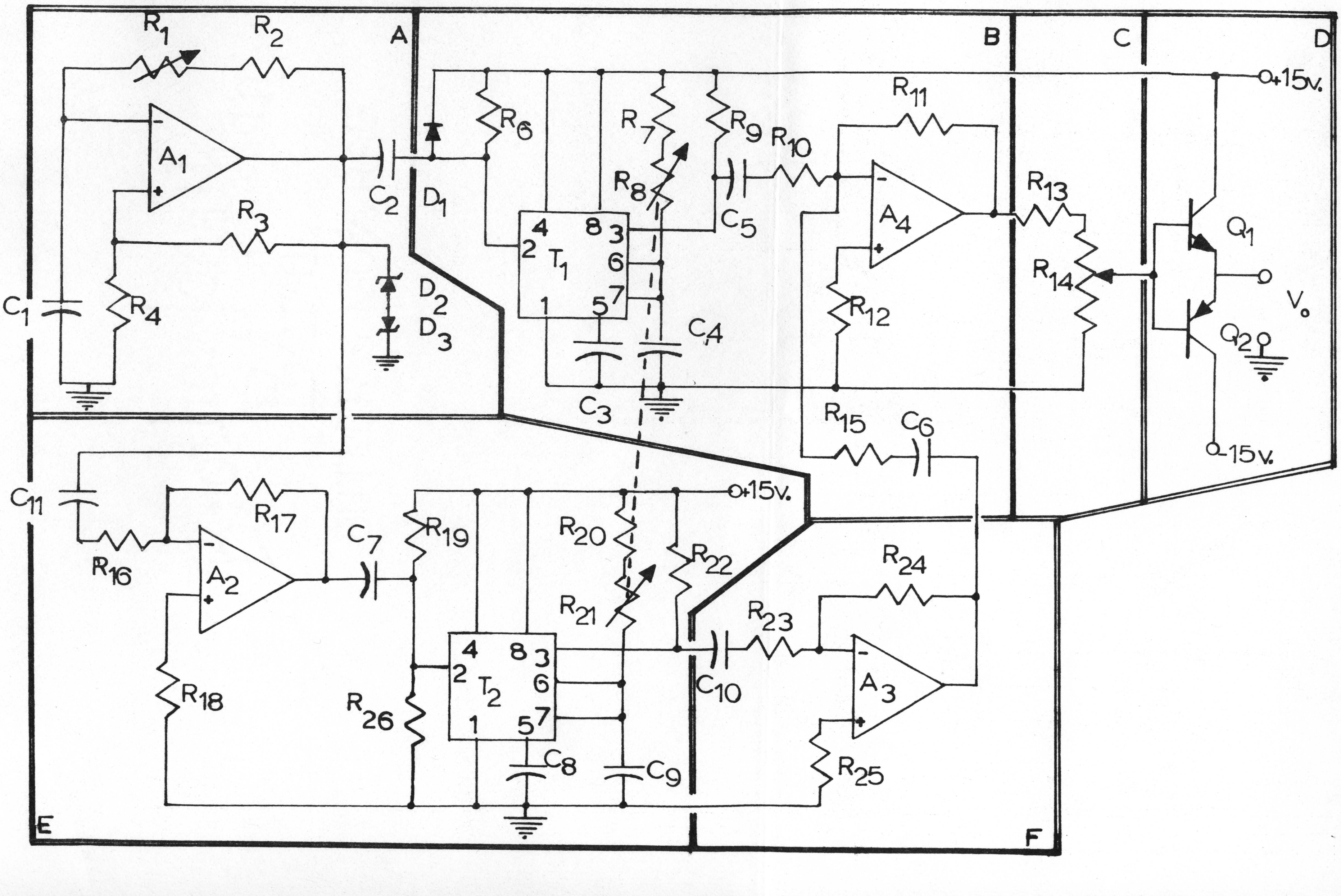
Figure 4. Location of points on the goat which were used for anesthsia trials and millivolt studies. The dotted circles are points on the hidden side of the animal.

Figure 5. An illustration of the waveform generated by the acupuncture stimulator designed and built at Iowa State University. Each channel is capable of producing a pulse of 0 - 12 volts peak, at frequencies of 60 to 360 Hertz with a pulse width of 0.1 - 1.4 milliseconds. Schematic of stimulator is shown in Figure 6.


E_{out}
1/f
D
A
Time
Pulse Rate 1/f
Duration D
Amplitude A

0–12 volts peak, at frequencies of 60 to 360 Hertz with a pulse width of 0.1–1.4 milliseconds. A diagram of the stimulator circuit is shown in Figure 6. Section A is an oscillator triggering sections B and E, positive and negative pulse generators, respectively. Section F is an inverter and sections C and D form the amplifier and drive stages. R21 and R8 are ganged linear potentiometers controlling pulse width. Potentiometer R1 controls the frequency and R14 controls the output voltage.

Figure 6. Acupuncture stimulator schematic of one channel. The unit contains six isolated channels. Parts: A. – Oscillator; B. – Positive pulse generator; C. – Amplifier; D. – Driver stage; E. – Negative pulse generator; F. – Inverter. Functional potentiometers: R_1 – Frequency control; R_8 & R_{21} – Ganged linear potentiometers for pulse width control; R_{14} – Voltage control. For parts list see Appendix B.


A
B
C
D
E
F
R1
R2
A1
C1
R4
R3
C2
D1
D2
D3
R6
R7
R8
R9
T1
C3
C4
C5
R10
R11
A4
R12
R13
R14
R15
C6
Q1
Q2
Vo
+15v.
-15v.
C11
R16
R17
A2
R18
C7
R19
R26
T2
C8
C9
R20
R21
R22
+15v.
C10
R23
R24
A3
R25

RESULTS AND DISCUSSION

The results and discussion are divided into four sections. The first section is an evaluation of the methods used to locate acupuncture points. The second section describes the animal maps and how they relate to each other and to the human system. The third section covers the determination of the millivolt potentials of selected acupuncture points. The fourth part contains a description of the anesthesia trials.

Method Evaluation

Acupuncture is a human medical system that has not evolved from research on animals. Instead, animal research of acupuncture is arising from technical developments in human acupuncture. Much of the research on acupuncture is still oriented towards testing its effectiveness and scope through human research. A major part of this work has been to adapt and evaluate human acupuncture techniques for animal research.

The L.S.C.R. method (Devine, 1970) and the millivolt potential method (Brown et al., 1974) were the two techniques used for point detection. Both techniques are effective in localizing acupuncture points on animals. Both techniques, however, have an inherent problem in their application. This problem is the variability in the physical interaction of the probe with the skin that is critical to the electrical phenomena upon which each method is based.

The probes in this study and in those of Brown et al. (1974) and Ionescu-Tirgoviste et al. (1974) were not designed to standardize probe contact pressure against the skin. Any area of the skin will exhibit a low resistance response if the probe is applied with sufficient pressure. The millivolt measurements are not as sensitive to high probe pressure. False points are not measured with the millivolt potential apparatus. Measured millivolt values at "real" points can be changed to a minor degree with extreme probe pressures. To avoid these problems, the probe was applied to animals with as minimal pressure as possible. Attempts to measure resistance values of L.S.C.R. points failed because of probe pressure variances and electrical changes that occurred on the skin as current was applied through the probe. The L.S.C.R. points show a capacitive effect when current is applied. When a d.c. current was used to measure resistance, the resistance of a point increased with time. Brown et al. (1974) has observed similar characteristics in human subjects.

The condition of the skin also affects these methods. Because the L.S.C.R. method is based on differences in resistance, any area of skin which is moist or damp will produce false points. Areas which are generally moist such as the nose and mouth, can not be studied. The millivolt method will register small potentials of 1-3 millivolts in these types of areas also. In human studies, sweat can cause interference with both methods, but most animals do not have active sweat glands over the entire body. Other dermal conditions can cause interference in these methods. In the development of the L.S.C.R. map of the goat, the test animals were clipped before each determination. During the later part of the study, the animals began to develop a dermal condition in which the skin became dry and scaly. As the probe was moved over the skin, it would collect debris on the copper wire and thus the probe would fail to make effective contact with the skin. This required the probe to be cleaned periodically. The number of points on the goats began to decrease toward the end of the mapping trials as a direct result of the deteriorating condition of the skin.

In comparing the two methods, the L.S.C.R. method was adequate for locating points but could not be used to gather quantitative information on the points. The millivolt method could be used to locate points and with some changes in probe design would permit a more accurate recording of electrical properties of points. The millivolt studies in this research indicate that the probe design in this work was sufficiently adequate to maintain standard deviations below 5% (Table 1).

Animal Maps

The L.S.C.R. method was used to develop maps for the goat and dog. This method also was used to confirm parts of the acupuncture map of the cow developed in China (Chiang-hsi Provincial Veterinary Preventive Medicine Station, 1972). The millivolt method was used to check the goat map derived by the L.S.C.R. method and to collect data on electrical properties of a series of test points on the goat.

Goat map

The L.S.C.R. map of the goat is shown in Figure 7. Three goats were used for the determination of this map. Each point was identified at least three times on each goat. The map was developed by visually transposing photographic and illustrated records onto a single map. All points are distributed bilaterally except those over the spine. Areas on the underside of the animals and genital areas were not studied because it was too difficult to orient the animal to permit a thorough search. Points were found on the neck,

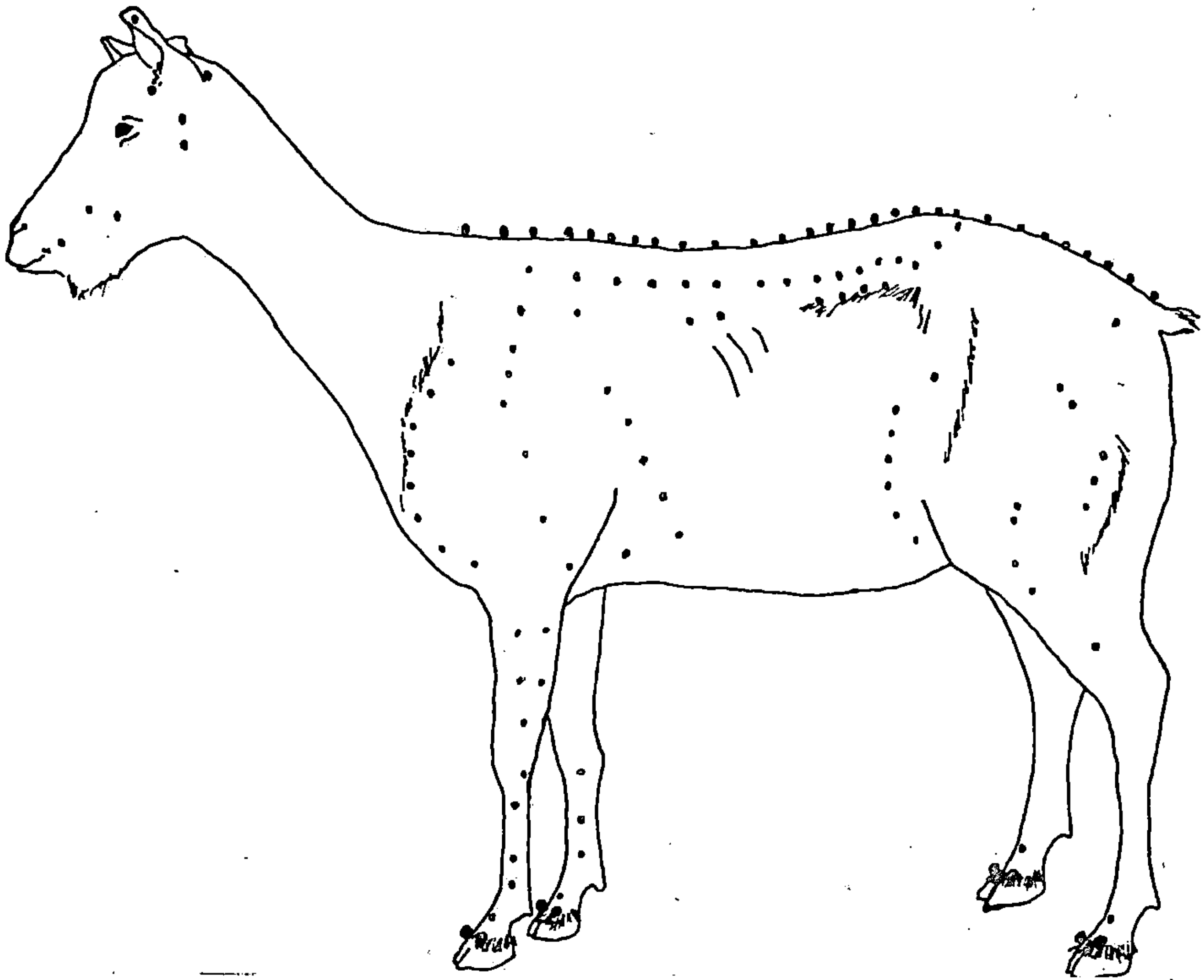


Figure 7. L.S.C.R. points of the goat. Each point was located at least three times on three different goats. Points at the top of the hoof are marked larger to permit viewing.

but they were few and could not be consistently localized from goat to goat. No sex differences in point patterns were observed.

Considering the type of recording used to note the location of points, point locations were constant between animals and from day-to-day on the same animal. This part of the study was conducted over a period of six months. During this time, the animals grew and their point patterns spread but maintained the same relative configuration. Point pattern data was determined by two individuals working independently. Each animal was studied at time intervals sufficiently long enough to allow dye markings of previous experiments to be no longer visable. These precautions were taken to reduce bias in localization of points. The diameter of the points could be estimated only to a minimum of 2 millimeters, which was the size of the copper bead in the probe. The probe could not be moved any significant distance once a point had been located. Because the points are on the skin, their location is only fixed by the skin position and not the underlying skeletal structure. The map probably does not list all L.S.C.R. points of the goat, because it is not possible to insure that all areas were thoroughly studied.

Because Sparine was used in the initial part of the study, comparisons were made to determine if its use affected the point patterns. No effect was observed. During one of the trials, the goat was allowed to consume salt from a salt block. This caused false points to appear all over the body. Subsequently, salt was only given mixed with the grain ration. No other studies to explain this salt effect were made.

<u>Dog map</u>

Figure 8 is the L.S.C.R. map of the dog. One dog was used over a period of two weeks to compile this map. Each point was located at least three separate times. As with the goat, points are bilateral except those located over the spine. The lower abdomen and the genital area were not studied. The points are marked in reference to a skeletal structure but have been located as skin "sites". The area marked (A) exhibited low resistance properties over the entire region; individual points were difficult to distinguish in this area.

<u>Cow map</u>

The Chinese acupuncture map of the cow is shown in Figure 9 (Chiang-hsi Provincial Veterinary Preventive Medicine Station, 1972). The circled points were located on a calf by the L.S.C.R. method and serve to confirm the Chinese acupuncture map of the cow. This experiment was

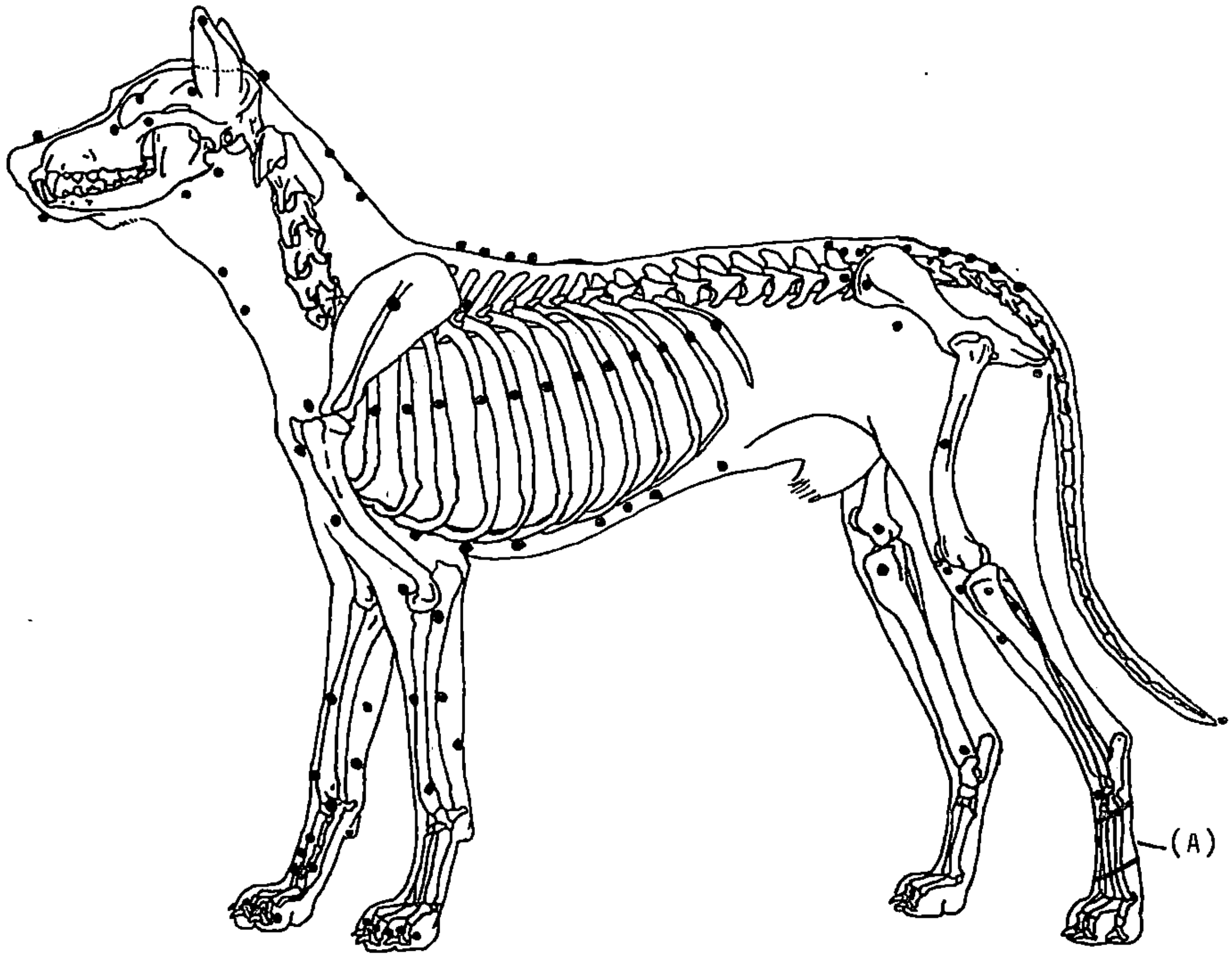
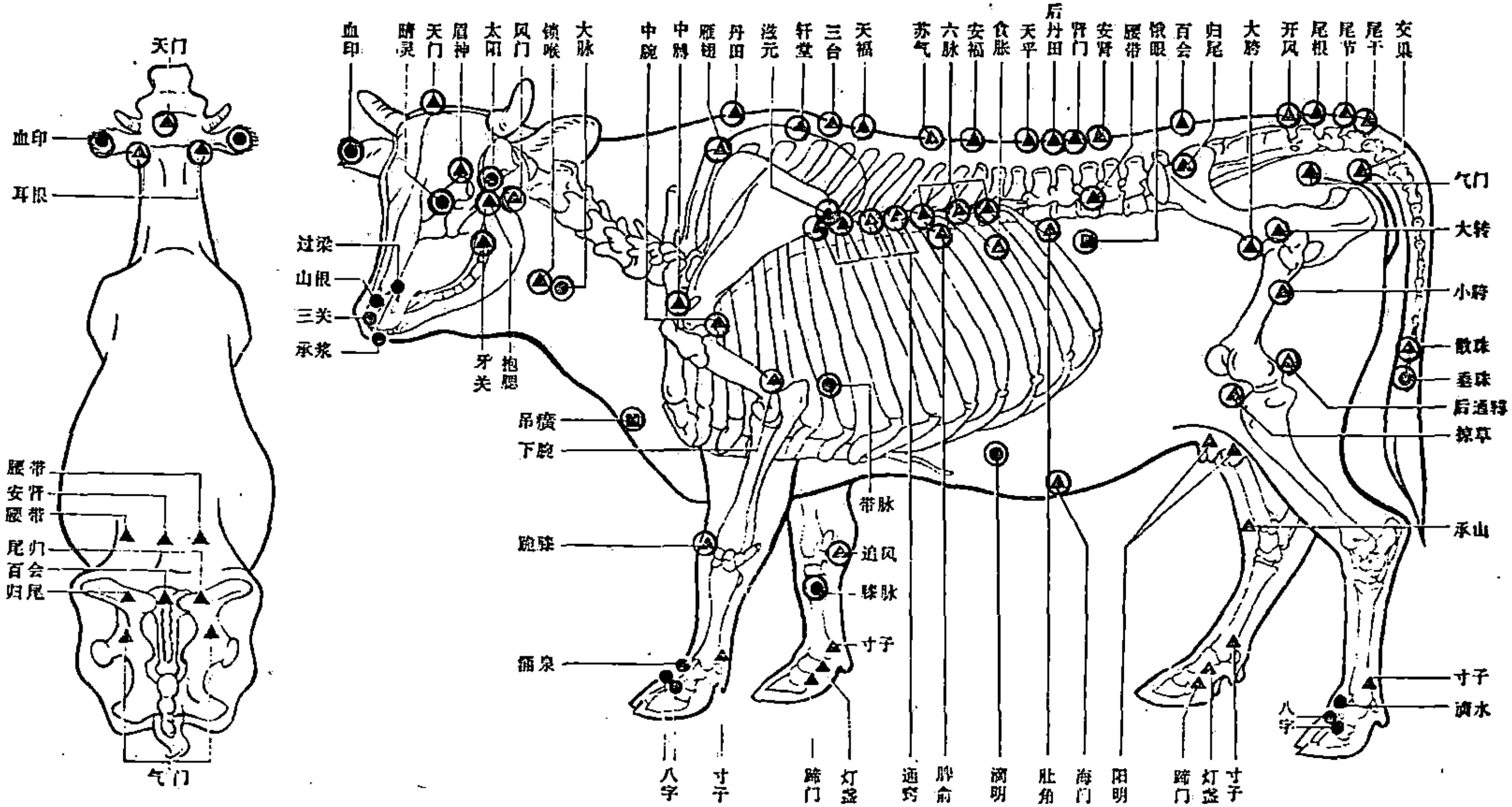


Figure 8. L.S.C.R. point map for the dog. The area marked (A) showed low resistance properties over the entire region.



牛骨骼及针灸穴位

Figure 9. Chinese acupuncture map of the cow with L.S.C.R. points circled. Map published by the People's Republic of China (Chiang-hsi Provincial Veterinary Preventive Medicine Station, 1972).

performed only once. The points on the feet and nose not circled were not tested because of the inconvenient location. Other L.S.C.R. points were located on the calf but are not marked on the map. These results confirm the Chinese cow map and relate L. S. C.R. points to acupuncture points.

General comments on mapping

The millivolt method was used to confirm all the L.S.C.R. points of the goat. All the L.S.C.R. points exhibited millivolt potentials of 5-60 millivolts. The dog was studied by the millivolt method, and it was found that the dermal structure of the dog was such that the millivolt apparatus recorded muscle potentials in the local area and this interfered with localizing points. A millivolt study of the cow was not made. The veterinary acupuncture manual, from which the cow map was taken, has been translated into English by King-yin Kong at Iowa State University (Chiang-hsi Provincial Veterinary Preventive Medicine Station, 1972). The text contains maps of the pig (Figure 10) and poultry. Maps of the horse (Figure 11) have also been developed in China. This text outlines acupuncture treatment patterns for a wide variety of animal disorders. Detailed instructions are given for the treatment of problems such as fodder poisoning and cystitis. This text could serve as the basis for a large number of therapeutic trials

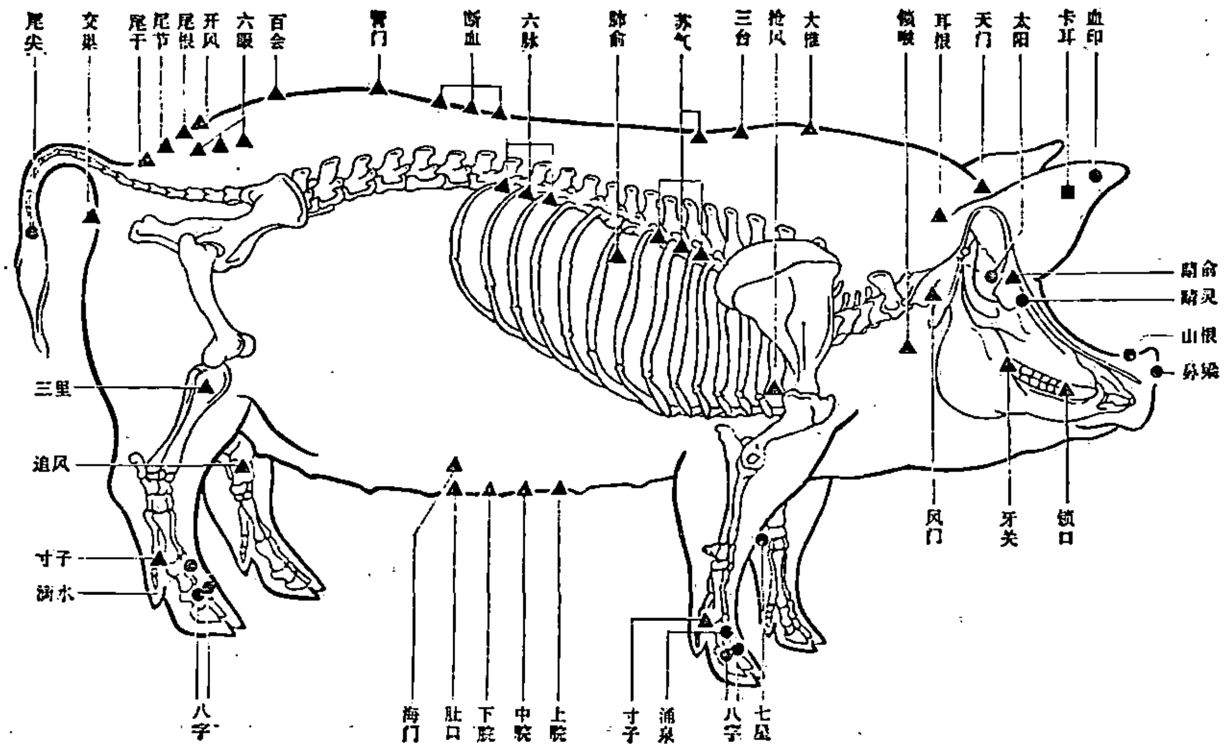


Figure 10. Acupuncture map of the pig as published by the People's Republic of China (Chiang-hsi Provincial Veterinary Preventive Medicine Station, 1972).

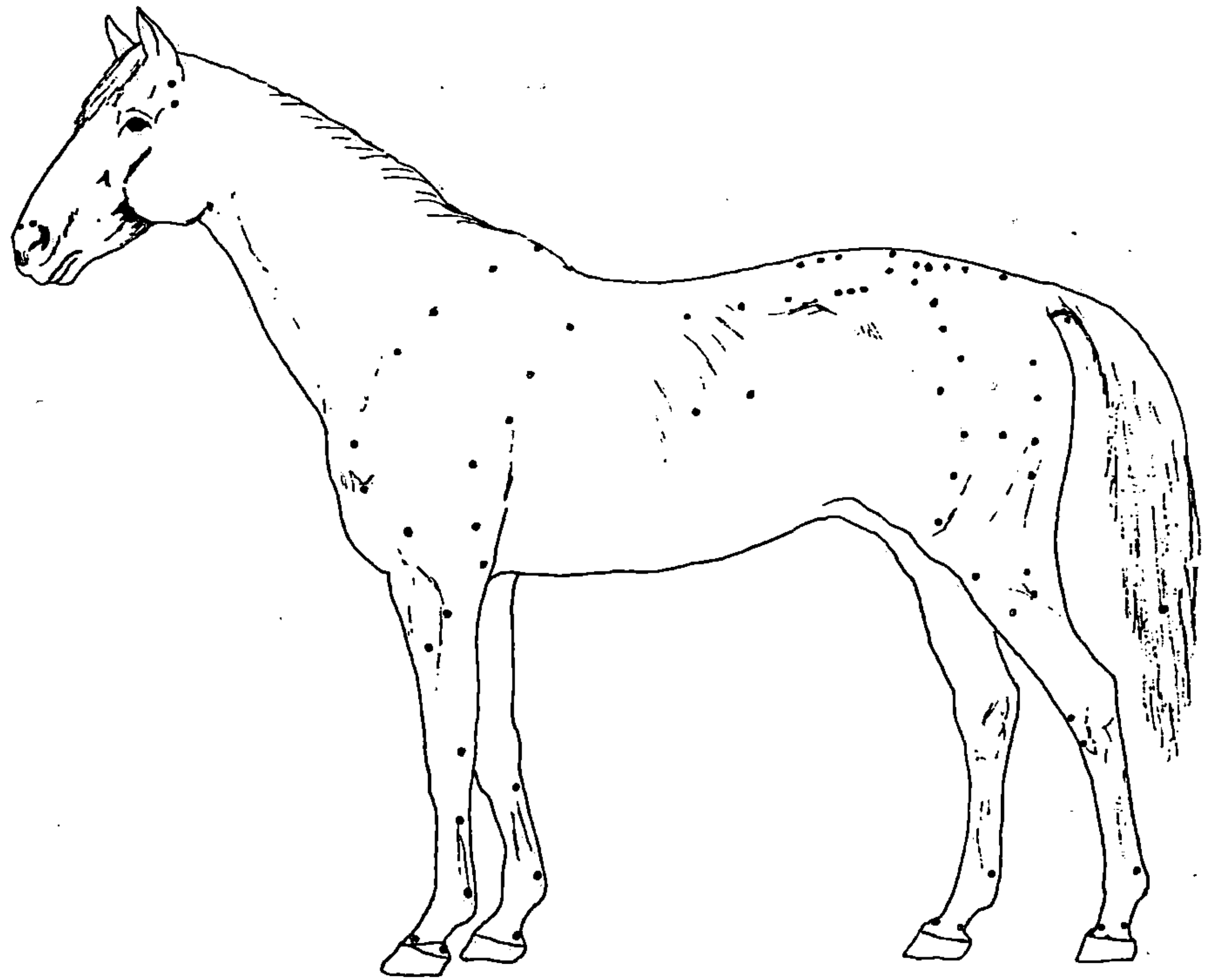


Figure 11. Acupuncture points of the horse. This map was developed in the People's Repulic of China (source unknown).

and basic physiological experiments. No information, however, is given as to how the maps were derived. Also, the points are not organized into a meridian system as for the human body (Figure 1). Kothbauer (1974) has attempted to organize a set of points on the back of the cow to describe the bladder meridian similar to the human system. No details, however, were given as to the techniques used for this determination.

In comparing the five maps in this text and relating them to the maps determined for the goat, certain similarities become apparent. The set of points following the backbone are common to all the animals. The points in the intercostal spaces can be seen in the dog (Figure 8), cow (Figure 9) and pig (Figure 10). The same ear point appears in the goat (Figure 7), dog, cow and pig. The animals with cloven hooves--goat, cow and pig--show a point pattern on the lower front and rear legs which are identical. Also, all the animals with tails have acupuncture points at the end of the tail. Differences in the patterns are probably due to the different anatomical structures of the animals.

In attempting to relate these maps to the human acupuncture map (Figure 1), a limited number of comparisons can be drawn. The points along the backbone are related to the governing vessel in the human. Other comparisons can be based only on individual points such as Stomach-36. This point is located just below the knee on the outside of the leg near the shin. By locating the second joint from the pelvis on the rear leg, it is possible to find the point Stomach-36 on the goat, dog, pig and horse. Stomach-36 points were used in the millivolt studies and are marked 3 and 4 in Figure 4. A similar extrapolation was used to locate Large Intestine-4 on the inside of the front leg (marked as points 1 and 2 in Figure 4).

The similarities in these maps provide evidence that these unique skin areas are related to the normal development of these vertebrates and that the L.S.C.R. and millivolt methods can locate these points. If the points of the cow and pig are defined as acupuncture points, then certain related points of the dog and goat can be defined as acupuncture points and can be used to treat the same disorders as those treated in the cow. In extrapolating this principle to the human system, it should be possible to use animals to test acupuncture techniques and to relate the information to humans through the corresponding point relationships.

Millivolt Potential Characterization of Acupuncture Points

The millivolt potentials of 10 points (Figure 4) were recorded over a 4-week period by using six goats. The points were studied to determine what range of values were charac-

Table 1. Millivolt potentials of six goats as measured over a 4-week period. Acupuncture point numbers correspond to points illustrated in Figure 4. Each number is the average of three measurements. All values are expressed in millivolts. Complete data listing is in Appendix C.

	Acupuncture Points										
Date	1	2	3	4	5	6	7	8	9	10	Ave. S.D.[1]
					Goat no. 160						
7/9	25.2	26.9						41.8		23.2	1.4
7/12	17.4	14.1	14.9	14.0	13.1	3.9	5.2	19.8	14.1	17.9	0.3
7/18	28.9	35.0	29.4	27.6	34.7	22.5	13.0	29.8	25.3	31.5	1.3
7/19	16.3	19.2	17.4	18.5	10.4	16.0	13.6	16.5	16.5	17.8	0.8
7/22	22.1	21.5	20.0	19.1	20.5	14.1	17.5	18.6	20.5	20.4	0.5
7/23	19.3	19.0	12.6	14.5	11.6	12.4	20.6	15.9	16.3	14.0	0.7
8/1	47.3	46.7	45.3	53.7	45.7	44.7	47.0	47.3	47.7	45.0	1.4
					Goat no. 169						
7/10	38.0	32.5	28.0	22.5	24.7	10.7	13.0	31.3	24.4	37.7	1.0
7/12	16.7	19.6	16.3	14.2	13.8	3.1	9.1	14.6	14.0	13.0	0.8
7/12	15.4	16.1	10.2	12.7	19.9	9.1	5.4	10.7	13.1	14.2	0.8
					Goat no. 171						
7/10	36.5	38.6	35.3	38.6	20.0	14.6	17.3	32.6	35.6	35.0	1.2
7/12	11.0	11.0	9.0	7.3	14.7	7.0	4.9	7.1	7.0	15.2	0.2
7/18	41.3	48.1	21.8	23.3	13.1	19.3	28.7	27.5	41.3	31.0	1.1
7/19	12.8	13.9	14.2	13.0	13.9	14.1	13.6	13.8	13.6	13.7	0.3
7/23	21.2	21.3	17.2	20.8	19.3	17.0	19.3	17.0	21.1	20.9	0.4
8/1			67.1	85.1	97.9				84.3	35.0	3.2
8/6	5.1	5.1	5.1	5.0	5.2	5.0	5.0	7.3	5.3	5.5	0.2

[1]Average standard deviation for all averages in each experimental day.

Table 1. (continued)

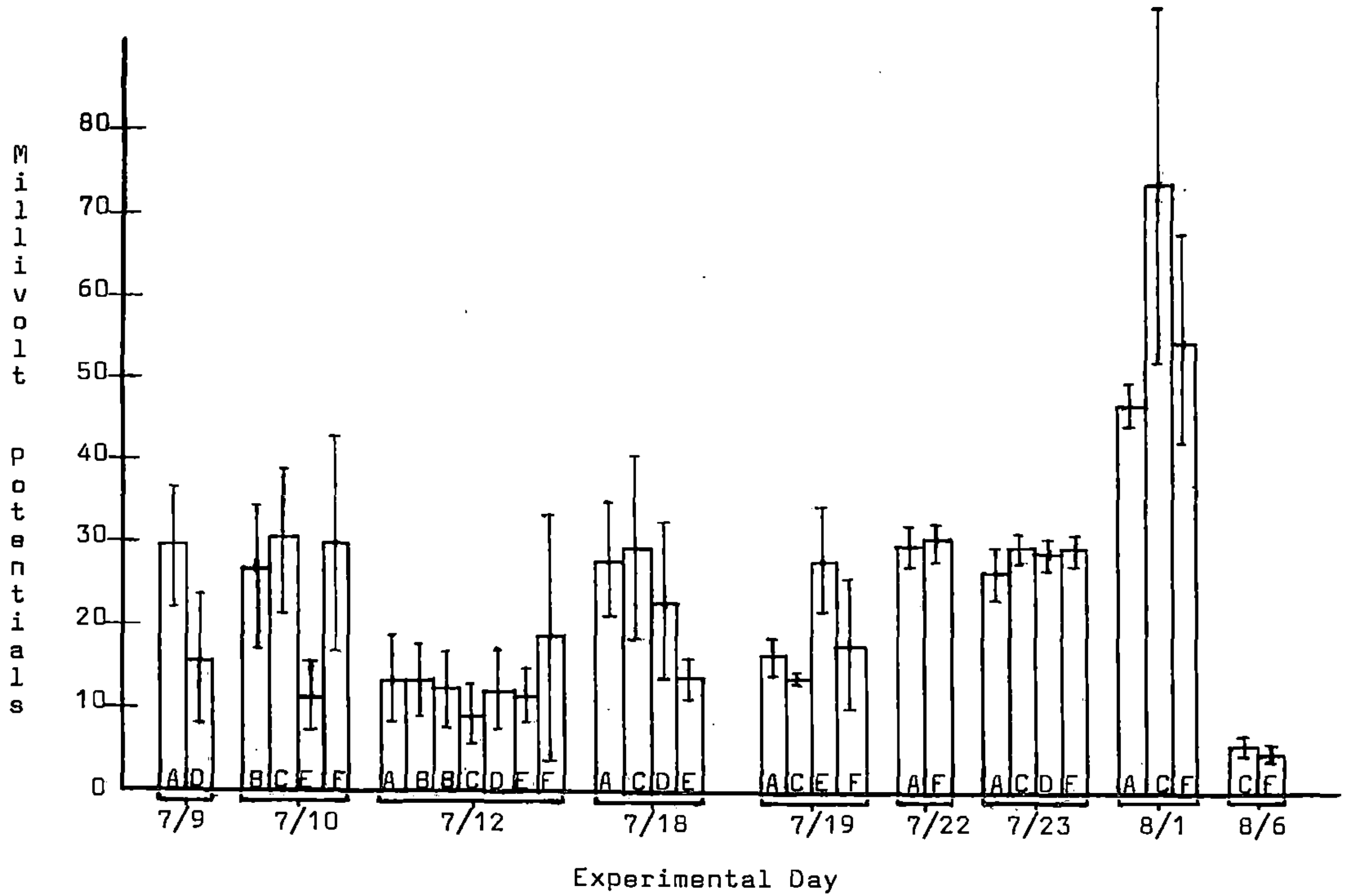
Date	Acupuncture Points 1	2	3	4	5	6	7	8	9	10	Ave. S.D.
						Goat no. 185					
7/9	14.2	6.5	18.7	17.9	25.4	6.9	7.5	26.3	23.9	8.5	1.0
7/12	18.1	19.5	5.6	8.5	7.1	14.1	15.4	16.8	6.6	10.3	0.4
7/18	22.8	32.9	18.9	14.0	29.6	9.4	9.1	29.6	35.5	26.4	0.6
7/23	20.2	20.4	16.0	19.8	17.1	20.4	19.1	20.1	18.9	18.8	0.4
						Goat no. 188					
7/10	11.0	11.1	15.7	6.1	15.9	6.1	12.0	11.1	6.3	16.9	0.7
7/12	10.2	12.8	17.9	11.8	13.7	6.1	8.6	8.4	12.2	12.2	0.6
7/18	9.8	13.4	13.4	10.0	12.4	14.3	12.8	13.3	16.8	18.0	0.6
7/19	32.2	35.0	16.7	26.9	28.0	37.0	32.9	24.4	22.8	23.1	1.2
						Goat no. 189					
7/10	41.0	41.7	23.0	30.9	37.7	10.9	4.0	39.1	38.3	31.0	1.1
7/12	10.5	9.2	13.7	12.2	43.4	4.6	12.9			41.4	0.6
7/19	15.8	34.4	20.7	19.9	19.6	7.0	3.9		17.4	18.8	0.9
7/22	18.4	21.8	21.4	21.2	20.6	15.2	20.5	20.9	20.3	20.8	0.5
7/23	16.0	21.7	19.4	19.1	21.0	17.6	19.1	19.9	19.9	20.5	0.3
8/1	74.7	86.9	66.5	72.4	56.0	47.3	50.0	60.0	68.3	63.7	2.2
8/6	4.9	4.9	4.9	4.4	4.7	4.9	4.9	4.1	4.1	4.9	0.2

teristic of acupuncture points and how constant these values were. Table 1 lists the millivolt values recorded for each goat through the 4-week period. Each number is the average of three consecutive readings (Appendix C is a complete list of all values recorded; included are body temperatures of the test animals and room temperature as measured immediately before each trial). The standard deviation at the end of every row of data was determined by averaging the individual standard deviations for each millivolt average per experimental day for each animal.

The points 1, 2, 3 and 4 were selected because of their correlation to human points. The other points were chosen because the positions were readily localized. The millivolt values range from 3.0 to 101.2 millivolts. The range of values between points is so large that a single average of all values is not significant. Nonacupuncture point areas register millivolt potentials of less than 1.0 millivolt.

Figure 12 presents the average value for each animal on each experimental day (Table 3 in Appendix C lists numerical values for the data in the figure). The standard deviation for each set of points indicates a high degree of variation between points for a particular goat on a given day. Points 6 and 7 were generally lower in electrical activity. Bilateral points generally showed similar activity (e.g. points 1 and 2). Figure 12 indicates a pattern of

Figure 12. Average millivolt potentials of six goats over a 4-week period graphed by experimental day. Each average includes standard deviation as marked by intersecting line. Letter notation and corresponding data to this figure can be found in Appendix C, Table 2.


Millivolt potentials
80
70
60
50
40
30
20
10
0
A D
7/9
B C E F
7/10
A B B C D E F
7/12
A C D E
7/18
A C E F
7/19
A F
7/22
A C D F
7/23
A C F
8/1
C F
8/6
Experimental Day

group reaction that changes on a daily basis. All goats tested on a given day have similar average values and these values fluctuate as a group. These daily fluctuations are not machine error because nonacupuncture points areas always registered similar voltages. The millivolt potentials of goat E (no. 188) did not conform to that of the other goats on a given day. The combination of goats was different for each day. This indicates that the variation was caused by some factor affecting all goats. The fluctuations can not be related to goat body temperature changes or changes in room temperature. Goats A and B were tested at the same time every day (time of each trial is listed in Appendix C) to eliminate diurnal fluctuations. However, these goats conform to the same pattern as the rest of the test goats. Goats were fed late in the afternoon, so possible changes because of digestive action would be minimized. The cause of this group action cannot be determined from the information recorded. Other factors such as skin temperature or the temperature of the barn where the goats were housed might be related to this activity.

Results of the voltage measurements indicate that the electrical properties of acupuncture points are dynamic and accessible to measurement. More detailed information needs to be collected to determine the significance of these properties. If Bergsman and Wooley-Hart (1973) are correct in their theory that these electrical skin properties are indicative of certain internal functions, then detailed metabolic studies should be conducted in conjunction with the measurement of these points to determine if some relationships do exist. No conclusions can be drawn from this study as to the structural nature of these points. Further work needs to be conducted to develop electronic systems designed to more thoroughly study these properties.

Anesthesia

Seven anesthesia trials were conducted using four goats. In six of the trials, deep analgesia was observed in the lower lip and lower abdomen. The analgesic condition was indicated by the amount of flinch response evoked by inserting a hypodermic needle into test areas. Before each experiment, the goat was tested for a normal flinch response to a needle prick. In all cases, the goats pulled away or kicked at the first sensation of the needle. The goats' eyes were covered during the needle test to eliminate any visual response to the needle.

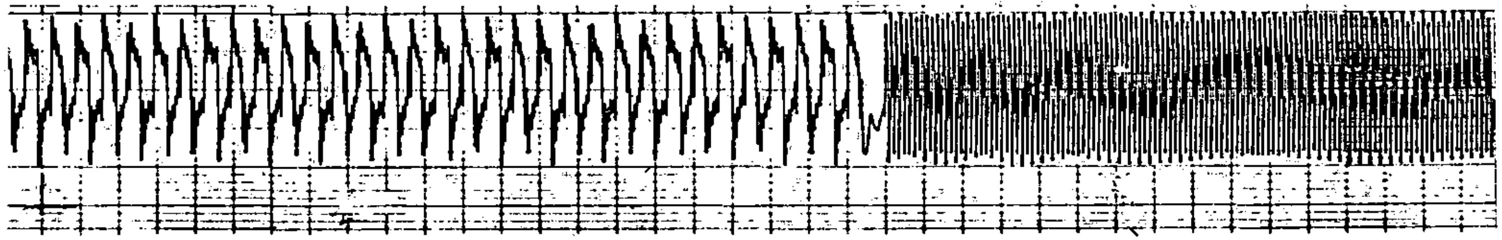
After the goat had been connected to the electrical stimulator, a voltage of 4-7 volts was applied in gradual increments. The maximum voltage was determined by observing the level at which the goat began attempting to remove the needle electrode. When this action was observed, the increase in voltage was stopped. The stimulator pulse was 1.0 millisecond in pulse width, and the frequency was varied approximately every 5 minutes to avoid adaptation to the stimulus. The frequency ranged from 60 to 360 Hertz. Pain stimuli were applied at 5-minute intervals. Analgesia was noted in the abdomen and lower lip 15-30 minutes after stimulation was begun. The level of analgesia became sufficient to permit multiple perforations of the lower lip and abdominal body wall without any response from the blindfolded goat. The analgesic state could be maintained from 30 to 90 minutes. Although analgesic periods were not extended, indications are that longer periods are possible. After electrical stimulation was stopped, the analgesic effect remained for approximately 30 minutes.

Other areas of the body were tested for analgesic effects. In general, a lower response was noted all over the goat, but the analgesic response was markedly greater in the target areas. No analgesia was noted near the area of the needle electrode.

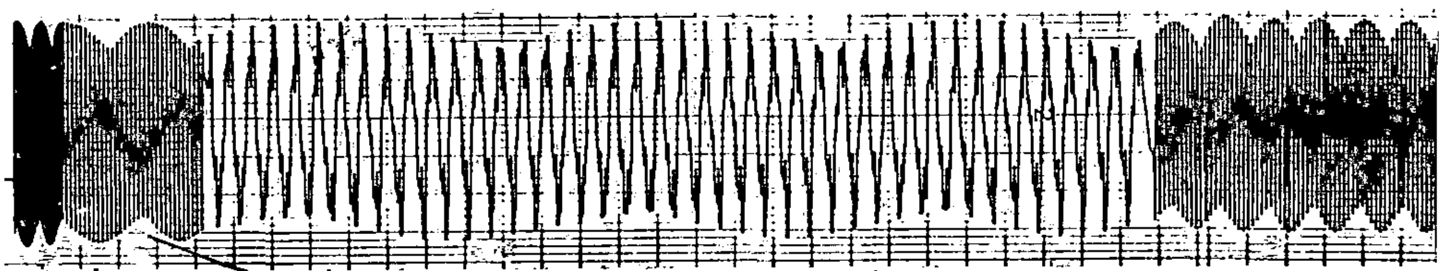
Another physiological change was observed in the goats when electrical stimulation was begun. Although heart rates remained stable, respiratory rates decreased. The goats also displayed behavioral changes during stimulation, becoming very quiet and, in two trials, lying down with the appearance of falling into sleep. After analgesia had been induced, urination and defecation usually occurred. The one trial considered to be a failure was terminated at an early stage because of electrical problems with the stimulator.

During the anesthesia experiments, millivolt potentials were recorded for a series of points on the goat. Figure 13 presents the results for one set of these recordings. The recordings were made after the analgesic effect was observed in the goat. Each trace was recorded at a different stimulating frequency as noted in Figure 13. The voltage and pulse width of the stimulation were kept constant. Other recordings, not included, were made while varying voltage and pulse width of the stimulating pulse. It was observed that if any characteristic of the stimulating pulse was changed, skin millivolt potentials changed amplitude, pattern and frequency. It was discovered that any point could be used to record potential patterns, and no difference in the output patterns would result for a particular stimulating pulse. Furthermore, recordings made before the analgesia had occurred appeared similar to those made during analgesia. The degree of similarity between recordings was difficult to determine because of the complexity of the output patterns. Comparison of the input pulse (Figure 5) with those recorded on the skin indicates that a number of events are occurring that modify the input pulses. These

Figure 13. Millivolt potential recordings measured during electrical stimulation of acupuncture points during acupuncture anesthesia procedure on a goat. Chart speed at which each trace was recorded is listed below related section. All recordings were made at 2 millivolts/division sensitivity as illustrated on the chart paper. Traces A through G represent recordings made at different stimulation frequencies with voltage and pulse width held constant at 4 volts and 1.0 millisecond respectively. Recordings: A - 60 Hertz; B - 80 Hertz; C - 120 Hertz; D - 150 Hertz; E - 200 Hertz; F - 300 Hertz; G - 360 Hertz.



A.



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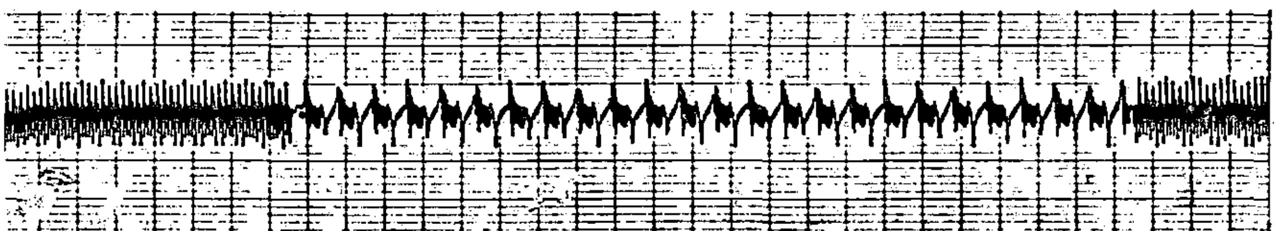

C.

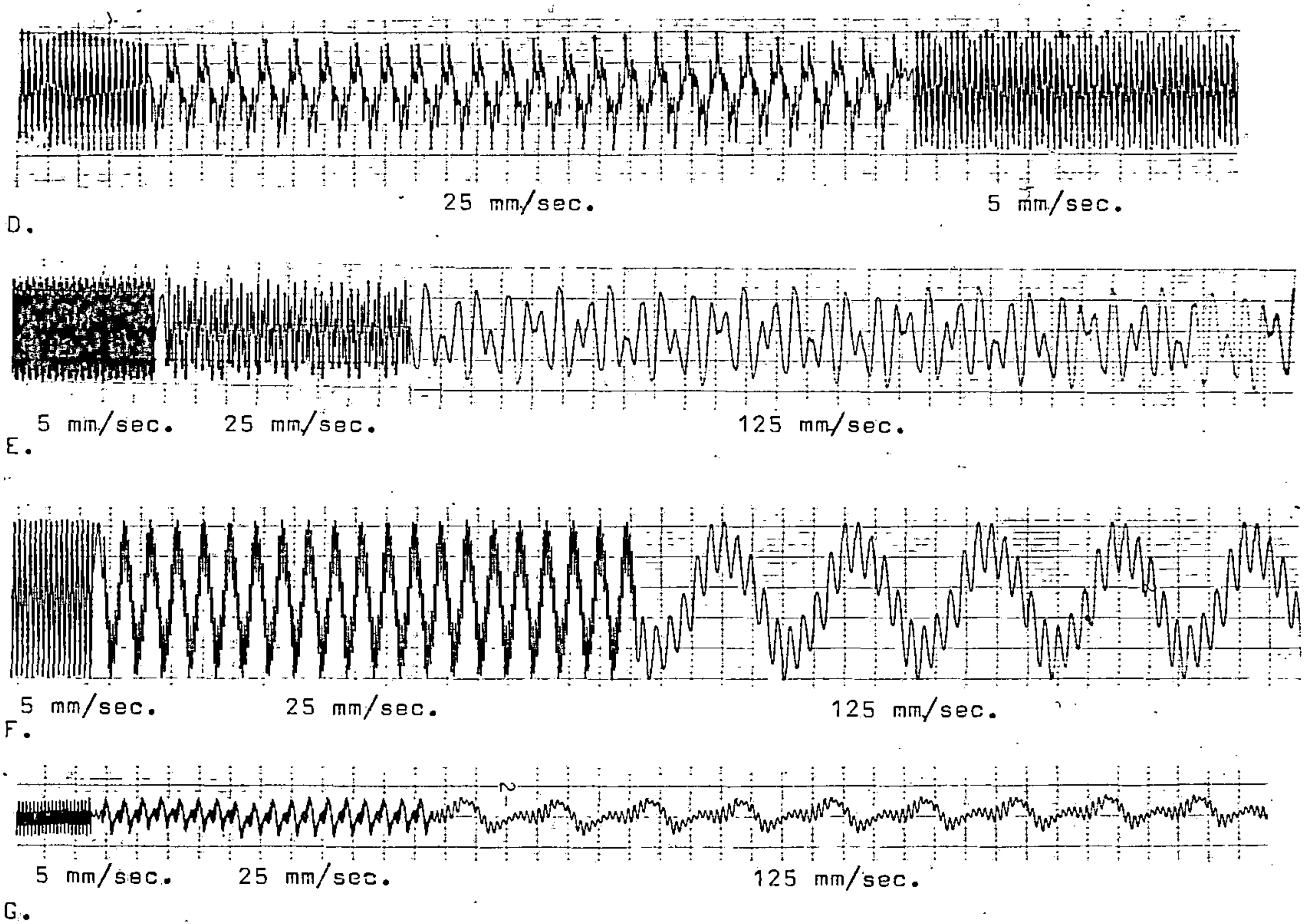

Figure 13 (continued).

modifications may be muscle potentials triggered by the stimulating pulse, but the patterns are identical all over the body indicating a central rather than a local effect such as a muscle potential. The nature of this central effect is not understood. Further detailed recordings of this nature are necessary to permit a more complex analysis of recurring electrical events.

The results indicate that acupuncture anesthesia procedures have animal applications; however, because full surgical procedures require greater control of an animal, these results are not fully indicative of the practicality of this procedure. Further mechanical procedures need to be developed to make this procedure fully practical.

SUMMARY

There were two main objectives to this research. First, to adapt human techniques for the location of acupuncture points for animal use and to develop acupuncture maps for the animals studied. Secondly, to test the validity of certain points located in the first part of the study by using a simple anesthesia trial.

The results presented here indicate that two electrical properties of acupuncture points can be used to determine their location on large animals. Acupuncture points exhibit lower resistance and higher millivolt potentials than nonacupuncture point areas. Both properties were used to determine acupuncture point patterns for the goat and dog and to confirm the acupuncture map of the cow as developed in the People's Republic of China. Both techniques need to be further refined in order that the results of these methods provide more accurate information. The data collected on the millivolt potential characteristics of certain acupuncture points of the goat indicate that these properties are dynamic and may be associated with some biophysical changes in the goat. The nature of these biophysical changes is not evident from the results of this study. The validity of the maps developed in this study is augmented by the similarities to acupuncture maps developed in China.

Further proof of the accuracy of these maps is provided by the positive results observed in the acupuncture anesthesia trials conducted with goats. By the use of electrical stimulation through needles at acupuncture points, an obvious analgesic condition was induced in target areas as predicted by human acupuncture anesthesia procedures. These initial results indicate that animal acupuncture anesthesia may provide a viable alternative to conventional chemical anesthetics.

In general, the results of this study add further evidence that acupuncture medicine is a legitimate approach to therapeutics and anesthesia for both human and animal use. Further work is required to fully realize the nature and scope of the Chinese art of acupuncture.

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APPENDIX A: PARTS LIST FOR L.S.C.R. DETECTOR

B1 – 9 volt battery.

R1 – 680,000 ohm resistor.

R2 – 100,000 ohm potentiometer.

R3, R4, R20 – 1,000 ohm resistor.

R5 – 1 megohm potentiometer.

R6 – 220,000 ohm resistor.

R7 – 82 ohm resistor.

R8 – 8,200 ohm resistor.

R9, R18, R19 – 10,000 ohm resistor.

R10, R17 – 10,000 ohm potentiometer.

R11, R12 – 47,000 ohm resistor.

R13 – 15,000 ohm potentiometer.

R14 – 220 ohm resistor.

R15 – 30,000 ohm potentiometer.

R16 – 4,700 ohm resistor.

C1 – 0.05 μF capacitor.

C2 – 0.001 μF capacitor.

C3 – 0.15 μF capacitor.

C4, C5 – 1 μF capacitor.

OA1, OA2 – 741C operational amplifier.

VCO – Signetics NE566 function generator.

Q1 – 2N3607 transistor.

Parts List for L.S.C.R. Detector (continued)

A – 1 mA full scale meter.

D1, D2 – 1N4001 diode (Si).

Sp – 8 ohm miniature speaker.

APPENDIX B: PARTS LIST FOR ACUPUNCTURE STIMULATOR

R1 - 20,000 ohm potentiometer.

R2 - 4,700 ohm resistor.

R3 - 150,000 ohm resistor.

R4, R17, R18 - 1 megohm resistor.

R6 - 680 ohm resistor.

R7 - 560 ohm resistor.

R8, R14, R21 - 10,000 ohm potentiometer.

R9, R22 - 10,00 ohm resistor.

R11, R12, R15, R16, R23, R24, R25 - 100,000 ohm resistor.

R13 - 1,500 ohm resistor.

R19 - 470 ohm resistor.

R20 - 560 ohm resistor.

R26 - 1,200 ohm resistor.

C1, C2, C4, C7, C9, C11 - 0.1 μF capacitor.

C3, C8 - 0.01 μF capacitor.

C5, C6, C10 - 7 μF capacitor.

D1 - 1N118 diode (Ge).

D2, D3 - Zener diode 10 volt.

A1 + A2, A3 + A4 - 747 dual operational amplifier.

T1, T2 - LM555C timer.

Q1 - 2N5172 npn transistor.

Q2 - 2N5355 pnp transistor.

APPENDIX C: TABLES

Table 2. Millivolt potentials of six goats as measured over a 4-week period. All values are expressed in millivolts.

Goat no. 160 Sex: Female Weight: 20 kg. Age: 5 months

Points[1] / Date	1	2	3	4	5	6	7	8	9	10
7/9	23.6	26.0						39.3		23.9
	24.5	27.4						43.0		22.9
	27.4	27.4						43.0		22.9
Ave.	25.2	26.9						41.8		23.2
S.D.[2]	2.0	0.8						2.2		0.6
Time: 10:30 B.T.[3]: 40.6 R.T.[4]: 22.2										
7/12	17.1	14.0	15.3	14.4	13.2	3.7	5.2	19.8	14.4	17.1
	18.0	14.1	15.0	13.2	13.1	4.2	5.3	19.8	14.0	18.2
	17.1	14.0	14.4	14.4	13.0	3.7	5.2	19.8	14.0	18.5
Ave.	17.4	14.1	14.9	14.0	13.1	3.9	5.2	19.8	14.1	17.9
S.D.	0.5	0.2	0.5	0.7	0.1	0.3	0.1	0.0	0.2	0.7
Time: 13:55 B.T. : 40.1 R.T. : 23.4										

[1]The points referred to are illustrated in Figure 4.

[2]Standard deviation.

[3]Body temperature in centigrade.

[4]Room temperature in centigrade.

Table 2. (continued)

Points Date	1	2	3	4	5	6	7	8	9	10
7/18	28.2	35.2	28.9	29.1	34.2	24.1	13.0	28.2	23.8	31.0
	29.2	36.5	28.9	27.3	34.9	22.8	13.0	29.2	24.7	32.9
	31.9	33.2	30.5	26.4	34.9	20.5	14.0	31.9	27.4	30.5
Ave.	29.8	35.0	29.4	27.6	34.7	22.5	13.0	29.8	25.3	31.5
S.D.	2.1	1.7	0.9	1.4	0.3	1.9	0.0	1.9	1.8	1.3
Time: 10:30	B.T. : 40.6	R.T. : 23.3								
7/19	16.0	19.5	16.9	18.2	11.6	16.1	14.3	16.0	15.5	18.0
	16.9	19.5	17.1	18.7	10.5	15.0	13.6	16.5	17.1	17.1
	16.0	18.7	18.2	18.7	9.1	16.9	13.8	17.1	16.9	18.2
Ave.	16.3	19.2	17.4	18.5	10.4	16.0	13.6	16.5	16.5	17.8
S.D.	0.5	0.5	0.7	0.3	1.2	1.0	0.9	0.6	0.9	0.5
Time: 15:10	B.T. : 40.6	R.T. : 26.7								
7/22	22.1	21.0	20.1	18.2	20.5	14.1	18.0	18.0	21.0	20.1
	22.0	21.6	19.9	19.5	21.0	14.0	18.0	18.2	20.2	20.1
	22.3	22.0	19.9	19.6	19.9	14.0	16.5	19.5	20.2	21.0
Ave.	22.1	21.5	20.0	19.1	20.5	14.1	17.5	18.6	20.5	20.4
S.D.	0.2	0.5	0.1	0.8	0.5	0.2	0.5	0.8	0.5	0.5
Time: 10:25	B.T. : 40.0	R.T. : 26.7								

Table 2. (continued)

Points Date	1	2	3	4	5	6	7	8	9	10
7/23	18.7	18.2	12.2	14.8	12.0	13.0	21.7	16.0	17.0	14.4
	20.5	20.1	11.6	15.0	12.0	12.2	20.5	16.0	15.8	13.8
	18.7	18.7	14.0	13.8	10.9	12.0	19.5	15.8	16.0	13.8
Ave.	19.3	19.0	12.6	14.5	11.6	12.4	20.6	15.9	16.3	14.0
S.D.	1.0	1.2	0.6	0.6	0.6	0.5	1.2	0.1	0.6	0.4
Time: 10:15	B.T. : 39.9		R.T. : 26.1							
8/1	49.0	48.0	47.0	54.0	47.0	44.0	47.0	47.0	45.0	44.0
	46.0	47.0	47.0	54.0	44.0	44.0	48.0	48.0	49.0	45.0
	47.0	45.0	42.0	53.0	46.0	46.0	46.0	47.0	49.0	46.0
Ave.	47.3	46.7	45.3	53.7	45.7	44.7	47.0	47.3	47.7	45.0
S.D.	1.5	1.5	2.9	0.6	1.5	1.2	1.0	0.6	2.3	1.0
Time: 10:30	B.T. : 40.1		R.T. : 23.1							

Goat no. 169 Sex: Female Weight: 20.7 kg. Age: 5 months

	1	2	3	4	5	6	7	8	9	10
7/10	35.6	31.9	26.4	22.8	24.7	10.0	12.1	30.1	23.8	37.5
	38.4	32.8	30.1	22.8	23.8	11.0	12.6	31.9	24.7	37.5
	40.1	32.8	27.4	21.8	25.5	11.1	14.4	31.9	24.7	38.2
Ave.	38.0	32.5	28.0	22.5	24.7	10.7	13.0	31.3	24.4	37.7
S.D.	2.3	0.5	1.9	0.6	0.8	0.6	1.0	1.1	0.5	0.4
Time: 14:15	B.T. : 40.6		R.T. : 32.9							

Table 2. (continued)

Points / Date	1	2	3	4	5	6	7	8	9	10
7/12	17.0	18.0	15.8	13.3	12.2	3.2	8.7	14.0	14.4	12.6
	16.0	20.8	15.5	13.8	14.4	3.0	8.7	14.9	13.8	13.2
	17.0	20.0	17.6	15.5	14.9	3.0	10.0	14.9	13.8	13.2
Ave.	16.7	19.6	16.3	14.2	13.8	3.1	9.1	14.6	14.0	13.0
S.D.	0.6	1.4	1.1	1.1	1.4	0.1	0.7	0.5	0.3	0.3
Time: 10:20 B.T. : 40.0 R.T. : 23.3										
7/12	14.4	14.0	10.1	11.2	20.1	8.6	5.2	10.5	12.6	14.4
	15.9	17.1	10.1	13.0	20.1	8.6	5.8	10.0	13.0	14.9
	15.9	17.1	10.5	14.0	19.4	10.1	5.2	11.7	13.7	13.2
Ave.	15.4	16.1	10.2	12.7	19.9	9.1	5.4	10.7	13.1	14.2
S.D.	0.8	1.7	0.2	1.4	0.4	0.8	0.4	0.9	0.5	0.9
Time: 14:15 B.T. : 39.7 R.T. : 23.3										
Goat no. 171 Sex: Female Weight: 19.5 kg. Age: 5 months										
7/10	32.8	39.9	36.5	38.3	23.1	14.4	18.0	34.7	36.5	33.8
	37.4	38.3	34.7	39.3	19.0	14.4	17.0	31.2	36.5	34.7
	39.3	38.3	34.7	38.3	17.9	15.0	16.9	31.8	33.8	36.5
Ave.	36.5	38.6	35.3	38.6	20.0	14.6	17.3	32.6	35.6	35.0
S.D.	3.2	0.6	1.0	0.6	2.7	0.3	0.6	1.9	1.6	1.4
Time: 13:30 B.T. : 39.4 R.T. : 23.9										

Table 2. (continued)

Points Date	1	2	3	4	5	6	7	8	9	10
7/12	11.2	10.9	9.0	7.5	13.8	6.0	5.0	7.2	7.0	14.9
	10.9	11.2	9.0	7.2	14.0	8.0	4.9	7.2	7.0	15.4
	10.9	10.9	9.0	7.0	15.0	7.0	4.8	7.0	6.9	15.4
Ave.	11.0	11.0	9.0	7.3	14.7	7.0	4.9	7.1	7.0	15.2
S.D.	0.2	0.2	0.0	0.2	0.6	0.1	0.1	0.1	0.1	0.3
Time: 13:30	B.T. : 39.7	R.T. : 24.0								
7/18	41.0	47.8	21.2	22.7	13.2	18.3	31.0	27.2	41.0	30.1
	41.0	47.8	20.5	22.7	13.0	19.4	29.8	27.2	41.0	30.1
	42.0	48.6	23.7	24.6	13.1	20.1	25.3	28.2	42.0	32.8
Ave.	41.3	48.1	21.8	23.3	13.1	19.3	28.7	27.5	41.3	31.0
S.D.	0.6	0.4	1.5	1.1	0.1	0.9	3.0	0.6	0.6	1.6
Time: 13:30	B.T. : 40.0	R.T. : 23.9								
7/19	13.0	14.0	14.1	12.9	14.0	14.1	14.0	14.0	14.0	13.7
	13.5	14.0	14.0	13.0	13.7	14.1	13.5	13.5	13.5	13.6
	12.0	13.7	14.6	13.1	14.0	14.1	13.2	14.0	13.2	13.7
Ave.	12.8	13.9	14.2	13.0	13.9	14.1	13.6	13.8	13.6	13.7
S.D.	0.7	0.2	0.3	0.1	0.2	0.0	0.4	0.3	0.4	0.1
Time: 13:40	B.T. : 40.6	R.T. : 26.7								

Table 2. (continued)

Points / Date		1	2	3	4	5	6	7	8	9	10
7/23		21.7	21.7	16.9	20.5	19.3	17.9	19.4	16.5	20.9	20.5
		21.7	21.2	17.1	20.9	20.0	16.1	19.4	17.2	21.2	20.9
		20.1	20.9	17.5	20.9	18.7	16.9	19.0	17.2	21.2	21.2
	Ave.	21.2	21.3	17.2	20.8	19.3	17.0	19.3	17.0	21.1	20.9
	S.D.	0.8	0.4	0.3	0.2	0.7	0.9	0.2	0.4	0.2	0.4
Time: 14:45	B.T. : 39.6	R.T. : 24.7									
8/1				64.0	90.0	101.2				82.5	34.2
				67.2	84.9	98.0				84.3	33.2
				70.0	80.5	94.5				86.2	37.5
	Ave.			67.1	85.1	97.9				84.3	35.0
	S.D.			3.0	4.8	3.4				1.9	2.3
Time: 13:25	B.T. : 38.3	R.T. : 23.9									
8/6		5.1	5.1	5.1	5.0	5.1	5.0	5.1	6.9	5.4	5.3
		5.1	5.1	5.1	5.1	5.1	5.0	5.1	7.4	5.4	5.6
		5.0	5.1	5.0	5.0	5.4	5.1	4.9	7.7	5.1	5.7
	Ave.	5.1	5.1	5.1	5.0	5.2	5.0	5.0	7.3	5.3	5.5
	S.D.	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.4	0.2	0.2
Time: 10:15	B.T. : 40.0	R.T. : 24.0									

Table 2. (continued)

Goat no. 185 Sex: Female Weight: 17.2 kg. Age: 5 months

Points / Date		1	2	3	4	5	6	7	8	9	10
7/9		13.9	6.8	18.3	18.3	23.6	6.5	7.6	26.3	23.6	6.7
		13.9	6.8	17.0	18.3	26.3	6.5	7.0	25.4	23.6	8.9
		14.9	5.8	20.8	17.0	26.3	7.8	8.0	27.3	24.6	10.0
	Ave.	14.2	6.5	18.7	17.9	25.4	6.9	7.5	26.3	23.9	8.5
	S.D.	0.5	0.6	1.9	0.8	1.6	0.8	0.5	1.0	0.6	1.4
Time: 15:00 B.T. : 37.8 R.T. : 23.3											
7/12		18.0	20.0	5.5	8.7	8.2	14.4	15.8	16.9	5.9	10.9
		18.2	19.3	5.5	8.7	7.0	14.0	16.1	16.9	7.0	10.0
		18.2	19.3	5.9	8.0	6.2	14.0	14.4	16.5	7.0	10.0
	Ave.	18.1	19.5	5.6	8.5	7.1	14.1	15.4	16.8	6.6	10.3
	S.D.	0.1	0.4	0.2	0.4	0.9	0.2	0.9	0.2	0.6	0.5
Time: 11:25 B.T. : 39.2 R.T. : 24.2											
7/18		22.8	32.0	18.9	14.0	28.3	8.6	8.6	28.3	35.6	27.3
		22.8	32.9	18.9	14.0	30.5	9.5	8.6	30.0	35.6	26.4
		22.8	33.8	18.9	14.0	30.0	10.0	10.2	30.5	34.7	25.4
	Ave.	22.8	32.9	18.9	14.0	29.6	9.4	9.1	29.6	35.5	26.4
	S.D.	0.0	0.9	0.0	0.0	1.2	0.7	0.8	1.2	0.5	1.0
Time: 11:20 B.T. : 38.3 R.T. : 23.3											

Table 2. (continued)

Points Date		1	2	3	4	5	6	7	8	9	10
7/23		20.1	20.5	15.9	19.4	16.9	20.5	19.9	20.1	18.7	17.9
		20.5	20.1	15.9	19.0	16.9	20.5	18.7	20.1	18.7	19.0
		20.1	20.5	16.1	21.0	17.5	20.1	18.7	20.1	19.4	19.4
	Ave.	20.2	20.4	16.0	19.8	17.1	20.4	19.1	20.1	18.9	18.8
	S.D.	0.2	0.2	0.1	1.1	0.3	0.2	0.7	0.0	0.4	0.8
Time: 11:20 B.T. : 38.9 R.T. : 23.3											
Goat no. 188 Sex: Female Weight: 19.1 kg. Age: 5 months											
7/10		10.8	11.0	16.5	5.5	16.9	6.9	12.4	11.8	6.7	17.1
		11.0	12.0	15.3	6.1	14.3	5.3	12.4	10.8	6.1	17.1
		11.2	10.2	15.3	6.8	16.4	6.0	11.3	10.8	6.1	16.4
	Ave.	11.0	11.1	15.7	6.1	15.9	6.1	12.0	11.1	6.3	16.9
	S.D.	0.2	0.9	0.6	0.7	1.5	0.8	0.6	0.6	0.3	0.4
Time: 10:30 B.T. : 40.1 R.T. : 23.9											
7/12		9.8	12.9	18.0	11.2	13.2	5.4	8.3	8.8	13.7	13.0
		9.9	12.9	18.0	12.0	13.8	6.4	8.7	8.0	12.0	12.0
		11.0	12.6	17.6	12.2	14.0	6.4	8.9	9.0	11.0	11.6
	Ave.	10.2	12.8	17.9	11.8	13.7	6.1	8.6	8.4	12.2	12.2
	S.D.	0.7	0.2	0.2	0.5	0.4	0.6	0.3	0.5	1.4	0.7
Time: 14:55 B.T. : 40.0 R.T. : 23.3											

Table 2. (continued)

Points Date	1	2	3	4	5	6	7	8	9	10
7/18	10.0	13.3	13.2	9.0	12.1	14.2	12.3	12.7	16.6	17.1
	9.5	12.8	13.7	9.9	12.3	14.3	12.9	12.8	16.8	18.0
	10.0	14.3	13.2	11.0	12.7	14.5	13.3	14.5	17.0	19.0
Ave.	9.8	13.4	13.4	10.0	12.4	14.3	12.8	13.3	16.8	18.0
S.D.	0.2	0.7	0.2	1.0	0.3	0.2	0.8	1.1	0.2	1.0
Time: 14:55 B.T. : 40.0 R.T. : 26.1										
7/19	31.9	32.9	17.0	28.2	28.3	35.5	31.9	22.7	21.8	23.8
	32.8	35.6	17.0	26.2	28.3	35.5	32.8	23.8	22.7	22.7
	31.9	36.5	16.0	26.2	27.3	40.0	34.0	26.8	23.8	22.7
Ave.	32.2	35.0	16.7	26.9	28.0	37.0	32.9	24.4	22.8	23.1
S.D.	0.5	1.9	0.6	1.2	0.6	2.6	1.0	2.0	1.0	0.6
Time: 15:45 B.T. : 40.6 R.T. : 24.2										
Goat no. 189 Sex: Female Weight: 20.7 kg. Age: 5 months										
7/10	41.0	41.0	22.8	30.1	37.5	10.2	4.0	38.3	35.5	33.8
	42.0	41.0	22.8	30.8	38.3	10.6	3.9	39.0	41.1	30.0
	40.0	43.0	23.5	31.8	38.3	12.0	4.0	40.0	38.3	29.1
Ave.	41.0	41.7	23.0	30.9	37.7	10.9	4.0	39.1	38.3	31.0
S.D.	1.0	1.2	0.4	0.8	0.5	1.0	0.1	0.8	2.8	2.5
Time: 15:40 B.T. : 40.0 R.T. : 23.9										

Table 2. (continued)

Points Date	1	2	3	4	5	6	7	8	9	10
7/12	10.5	8.7	14.0	11.7	42.1	4.0	13.3			42.1
	10.5	9.0	14.0	12.2	44.0	4.9	12.2			41.0
	10.5	9.9	13.2	12.7	44.0	5.0	13.3			41.0
Ave.	10.5	9.2	13.7	12.2	43.4	4.6	12.9			41.4
S.D.	0.0	0.6	0.5	0.5	1.2	0.5	0.6			0.6
Time: 10:55 B.T. : 39.2 R.T. : 23.3										
7/19	16.8	33.8	22.0	21.5	20.0	7.0	4.0		16.0	18.0
	15.8	35.7	20.5	18.5	20.0	7.0	3.8		17.5	18.0
	14.9	33.8	19.5	18.7	18.7	7.0	3.8		18.7	20.5
Ave	15.8	34.4	20.7	19.9	19.6	7.0	3.9		17.4	18.8
S.D.	1.0	1.2	1.2	1.5	0.8	0.0	0.1		1.3	1.4
Time: 14:05 B.T. : 40.0 R.T. : 26.7										
7/22	19.9	21.8	21.8	21.2	20.5	13.8	20.5	21.2	20.9	21.8
	18.7	21.8	21.2	21.2	20.9	14.9	20.5	20.9	20.0	20.5
	16.5	21.8	21.2	21.2	20.5	16.9	20.5	20.5	19.9	20.0
Ave.	18.4	21.8	21.4	21.2	20.6	15.2	20.5	20.9	20.3	20.8
S.D.	1.7	0.0	0.3	0.0	0.2	1.6	0.0	0.4	0.5	0.7
Time: 11:00 B.T. : 40.1 R.T. : 26.7										

Table 2. (continued)

Points / Date	1	2	3	4	5	6	7	8	9	10
7/23	15.9	22.0	19.9	19.3	21.1	18.2	19.3	19.9	19.9	20.5
	16.2	21.1	19.3	19.3	20.9	17.6	19.3	19.9	19.3	20.5
	15.9	22.0	19.0	18.7	20.9	16.9	18.7	19.9	20.5	20.5
Ave.	16.0	21.7	19.4	19.1	21.0	17.6	19.1	19.9	19.9	20.5
S.D.	0.2	0.5	0.4	0.3	0.1	0.7	0.3	0.0	0.6	0.0
Time: 11:00 B.T. : 39.6 R.T. : 26.1										
8/1	73.0	80.6	63.0	71.8	56.0	48.0	51.0	58.0	65.0	63.0
	76.1	90.0	68.2	68.2	56.0	46.0	50.0	60.0	68.2	64.0
	75.0	90.0	68.2	77.2	56.0	48.0	50.0	62.0	71.8	64.0
Ave.	74.7	86.9	66.5	72.4	56.0	47.3	50.0	60.0	68.3	63.7
S.D.	1.6	5.4	3.0	4.5	0.0	1.2	0.6	2.0	3.4	0.6
Time: 11:15 B.T. : 39.7 R.T. : 32.1										
8/6	4.9	5.0	4.9	4.9	4.3	5.0	4.9	4.1	4.1	4.9
	5.0	4.9	5.0	4.1	4.9	5.0	4.9	4.1	4.0	5.0
	4.9	4.9	4.9	4.1	4.9	4.6	5.0	4.1	4.3	4.9
Ave.	4.9	4.9	4.9	4.4	4.7	4.9	4.9	4.1	4.1	4.9
S.D.	0.1	0.1	0.1	0.5	0.3	0.2	0.1	0.0	0.1	0.1
Time: 15:00 B.T. : 40.0 R.T. : 24.2										

Table 3. Daily averages of millivolt potentials of six goats over a 4-week period. Each number is the average of all points measured on a given experimental day for each goat. Data is illustrated in Figure 12. All values are expressed in millivolts. Letter identifications coincide with Figure 4.

	Experimental Day								
Goats	7/9	7/10	7/12	7/18	7/19	7/22	7/23	8/1	8/6
(A)160	29.3		13.4	27.8	16.2	19.4	16.4	47.0	
S.D.[1]	7.3		5.1	6.4	2.5	2.3	3.3	2.5	
(B)169		26.3	13.4 (12.6)[2]						
S.D.		9.2	4.5 (4.1)						
(C)171		30.4	9.4	29.5	13.6		19.5	73.9	5.7
S.D.		9.3	3.5	11.1	0.5		1.7	21.8	0.8
(D)185	15.6		12.2	22.8			19.1		
S.D.	8.0		4.8	9.6			1.5		
(E)188		11.2	11.4	13.4	27.9				
S.D.		4.1	3.3	2.6	6.4				
(F)189		29.8	28.5		17.5	20.1	19.4	64.6	4.6
S.D.		13.2	15.1		8.7	2.0	1.6	12.0	0.4

[1] Standard deviation.

[2] Two sets of data were recorded on 7/12 for goat 169.