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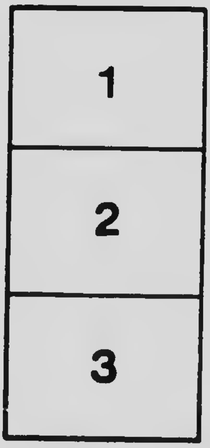

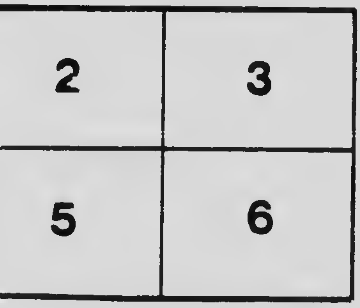

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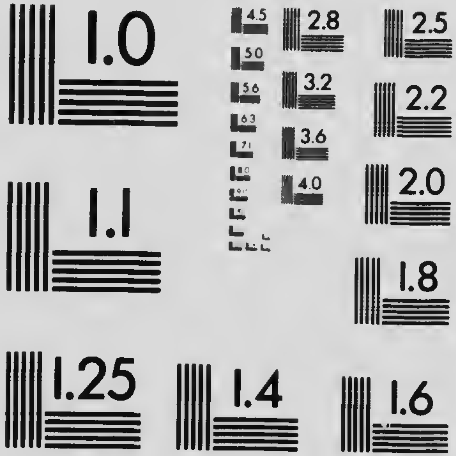

AIDS
TO
ELECTRO-THERAPEUTICS

J. MAGNUS REDDING

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TO

ELECTRO-THERAPEUTICS

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TORONTO

THE MACMILLAN COMPANY OF CANADA LTD

1920

6565

Printed in Great Britain

PREFACE

IN this small book I have attempted to provide a practical guide in the art of electro-therapy.

Theoretical considerations have been dealt with only in so far as it has appeared necessary for the proper understanding of the subject; on the other hand, the more common forms of apparatus employed and the methods of using them have been described in some detail, and it is hoped that no essential points of technique have been omitted.

J. MAGNUS REDDING.

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AIDS TO ELECTRO-THERAPEUTICS

CHAPTER I

INTRODUCTORY

FEW advances in medicine have suffered so much and been threatened with such ill repute as the application of electricity as a therapeutic agent in the treatment of disease. This was due, to a great extent, to the ease with which unqualified and often profoundly ignorant persons were able to impose upon the credulity of the public, the imposition, as is usual in such cases, depending largely on promises of attaining a cure in conditions which had resisted the endeavours of orthodox medicine and surgery, and which were, pathologically, though not necessarily symptomatically, incurable. The natural result of the manifold disappointments and financial losses, which form inseparable companions to such a state of affairs, was a tendency to regard the electrotherapist as little better than a charlatan; and there is no doubt that this conclusion, as applied to a considerable section of the untrained lay public engaged in "electrical treatment," was fully justified. During the last few years, however, the devoted work of a certain number of scientific medical men has succeeded in freeing the bona fide electrotherapist from the cloud of suspicion which threatened to completely overshadow him, and the subject is now rightly regarded as one which is deserving of the closest attention.

In order that the present satisfactory status of electro-therapy should be maintained, it is essential that all engaged in its application should keep certain salient facts prominently before their minds.

1. Always attempt to arrive at an accurate diagnosis. Do not be satisfied with labelling a case "neuritis" or "rheumatism" until every possible causative factor has been excluded, and if any such factor is discovered insist upon its adequate treatment.

2. Empiricism is bound to result in disappointment, failure, and ultimate retrogression of what should be one of the most scientifically progressive branches of medicine. The theories of the action on the tissues of electrical agents should be thoroughly mastered, and the line of treatment to be adopted in every case should be governed by their application.

3. A fairly large proportion of the cases which are sent to the electro-therapist have already shown themselves resistant to other lines of treatment; some of these will respond to electrical treatment in a most gratifying manner; others, which may appear to be identical in their clinical features with the former group, will resolutely resist all efforts to procure amelioration. Therefore be exceedingly guarded in giving a prognosis, and never hold out rash promises of a speedy cure.

4. Never prescribe electrical treatment in a case where no improvement can result; and in cases which are incurable, but capable of relief, always give the patient a frank estimate of the benefit which he may reasonably expect to derive from such treatment.

The changes which can be induced by electrical agents in the tissues of the human body are far more perfectly understood than was the case a few years ago, although in many instances considerable further investigation is necessary for their more complete elucidation. They may be classified as follows, bearing in mind that many forms of treatment will produce changes belonging to more than one class:

1. Physiological.
2. Chemical.
3. Physical.
4. Psychic.

1. **Physiological.**—The best examples of purely physiological changes are provided by the reaction of living tissues to X-radiation and radium radiations. The association between these forms of radiation is discussed in Chapters XIII. and XIV., and a more full account given of the tissue changes induced. For the present purpose an example of purely physiological action may be quoted: If a malignant growth, such as a carcinoma, be subjected to suitable exposures of X-radiation, certain of the tumour cells will undergo various changes. These changes may be of a retrogressive or destructive character, resulting in the ultimate death of the cell, or may be of a stimulating nature, resulting in increased physiological activity of the cell and rapid cell-multiplication, and, where this stimulation is in excess of or unaccompanied by destructive action, in the rapid increase in size of the tumour as a whole.

These changes must, the present state of our knowledge, be considered as dependent upon some direct alteration induced in the vital activity of the living cell protoplasm. Possibly with increased research this group of changes may be included in the class next to be considered.

2. **Chemical.**—To understand the nature of the chemical changes which take place on the passage of a current of electricity through the body, it is necessary to consider in some detail the nature and behaviour of ions.

Certain substances known as electrolytes, if dissolved in water, have the property of becoming dissociated to a greater or lesser extent into ions, the ion being an atom of the substance combined rather loosely with a negative or positive charge of electricity. *E.g.*, sodium chloride will become dissociated into ions of sodium and chlorine, the sodium having a positive charge, the chlorine a negative. In such a solution only a certain percentage of the molecules present will be dissociated into their component ions at any one time, and the more dilute the solution the larger will be the percentage of dissociation. In the case of complex substances the dissociation may not be into its elements, but into less complex substances.

The same ions do not remain in their dissociated state all the time, but are constantly in a state of movement, undergoing recombination to form a molecule of the salt once more. This state of movement is aimless, and does not result in excess of ions of either polarity in any part of the solution. If, now, two electrodes connected to the poles of a battery of cells or other source of constant electrical current be introduced into the solution, a current will pass through the solution, and the following changes will take place: The sodium ions with their positive charge will be attracted to the negative electrode (since like charges dispel, and unlike attract, each other). Any one sodium ion will only travel a very short distance, and will then displace another sodium atom from its association with the chlorine atom, combining temporarily with the chlorine atom to form an associated molecule. In this way a number of sodium ions will arrive at the negative electrode. Here the positive charge of the ion will be neutralized by the negative electrode, and a free atom of sodium will result. This is the primary change, but immediate secondary chemical changes take place. The sodium atom splits up the water into the hydroxyl radical OH, with which it combines to form caustic soda, and free hydrogen, the latter escaping in the form of bubbles of gas from the surface of the solution around the electrode; while certain of the hydroxyl radicals, which possess a negative charge, will be started on their journey towards the positive electrode.

In the same way the chlorine ions will arrive at the positive electrode, part with their electrical charge, and become free atoms of chlorine. This immediately splits up the water, the hydrogen combining to form hydrochloric acid, with liberation of oxygen. Thus around the negative electrode alkali is produced, around the positive acid.

Solutions of salts, bases, and acids form electrolytes; but carbohydrates, proteins, and some other chemical substances do not, and no current will flow through a solution of such a substance, indicating that the changes above described are essential to the passage of electricity throu[illegible] a liquid. Some gases and solids, or melted solids [illegible]re electrolytes.

The human body, having a large number of different salts in solution, will obviously act as an electrolyte, and a constant current in its journey through the body will produce many ionic changes; a consideration of the changes possible will go far to point out a rational line of treatment.

The movement of ions will also act upon muscles and nerves (motor and sensory) under certain circumstances, causing contraction in the muscles involved—an example of combined chemical and physiological action.

3. **Physical.**—The physical effects of electrical treatment are chiefly dependent upon the production of heat in the body. This may be confined almost entirely to the surface, as in exposure to radiant heat (electric light bulbs arranged under a suitable reflector), or be produced fairly uniformly throughout the tissues under treatment. The latter conditions are attained by the use of high-frequency and diathermy currents; these currents are of an oscillating character, the oscillations being of such enormous rapidity that no ionic movement can take place. The warming of the tissues is due to the resistance which they impose to the passage of the current, and is not accompanied by any muscular contraction or sensation other than that of heat, owing to the absence of ionic movement mentioned above.

These physical effects of electricity are always accompanied by physiological changes—*e.g.*, vaso-dilatation, increased metabolism, acceleration in removal of waste products.

4. **Psychic Effect.**—It is of the greatest importance to form a correct estimate of the value of this factor in electrical treatment, and to discriminate carefully those cases where it should be introduced. It is quite unnecessary to seek to affect the mental attitude of a patient suffering from an ulcer of the leg by means of imposing apparatus and the production of adventitious noises. Such ruses do not influence the healing of the ulcer, nor do they add to the dignity of the medical profession. On the other hand, many cases present either a pure neurosis or else a definite pathological lesion combined with a neurosis; in these it is desirable to make as profound a mental impression on the patient as is compatible with the adoption of a rational line of electrical treatment.

CHAPTER II

STATIC ELECTRICITY

STATIC electricity has been described as electricity without motion. It is of very high voltage or potential, and small amperage. The existence of a static charge on any object implies that the object is perfectly insulated, otherwise the charge would immediately be dispelled. The simplest example of static electricity is afforded by rubbing a glass rod with a silk handkerchief. The glass receives a positive charge and the silk a negative. The glass rod, being a non-conductor, will retain the charge at the part not held in the hand until the finger is brought close to it, when a tiny spark will leap across to the finger, the rod thus being discharged.

The simplest form of electro-medical static machine for descriptive purposes is the Tœpler (Fig. 1). In this there is a fixed glass plate *D*, and a revolving glass plate *E* very close to it. On *D* are two strips of metal *X* and *Y*, which are connected with metal rods ending in collecting combs or brushes, *O* and *P*, which rub the surface of *E* distant from *D*. On this surface of *E* also are attached strips of metal, *A*, *B*, *C*, etc., arranged in a radial manner. There are also a pair of brushes *L* and *M*, connected by a rod *Z*, which rub these pieces of metal. The plate *E* is rapidly revolved. If *A* is followed, the following changes take place: The friction of the brush *L* produces a positive charge in *A*. Negative electricity is repelled along the rod *Z* to *B*, and positive attracted from *B* to *A*; *A* then passes on with a surplus positive charge. When it reaches *O* it parts with its surplus + charge to the metal plate *Y*, and becomes neutral. Passing beyond *O*, but still under inductive influence

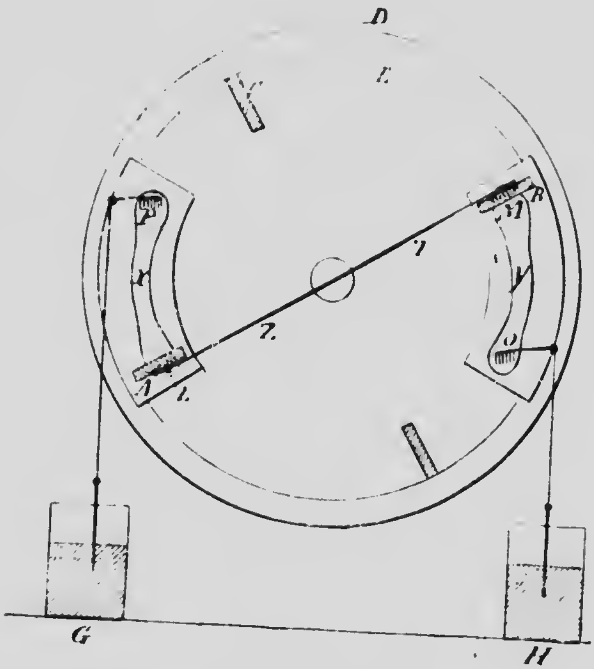

FIG. 1.

D, Larger fixed plate; *E*, smaller revolving plate; *X* and *Y*, metal strips on back of *D*; *A*, *B*, *C*, metal strips on front of *E*; *O*, *P*, brushes connected with *Y* and *X*, and rubbing front of *E*; *L*, *M*, brushes connected by *Z*, and rubbing front of *E*; *G*, *H*, Leyden jars.

from *Y*, it reaches brush *M*. Owing to inductance of *Y*, positive electricity is repelled from *A* to *B* along rod *Z*, and negative attracted to *A* from *B*. *A* then leaves brush *M* and the influence of plate *Y*, and approaches brush *P* armed with a negative charge, which it parts with to *P*, becoming neutralized; under inductive influence of *X*, *A* reaches *L*, where the negative portion of its neutral charge is repelled once more along *Z*, leaving *A* with a positive charge. In this way plates *Y* and *X* acquire positive and negative charges, and these charges are stored on large brass balls. Discharge will take place through the air between these balls if they are brought close enough together. The violence of the discharge is much increased, though rendered intermittent in character if *X* and *Y* are connected with the inner coats of Leyden jars, the outer coats of which are earthed or connected together.

The Holtz and the Wimshurst machines are similar in principle, though differing in detail. The Holtz requires to be given a small preliminary charge before it can be started. The polarity of all these machines is apt to vary on different occasions.

Methods of Application.—The patient is usually seated on a chair placed on a raised wooden platform insulated by means of glass legs. A metal plate may be placed on the platform, to which one pole of the static machine is connected. The other pole may be connected to various electrodes, generally consisting of an insulated handle with a brass terminal (ball or spikes), or a glass vacuum electrode (see High-Frequency) may be used.

Types of Application—1. *Static Bath.*—One pole connected to the platform, the other connected to earth, the brass balls or the poles (prime conductors) being separated to the full extent.

2. *Morton Wave Current.*—Connections the same, but prime conductors at first in contact, then gradually separated, a continuous series of sparks passing between them.

3. *Static Spark and Static Breeze.*—Connections as before, except that the terminal previously earthed

is provided with a suitable electrode (metal ball or number of points) and brought sufficiently close to the patient to permit of spark or effleuve discharge.

Indications.—Static bath in neurasthenia, debility, systemic treatment of pruritus and eczema.

Morton wave current in prostatic hypertrophy and chronic pelvic disorders (rectal or vaginal electrode), incontinence of urine, dyspepsia, rheumatoid arthritis.

Static spark in chronic constipation, sciatica, acute muscular pain.

Static breeze in suppurating wounds, pruritus and other skin diseases, synovitis, arterial hypertension.

CHAPTER III

DYNAMIC ELECTRICITY

DYNAMIC electricity may be described as electricity in motion, the supposed motion taking place along suitable conductors. The direction of flow is generally taken as from positive to negative, but this is only for ease of description, as any change in the one direction is accompanied by an equal change in the other.

Scurces of Supply for Therapeutic Purposes—1. *Electric Mains.*—This is the ideal source. As supplied from the power station for lighting, etc., electric current may be direct (written D.C.) or alternating (written A.C.). In the direct the direction of flow is constant; in the alternating the direction of flow is periodically reversed—*i.e.*, in one cable the current will rise very rapidly from neutral to 100 volts positive pressure (if it is a 100-volt circuit), remain for an appreciable time at that potential, then fall rapidly to 100 volts negative pressure (see Fig. 2). From *A* and *B* is one complete cycle, and the periodicity of the cycles varies on different circuits. It is commonly 50 per second, or somewhat higher.

The direct current is, generally speaking, the more convenient for therapeutic purposes. It can be used without much modification in the common types of X-ray apparatus, for the generation of high-frequency currents, and for the electric arc; with suitable modifications, for galvanism and faradism, and for charging accumulators. Alternating current is necessary for diathermy, and can be used in some types of X-ray apparatus. Either variety can be employed to drive the small earth-free generators embodied in such appliances as the pantostat and multistat, for the production of galvanic and sinusoidal currents. In this example the mains are simply utilized to provide the motor power for driving the generator and are not electrically connected with the windings of the generator. The full voltage produced by the latter is not sufficient to give a dangerous shock, though it may give an

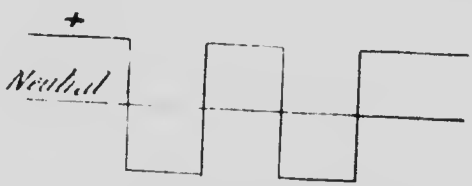

FIG. 2.—ALTERNATING CURRENTS.

unpleasant one, and in this way the patient is protected from any possibility of a serious accident.

2. If the electric light mains are not available, a generator driven by a small petrol engine may be installed. The generator should produce a current of not less than 50 volts, preferably 100.

3. In default of either of these sources of supply, the operator must rely on batteries of primary or secondary cells. The primary cell is one in which electrical current is generated by the action of a liquid on two dissimilar metals; a convenient modification is the "dry cell," in which the amount of liquid is small and is absorbed by some material such as sawdust, thus preventing spilling. The potential of a single dry cell varies with its type, but ranges somewhere about 1 volt. These cells require practi-

cally no attention, and when worn out must be replaced.

The secondary cell, commonly called an accumulator, or storage cell, consists of two plates, one of lead, the other of lead peroxide, immersed in diluted sulphuric acid of specific gravity 1·20. This is much stronger than "dilute sulphuric acid." These cells do not in themselves generate an electrical current, but have the power to store up current passed through them, and give off this current in a reverse direction if the terminals are subsequently connected to a conducting circuit. In charging, the positive terminal of the charging circuit is connected to the positive terminal of the accumulator, which is that attached to the peroxide plate, and which is coloured red, and the negative of the charging circuit to the negative terminal of the accumulator. The charging current thus passes through the cell in the reverse direction to the discharging. A secondary cell when fully charged has a potential of 2 volts. The amperage, or quantity of current, varies with the size of the cell, and is usually marked on the side. A cell marked "40 ampere-hours" is one that will produce (theoretically) a current of 1 ampere for forty hours, if the combined resistances of the cell itself and the external circuit equals 2 ohms. If the external resistance is diminished the amperage is increased, and the time correspondingly decreased There is a limit to the discharge rate of these cells, which if exceeded damages the cell, and this is usually set at one-tenth of the total capacity. The same applies to the charging rate. Thus a 40-ampere-hour cell should neither receive when charging nor give when discharging a current of more than 4 amperes. They should never be discharged fully; the voltage must not be allowed to drop below 1·9 volts. The plates must always be kept covered with the liquid, water being added when necessary to compensate for evaporation, and they should be charged about once a fortnight, even if never used during that period.

It will thus be seen that accumulators require considerable attention, but if this is devoted to them they form a very useful source of supply, and are very much cheaper in the long run than primary cells.

Resistances.—A resistance is an appliance used for regulating the current passing through an electrical circuit. It may be composed of various conducting materials, the essential being that the material used should impose a moderately great degree of obstruction to the passage of the current. A coil of German silver wire is commonly used, and the ordinary low candle-power electric lamp also makes an excellent resistance. A receptacle containing water into which two electrodes dip makes a good resistance, the current being increased by bringing the electrodes closer together, or immersing more of their surfaces in the water.

The variable resistance is commonly called a rheostat, whatever form it may take.

If a coil of German silver wire be employed, one terminal is fixed to one end of the coil, while the other is connected to a contact sliding on the coil, which enables the number of turns of the wire which are included in the circuit to be varied at will.

It will be worth while to consider in more detail the use of the lamp resistance. The electric lamp consists of a filament of carbon or metal, the ends of which pass through an insulating base to be brought into contact with the terminals leading from the source of supply. The filament is surrounded by a glass bulb, sealed to the base, and the bulb is exhausted of air. (This is necessary to prevent combustion of the filament.) The filament is very delicate and of high resistance, with the result that when current is forced through it becomes incandescent owing to the heat generated, and thus gives off a brilliant light. Lamps are made for various voltages, and must only be used with the voltage for which they are constructed.

The carbon filament lamp takes $3\frac{1}{2}$ watts per candle-power (roughly). Thus the current (amperage) which a lamp will allow to pass is arrived at by multiplying the candle-power by $3\frac{1}{2}$ and dividing by the voltage of the circuit. For example, a 16 c.p. lamp on a 100-volt circuit will take $\frac{16 \times 3\frac{1}{2}}{100}$ amperes $= \frac{28}{50}$, or rather more than $\frac{1}{2}$ ampere. If such a lamp be placed in the circuit, therefore, only about $\frac{1}{2}$ ampere can pass, however small the resistance of the rest of the circuit may be. By placing a number of lamps *in series*, the current may be reduced to as small a fraction of an ampere as desired, the current equalling the voltage divided by the sum of the resistances. If the lamps are placed *in parallel* the current is equal to the sum of the currents which each of the parallel paths would transmit singly.

A metal filament lamp only takes about 1 watt per c.p. It is hence much more economical commercially, but not so generally useful for the present purpose.

A resistance composed of lamps may be used alone, as in the case of charging accumulators, or may be used in conjunction with a variable wire rheostat, for therapeutic and other purposes. It forms an easy and safe means of curtailing the current, and obviates the use of the very heavy wire resistances which would otherwise be necessary.

The modern "$\frac{1}{2}$-watt" lamp (which only takes $\frac{1}{2}$ watt per c.p.) is not very suitable for purposes of resistance.

Series and Shunt Resistances.—There are two ways in which a resistance can be placed in relation to the electrical circuit and the patient. It may be (1) in series (Fig. 3), as is presumed in the foregoing remarks. Here all the current passes through the resistance and the patient. (2) In shunt (Fig. 4), where the resistance is arranged to form one alternative path for the current.

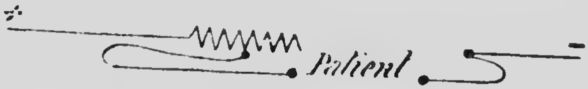

FIG. 3.—SERIES RESISTANCE.

The action of these two arrangements is different. The series resistance primarily controls the amperage, the shunt resistance (often called a volt-selector) primarily controls the voltage. A consideration of Fig. 4 will help to explain how this is brought about.

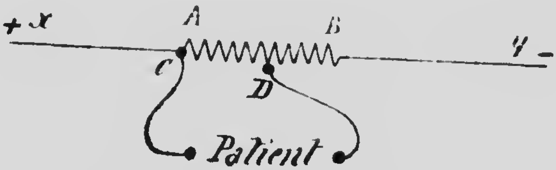

FIG. 4. SHUNT RESISTANCE.

X and *Y* are the poles of a dynamo generating current at 100 volts. *A*, *B*, is a heavy resistance coil placed in the circuit. The fall of potential between *X* and *Y* is 100 volts, but since the fall of potential in any part of a circuit is in direct proportion to the ratio which the resistance of that part of the circuit bears to the resistance of the remainder of the circuit, and since nearly all the resistance of the circuit *X* to *Y* lies in *A*, *B*, it is obvious that nearly all the fall in potential will take place *B*. Suppose the fall of potential from *A* to *B* is 90 volts. This fall of potential is evenly distributed along *A, B*. If there are ninety coils of wire in the resistance, the difference in potential between any two adjacent coils will be 1 volt. If nine adjacent coils are included, the fall of potential will be 10 volts, and so on. By connecting the two ends of the circuit in which the patient is placed to different parts of *A, B* (in the diagram to *C* and *D*), any desired voltage can be obtained. The amperage, or current passing through the patient's circuit, will, of course, vary inversely with the ratio which the resistance of the patient's circuit presents to the resistance *C, D*.

CHAPTER IV

APPLICATION OF THERAPEUTIC CURRENTS TO THE BODY

BEFORE considering the different forms of current in detail, it will be well to sketch in general outline the methods which may be adopted for applying them to the body. The following remarks apply particularly to the galvanic, sinusoidal, polyphase, and faradic currents.

Electrodes.—The first essential is to provide adequate contacts between the patient and the wires carrying the current. These contacts are commonly made of some malleable conducting material, such as sheet lead, tin, aluminium, chain mail, or wire gauze. They should for most purposes be of as large a size as possible, to enable a big current to be passed without the pain and even burning which results from concentration of current over a small area of skin. If both electrode are of equal importance they are the same size, but when it is desired to concentrate the action on one electrode (called the "active electrode"), it is usually made considerably smaller. The other larger one is then called the "indifferent electrode." In stimulating individual muscles or nerves the active electrode is small and round in shape—about $\frac{1}{2}$ inch to $\frac{3}{4}$ inch in diameter.

The electrodes are covered with several layers of lint or a thick sponge, and well soaked in warm normal saline solution. The dry skin, and also plain water, are both bad conductors of electricity. When more than a momentary application is being made, great care must be taken to see that the whole electrode is in good contact with the skin, otherwise concentration of current will take place at the points of good contact, and burning result. For the same reason any breach of the skin surface must be closed with collodion.

The lint or sponge covering the electrode must be of sufficient thickness to prevent the acid and alkaline bodies, formed by secondary chemical action at the electrodes and thence propelled (see Chapter), from reaching the skin surface. Twelve to sixteen layers of lint will suffice for a prolonged application. Any complaint of localized pain by the patient is an indication to immediately stop the application and examine the electrodes to make certain that they provide good even contact throughout the whole of their surfaces.

The electrodes should be maintained in position by an elastic bandage.

Another method of providing paths of ingress and egress for the current is to immerse the patient or his limbs in baths of water in which electrodes are placed. For the limbs suitable troughs are made of porcelain for the arms and legs (Schnee baths). All four limbs may be immersed for general applications, or two (*e.g.*, arm and leg, or both arms), or one limb only, forming the indifferent electrode, while the active consists of a smaller electrode placed on the spot desired. Baths are a very convenient method of applying current over a wide area, as they always provide perfect contact. If the patient complains of burning or irritation of the limb at the upper level of the water, this can be allayed by pouring a little glycerine on the fluid, or bandaging the limb for a few inches at the upper level of immersion. The full body bath is not so often used, but requires consideration on account of the dangerous possibilities it presents if the electric light mains are utilized as a source of supply. In the full body bath the patient is completely immersed to the neck, and the electrodes are placed in slots in the sides or ends of the bath, covered with an insulating lattice-work, to prevent contact with the patient. It is thought that about one-third of the current travels through the body, the remainder passing through the water. If any electrolyte such as salt be added to the water, thus increasing its conducting power, a correspondingly smaller proportion of current will traverse the patient.

Precaution against Shocks.—1. The bath should be of porcelain, glass, or wood.

2. It should stand on a thick rubber mat.

3. The outlet should open above the floor in the air—no pipe to provide contact with earth by means of metal, or the water the pipe would contain.

4. The inlet pipes should be completely out of reach of the patient, connection with the bath being made by rubber hose pipe before the patient enters the bath.

5. No metal objects of any sort should be within reach of the patient when in the bath.

The above directions should always be adhered to, but become of paramount importance when the electric light mains are utilized as a source of supply. In this case, also, a special precaution should be taken with the regulating resistance. This should be of the "shunt" type, with a lamp at either end, and neither of the connections leading to the patient should be at the end of the resistance coil (Fig. 5). In this way, even if the patient should become earthed, he will not receive more than an unpleasant shock. If, on the other hand, these precautions be neglected, an earth connection may be attended with very grave or even fatal results. Generally speaking, it is better not to employ the full body bath unless some form of "earth-free" generator, such as the pantostat, is available. If the mains must be used, a four-cell Schnee bath has nearly the same effect as, and is much safer than, the full body bath.

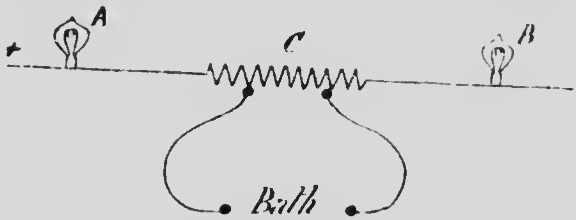

FIG. 5.—RESISTANCE FOR FULL BODY BATH OFF MAINS.

A and *B*, lamps; *C*, wire resistance.

Measurement of Current.—Direct, or the ordinary galvanic, current is measured usually by some modification of the galvanometer. The D'Arsonval milliamperemeter may be described as a type. This instrument consists essentially of a horseshoe magnet, between the poles of which is hung a coil of thin wire, wound upon a metal framework, and containing an iron core. This coil is connected with a pointer reading on a dial graduated in milliamperes, and is held in position by a spiral watch-spring so that the pointer indicates zero on the scale. The coil is then in such a position that its hollow centre, or its core, is at right angles to a line joining the poles of the horseshoe magnet. If a current be passed through the coil, it will immediately tend to turn so that this core is in a straight line with the line joining the poles of the horseshoe magnet. This movement is opposed by the spiral spring, and the dial is graduated so that the pointer, by its greater or less deflection, indicates the amount of current passing.

Usually a shunt or number of shunts are provided. Most of the current passes through this, but the dial is graduated to indicate the current through the shunt plus that actually flowing through the coil of the milliamperemeter. When more than one shunt is provided, the contact is marked with a number (*e.g.*, 5), which means that the figures on the dial must be multiplied by five to obtain a correct reading.

This type of milliamperemeter is known as "dead-beat," since the indicator comes to rest rapidly, and does not swing back and forth on the dial. This is due to the lines of force generated in the metal framework round which the small coil is wound.

Another type of milliamperemeter is the "hot wire." This consists of an indicator attached to a length of wire. When a current is passed through the wire it becomes hot and increases in length, and the indicator reads on a dial graduated to show the amount of current passing according to the expansion of the wire.

The D'Arsonval milliamperemeter will only give accurate readings of unidirectional currents, but the hot-wire instrument can be used for alternating current also.

The amperemeter is constructed on similar principles to the above, but is made for heavier currents, and graduated in amperes.

Variation in Current Strength.—It has been found in certain types of cases, generally speaking those in which some muscular contraction is desired, that results are much improved by partially interrupting the current at regular intervals. The current does not require to be entirely cut off, but reduced to a strength at which muscular contractions are not excited; also it is advisable for the increase and decrease to be gradual, so that the current takes on an undulatory form.

This is provided for by some variety of rhythmic interrupter, such as that devised by the late Dr. Lewis Jones. This instrument consists of an elongated metal cup, filled with water, and a metal rod which is made to pass up and down inside the water by means of a small motor. This appliance is placed in circuit with the patient, one wire being connected to the metal cup, the other to the rod.

As the rod passes farther into the water, a larger path is provided for the flow of current, which therefore rhythmically increases, and then diminishes as the rod is withdrawn. The rate of undulation is regulated by the speed of the motor. About one complete cycle a second is usually a suitable rate.

CHAPTER V

GALVANISM

GALVANISM is the term applied to the use of the unidirectional current for therapeutic purposes. It is usually derived from a motor generator of the pantostat type, a battery of dry cells, or, with the use of a suitable resistance, direct from the mains themselves (for precautions, see Chapter IV., full body baths). A simple and safe method of using the mains is to employ a water resistance, as in the appliance known as the galvanoset. Here two carbon electrodes lead the main current, after passing through lamps, into a glass bowl containing water. These electrodes (*A* and *B*, Fig. 6) dip into the water, and are fixed in position diametrically opposite to each other. Two more electrodes *C* and *D* are connected with the patient, and are placed at opposite ends of an insulated rod *E*, which is pivoted over the centre of the bowl. When *E* is at right angles to a line joining *A* and *B*, all the current passes directly through the water. *C* and *D* are then both equidistant from *A* and *B*, and are of equal potential. If *E* be now turned about its centre, so that *C* approaches *A* and *D* approaches *B*, an alternative path is provided for the current through the patient. This is increased the more *E* is turned, until the maximum current is obtained with *C* and *D* directly opposite *A* and *B*. *E* is made of considerably shorter length than the diameter of the bowl, so that the two sets of electrodes are never in actual contact, a certain amount of water always separating them.

The therapeutic applications of galvanism are very varied, and the rationale of this treatment is best considered by referring to the action of a constant current passing through an electrolyte (Chapter I.) If this has been mastered, it can readily be understood that many complex changes of an electrolytic nature will take place in the fluids of the human body, containing in solution as they do a very large number of electrolytes. The therapeutic benefit of

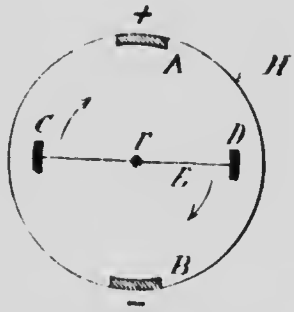

FIG. 6. WATER RESISTANCE.

H, Glass bowl containing water; *A* and *B*, electrodes connected to mains; *C* and *D*, electrodes connected to patient, attached to rod *E*; *F*, central point of *E* upon which *E* is pivoted.

galvanism certainly depends to a great extent on this electrolytic or ionic action. It is probable that ions resulting from disordered metabolism, disease, and fatigue, are driven out of tissues in which they have accumulated, fresh ions introduced, and a general ionic rearrangement brought about. It is obvious also that in some circumstances such disturbance of ionic arrangement may be detrimental to the organism, and ill effects result from its employment.

It will be seen from the above that the term

Ionization should logically be applied to all galvanic treatment, but it is customary to restrict it to those procedures which aim at introducing ions into the body from without; ionization, in the generally accepted sense of the word, is dealt with in the following chapter.

Galvanic applications may be general or local. In the former case, the patient is immersed in the full body bath, with the positive electrode at one end and the negative at the other; or he may have all four limbs immersed in Schnee baths, into all of which pass electrodes, the polarity being controlled at will.

In the case of local applications, two electrodes are applied to the part under treatment, or one electrode (the active) is applied to the desired spot while the indifferent electrode is formed by a Schnee bath. This latter arrangement is often found very convenient.

The galvanic current may be made undulatory by means of the rhythmic interrupter described in Chapter IV. Its general effects are then very similar to those of the sinusoidal current.

The therapeutic effects of galvanism are—

1. General stimulating (full body or Schnee baths).
2. Excitomotor (interrupted galvanic current).
3. Excitosensory.
4. Excitosecretory (heavy currents applied to superficial glands).
5. Sclerolytic.
6. Excitonutritive (cerebral and spinal galvanism).
7. Sedative.
8. Analgesic (the positive pole applied to the painful area).

Certain special applications will now be discussed in more detail.

1. **Central Galvanism.**—This may be applied to the spinal cord or to the brain. In the former case, the patient is seated upon a large positive electrode, while the negative electrode is moved up and down the spinal column.

The latter form (cerebral galvanism) requires considerable care in its application to avoid unpleasant or even dangerous consequences. Large electrodes are used, and are firmly fixed to the forehead and the nape of the neck; they must be symmetrical as regards the midline, otherwise vertigo will be produced. The hair must be thoroughly wetted with warm saline solution (the electric hot-air douche is convenient for drying this after treatment is completed). The patient reclines on a couch, and must avoid all movement during, or for a few minutes after, treatment. The frontal electrode is made the cathode, and the current is turned on and off very slowly and evenly. Any sudden increase or decrease will have most unpleasant and alarming results. The application should last for ten minutes at the first sitting, and be gradually increased to half an hour. The patient will rarely support a current of more than 5 to 6 ma., but 10 to 15 ma. should be aimed at.

If the polarity is reversed (positive to forehead), a feeling of heaviness, slownesss of thought, and somnolence is produced, which contrasts unfavourably with the sense of well-being and mental acuity which result from the polarity here recommended.

Cerebral galvanism is of great value in many conditions, as will be plain from the consideration of the controlling action of the central nervous system over all the functions of the organism. The following are given as types of cases when this treatment is indicated, or worthy of a trial.

(1) Ill-developed and backward children, whether

the defect is chiefly mental or physical or (as is often the case) a combination of both. Treatment should be given thrice weekly at first, and continued for some months with gradually diminishing frequency. Astonishingly satisfactory results are sometimes obtained.

(2) Epileptiform seizures in children and adults, and true epilepsy during the early months of its appearance.

(3) Mental deficiency in children, and the early manifestations of some forms of insanity in adults. This class deserves a fuller trial than has yet been accorded it; the few records up to the present are to some extent encouraging

(4) Neurasthenia and all forms of central exhaustion due to overwork, worry, or preceding ill-health. This especially applies to the lassitude in patients of deficient nervous vitality, which often follows confinement to bed from any cause. Hysteria is a contra-indication.

(5) Cerebral galvanism is deserving [illegible]ial in the after-treatment of gross lesions of the [illegible], such as hæmorrhage, embolism, laceration, etc. Treatment should not be commenced until all signs of activity of the disease have subsided—in the case of an uncomplicated hæmorrhage at least ten days from the onset should elapse, and then only very mild applications be made. It is reasonable to suppose, from our knowledge of the beneficial results of galvanism in lesions of peripheral nerves, that cerebral galvanism will assist in the re-establishment of nerve-paths which have been damaged but not destroyed.

(6) Headache of nervous origin.

(7) Neuroses. This form of treatment has been found of considerable value in the neuroses resulting from sudden mental or physical shock, so many examples of which have been afforded by the vicissitudes of modern warfare.

(8) Obesity, especially that which is associated with mental hebetude.

The above forms a guide to the lines along which this form of treatment should advance. It is deserving far more extensive trial than it has hitherto received.

2. **Galvanism in Joint Disorders.**—Acute synovitis with effusion in a superficial joint is greatly benefited by the passage of a heavy galvanic current. Large lateral electrodes are used; this may be preceded by faradic or galvanic stimulation of the muscles around the joint. The effusion is frequently absorbed with great rapidity.

In chronic synovitis with effusion and wasting, faradization of the surrounding muscles is of more value.

In acute gouty, rheumatic, or gonorrhœal arthritis, galvanism through the affected joint will nearly always bring about rapid relief of pain, and sometimes speedy resolution of the inflammatory condition. Deep-seated joints, such as the hip, are difficult to attack satisfactorily by this means.

3. **Galvanism in Neuritis.**—Mild galvanic currents are of great use if the condition is not of too long standing. The direction of the current is probably not of great importance, but, generally speaking, the positive pole should be placed centrally to the negative—*i.e.*, the current should flow from the central to the peripheral end of the nerve.

Brachial, intercostal, and sciatic neuritis are all very amenable to this treatment· herpes zoster sometimes speedily yields to it, a large positive electrode being placed along the spine over the affected nerve roots, and a negative electrode covering the vesicles on the chest wall.

The current in these cases should not exceed 15 ma., and in the acute stages considerably less is advisable. Long sittings up to half an hour are required.

Trigeminal neuritis is little affected by galvanism. Ionization (see Chapter VI.) has been fairly extensively used.

4. **Galvanic Stimulation of Muscles.**—This is more fully discussed in Chapter XIV. (Electrodiagnosis). A steady galvanic current does not excite any muscular contraction. Contractions are produced by the make and break of the current, or by any sudden increase or decrease in a current which is already flowing. Under normal conditions the contraction is excited with the minimum current when the cathode forms the active electrode and the current is made (*i.e.*, the circuit is closed). Galvanic stimulation is of the greatest value in maintaining the nutrition of muscles whose motor nerve has been damaged, and which, as a result, will not respond to faradism. It should be persisted in patiently until the lesion has recovered sufficiently for the muscle to react to faradism, when this form of stimulation should be substituted.

It is very important to obtain contractions if possible in all the affected muscles, and to assure this the operator must possess a sound knowledge of the position and *action* of the individual muscles. In practice it is usual to have a large indifferent electrode at some convenient point, and to stroke the small round active electrode down the affected muscles. The stroking provides the interruption of the current necessary to provoke contraction, and the flow of current during each stroke also probably has a beneficial nutritive effect upon the muscular tissue. As voluntary power returns it is most essential that the patient be encouraged to exercise this during treatment, and shown the movements necessary to bring the different muscles into play, so that he may exercise them up to the limit of slight fatigue at intervals during the day. Another point of paramount importance, upon which the electrotherapist is often asked to advise, is the splinting of the limb. If this is inefficient or unsuitable, deformities and contractures will result, which will render the most expert operative and skilled electrical treatment of no avail.

The electrotherapist should therefore always make sure that the muscles he is treating are properly relaxed by means of a splint during the remainder of the day and night, and that the splint be correctly applied after the séance is over.

5. **Galvanism in Constipation.**—A very large positive electrode is moulded to the patient's loins, or he may be made to sit upon it. A large negative electrode covers the front of the abdomen. Heavy currents are used, and made and broken by means of a key. Twenty or thirty interruptions at intervals of ten seconds will usually be sufficient. The treatment should be repeated daily, and good results are often obtained in obstinate cases.

Where it is urgently desired to obtain an action of the bowels, the electric "douche" may be employed. The positive electrode covers the abdomen. The negative consists of a malleable metal rod introduced into a long rubber rectal tube. The tube, and through it the large gut, is filled with hot saline solution and the current then repeatedly made and broken. A vigorous action of the bowels will nearly always result. Care must be taken that no part of the metal rod comes in contact with the patient.

Recta land urethral spasm have been treated by means of a positive electrode introduced into the rectum and the passage of a mild galvanic current.

6. **Galvanism in Pelvic Disorders.**—Imperfect de-

velopment of the uterus is benefited by undulatory galvanic currents, with periodic reversal of polarity. The active electrode is placed in the vagina, or if possible in the uterus, and a maximum of 15 ma. are passed in this way for ten minutes daily. The indifferent electrode is on the abdomen.

The resolution of pelvic exudates may be aided by the passage of a galvanic current (positive vaginal electrode), but high frequency is generally more advantageous in these cases.

Interstitial and submucous fibromyomata have also been treated with some degree of success by means of an intra-uterine positive electrode, armed with a platinum or carbon olivary tip, which is brought in contact with successive areas of the uterine mucosa. The interstitial fibroid will, however, yield far more readily to X-rays, while the submucous is probably better left to the surgeon.

7. **Galvanism in Tinnitus Aurium.**—A bifurcated electrode like a binaural stethoscope is applied behind the ears and connected with the anode. The cathode or indifferent electrode may be held in the hands. A current of 3 to 4 ma. is very gradually turned on, allowed to flow for five minutes, and as gradually turned off. This treatment may be reinforced by the high-frequency effleuve applied over the mastoid processes. Results are generally disappointing in the author's experience, but sometimes marked relief is obtained. The treatment is contra-indicated where the condition is associated with chronic otitis media.

CHAPTER VI

IONIZATION AND ELECTROLYSIS

Ionization.

This is the forcing of ions into the tissues from without, by means of the galvanic current. Electrolysis is a form of chemical cauterization, the active agents being the acids and alkalis formed by secondary chemical action at the poles of a galvanic circuit flowing through an electrolyte, the electrolyte generally being furnished by the fluids of the patient's tissues, into which one or both of the bare electrodes are introduced.

As has been described in Chapter I., a constant galvanic current flowing through an electrolyte, such as a solution of sodium chloride, splits up the molecules of the salt into ions of sodium and chlorine. The chlorine passes to the positive electrode, the sodium to the negative. Suppose the procedure to be modified by covering the two electrodes with many layers of lint soaked in sodium chloride solution, and binding them firmly to opposite sides of a limb. Then, when a constant galvanic current is passed the following changes will take place: At the positive electrode the chlorine ions migrate to the metal surface of the electrode itself, where they give up their electrical charge, and combine with the water of the solution to form HCl. Some of the acid radical is then propelled back through the lint.

Hence the need for many thicknesses of this material, to prevent cauterization of the skin.

The sodium ions at the positive electrode are repelled from the positive and attracted by the negative, and a certain number pass into and through the skin along the path of the electrical current.

At the negative electrode the reverse takes place: sodium ions are attracted to the electrode itself, where by secondary chemical action NaOH is formed; while chlorine ions are repelled into the body.

It will be understood that all electrolytes split up into two classes of ions, having charges of opposite polarity. Those having a negative charge are propelled towards the positive electrode, and are hence called "Anions." Those with a positive charge are propelled towards the cathode, and are called "Cathions."

It is obvious that if an anion is to be introduced into the body, the active electrode must be of negative polarity; while, to introduce a cathion, the active electrode must be of positive polarity. The short lists below classify the substances most commonly used in ionization.

1. **Anions** (driven in *from* the negative electrode)—
   Iodine.
   Chlorine.
   Salicylic acid.
2. **Kathions** (driven in *from* the positive electrode)—
   Copper.
   Zinc.
   Mercury.
   Lithium.
   Quinine.
   Cocaine.
   Magnesium.

It is clear that the ions introduced into the body will not long retain their ionic state, but will speedily give up their charge to hitherto associated atoms, which will in turn play their part in carrying the current a short distance before handing the charge on and again becoming associated.

It is on the therapeutic efficiency of this nascent substance (*i.e.*, the atom deprived of its electrical charge) that the rationale of ionic medication is based. Grave doubts have, however, been entertained as to the value of ionic treatment, for the following reasons.

The rate at which the ion travels is very slow, having no connection with the rate of flow of the electrical current. Different ion move at fixed rates of speed, which increase with the voltage and diminish with the length of electrolyte through which they have to pass. For example, lithium ions, acted upon by a potential of 1 volt, travel through an electrolyte 1 cm. long at the rate of 0·004 cm. per hour. Most ions are more rapid, but all are very slow. Hence it has been argued that, under the most favourable circumstances, the ions could only be introduced a very short distance into the body, and only skin and subcutaneous tissues be acted upon.

But an even more serious objection has been outlined above, where it has been pointed out that the ion, on entering the body, must almost immediately be deprived of its charge by the electrolytic salts of the body fluids. It is, in fact, indisputable that we cannot hope to introduce ions from outside the body into any but the most superficial tissues, and it is probable that the undoubted benefit which results from ionic medication in lesions of the deeper structures is dependent entirely on the passage of the galvanic current, with its ionic rearrangement of the body electrolytes, and derives no virtue from any medicinal solution in which the electrodes are soaked.

As the matter is still under discussion, however, and as many observers claim better results even in deep seated lesions with some medicinal electrolytes than with others, it is best to approach the question with an open mind, and record here the methods which are in common use, and which have been found to yield satisfactory results.

The technique of ionization is practically that of ordinary galvanism, with the proviso that the correct polarity be given to the active electrode. The indifferent electrode may be placed on the opposite side of the limb or body to the active electrode, or the active electrode may be made to surround a large part of the affected region, while the indifferent electrode is provided by immersing one of the limbs in a Schnee bath. It is unnecessary to moisten the indifferent electrode with solution of the salt which it is proposed to introduce—NaCl solution is equally efficient for this purpose, and generally much cheaper. Sometimes both poles are active—for example, in gouty arthritis the joint may be nearly enclosed between the two electrodes, of which the positive is moistened with a salt of lithium, and the negative with a salt of salicylic acid. In this way both electrodes drive into the tissues substances which are known to be inimical to the gouty condition.

The strength of the electrolytic solutions should be 1 per cent.; there is no advantage in making them stronger.

All the precautions enumerated in the chapter on Galvanism to guard against damaging the skin of the patient are equally necessary in the case of ionization, otherwise there is considerable risk of painful burns. Generally speaking, the current used in ionic medication should be the strongest which the patient can comfortably support. This varies with the idiosyncrasies of the patient, the part of the body under treatment, the presence or absence of hyperæsthesia, and, independently of these factors, with the size of the electrodes. With electrodes measuring 8 inches by 4 inches, it should be possible to gradually work the current up to 40 ma. in most cases. The length of time of each treatment should be not less than half an hour as a general rule.

It will be best now to consider in more detail the substances commonly employed in ionic medication, with their clinical indications, and any modifications of procedure necessary to meet special requirements.

Salicylic Ionization.—Solution of sodium salicylate is used. This is of value in acute articular rheumatism, where the lesion becomes localized to one or two joints. The affected joint is surrounded by the active electrode, and a current of 15 ma. (more can rarely be borne) is passed for half an hour. The treatment is repeated daily.

In chronic articular rheumatism the same procedure is adopted, but larger currents can be employed, and the treatment need only be given three times a week.

Polyarticular rheumatoid arthritis may be relieved by salicylic ionization of the affected joints during acute exacerbations. As a general form of treatment high-frequency currents are of more value.

Acute articular gout is sometimes much relieved, and the attack cut short by this treatment. The same may be said of muscular rheumatism, or, as it is probably more correctly designated, rheumatic fibrositis, both acute and chronic.

Idiopathic neuritis of superficial nerves is sometimes markedly benefited. A certain proportion of cases of tic douloureux have been cured. It should be employed in the early stages of neuritis of the seventh nerve, producing Bell's palsy.

Chlorine Ionization.—Solution of sodium chloride used. This is chiefly of value in virtue of the property possessed by the chlorine ion of aiding the resolution of fibrous tissue.

It should be tried, either alone or in conjunction with X-radiation, in the treatment of cicatricial contraction resulting from burns and wounds, and in cases of adhesions about joints and muscles resulting from old trauma or infective lesions. It has also been found of considerable value in neuritis resulting from involvement of a nerve trunk in scar tissue, provided that the nerve is fairly superficial at the site of its involvement. To obtain satisfactory results in any of the above cases, large electrodes must be used, and heavy currents passed for at least half an hour three or four times a week, and the treatment must be persisted in for several months. Chlorine ionization has been used for corneal opacities resulting from scarring. The active electrode is placed over the closed lid. The lachrymal secretion supplies the chloride solution.

Iodine Ionization.—Solution of potassium iodide, or of iodine in potassium iodide, is used. This agent is frequently used for chronic articular rheumatism and gout, especially where adhesions have formed.

It is sometimes successful in the treatment of chronic discharging sinuses, as an alternative to zinc or copper.

Copper and Zinc Ionization.—These two substances are used chiefly for their antiseptic properties, and their sphere of usefulness is hence generally confined to the treatment of infected lesions of the skin and mucous membranes, including suppurating wounds and sinuses.

The action of both is similar, but zinc is usually more effectual than copper, and should be tried first. If it fails, copper will sometimes succeed. In the treatment of ulcers and sinuses the first essential, and the most difficult one to attain, is to bring the electrolyte into contact with all parts of the affected surface. In the case of ulcers this difficulty can be overcome by filling all the interstices of the ulcerated surface with small pledgets of cotton-wool soaked in the zinc solution. When an even surface has in this way been obtained, the usual layers of lint, cut to the size and shape of the ulcer, are placed on top of the cotton-wool and surmounted by the metal electrode, also cut to the shape of, but somewhat smaller than, the ulcer. The tortuous sinus presents a far more difficult problem. It is usual to employ a fine needle or rod as the active electrode in this case, but it is clear that this alone will provide contact with only a small proportion of the sinus walls. The best method is to syringe the sinus out thoroughly with the zinc solution, to remove all collections of pus and débris; then to inject the sinus with a fresh supply of the zinc solution, which is left *in situ;* and finally to insert the zinc rod, round which is wrapped some cotton-wool, the latter forming a plug at the orifice of the sinus to prevent the escape of the injected fluid. Even when this has been done, it is impossible to be sure that some of the ramifications of the sinus have not escaped adequate attention, which explains the comparative inefficiency of this treatment.

Superficial ulcers and wounds, on the other hand, often heal with surprising rapidity after one or two ionic treatments. For these conditions repeated séances are not advisable. A week should elapse after the first treatment, and then if the ulcer or sinus is healing evenly no further application need be made. At the end of a fortnight the treatment should be repeated, and so on until a cure is accomplished. Zinc ionization will sometimes give satisfactory results with fissure-in-ano. Cocaine must be applied to the fissure before treatment.

Fistula-in-ano presents all the difficulties of the tortuous and multilocular sinus, and except in its simplest forms can rarely be cured by ionization.

Zinc and copper ionization have given encouraging results in chronic ulcerative colitis and proctitis The large bowel is washed out and then filled with a solution of zinc or copper sulphate by means of a rectal tube with lateral perforations. The active electrode, in the form of a zinc or copper rod, or wire spiral, is inserted into the rubber tube, and the latter closed around the rod to prevent escape of the solution. The large indifferent electrode is placed under the loins, and a current of 20 ma. passed for fifteen minutes.

Considerable advances have been made in the treatment of gonorrhœa, both acute and chronic, by copper ionization. In the female a vaginal or uterine electrode is used. In the male the urethra is irrigated through an insulating perforated catheter with the copper solution, at the same time as the current is being passed through a metal electrode inserted into the catheter. Very encouraging results are being obtained by this treatment, especially in the acute stages of the disease.

Pyorrhœa alveolaris has been treated by ionization of the pockets left by absorption of the alveolar process. Only very small currents can be borne (2 to 3 ma.). The treatment must be persisted in for some time before improvement can be hoped for. It is unlikely to succeed in advanced cases, and in mild cases is not easy of application. It should be combined with X-radiation, and possibly high frequency. The zinc needle is sometimes used to ionize boils and carbuncles. The head of the boil is punctured, the pus removed, and the zinc needle then inserted, and 5 to 10 ma. passed for five minutes.

Lithium Ionization.—Lithium chloride solution used. This is employed chiefly for gout, uric acid being many times more soluble in a solution of this substance than in the body fluids. In one method the affected limb is placed in a bath of the lithium solution, into which the positive electrode is introduced; or lithium and salicylate ionization may be combined, the positive electrode being on one side of the joint moistened with lithium chloride, the negative on the other side moistened with sodium salicylate.

Magnesium Ionization.—Magnesium sulphate solution used. This is chiefly used for flat warts. Zinc needling or X radiation is a more certain method of dealing with this condition.

Cocaine Ionization.—Ten per cent. solution of cocaine hydrochloride in guaiacol is used. This has been employed in the relief of neuralgia, and for local anæsthesia in small superficial operations. The skin surface must be intact.

Electrolysis.

This consists of the coagulative effect exerted upon the tissues by the secondary chemical substances formed at the electrodes. These electrodes commonly consist of needles made of platinum, or iridium, and introduced into the substance of the tissues which it is wished to destroy. Both poles may be connected to different needles, or sets of needles (the bipolar method); or one pole—usually the negative—is connected with the needles, while the other or indifferent electrode is formed by a large pad placed at some convenient spot (unipolar method).

If platinum or iridium needles are used, OH ions and NaOH are formed at the cathode, H ions and HCl at the anode.

The cauterizing effect is confined to a small area around the electrodes.

If the unipolar method be employed a steel needle may be used, provided that it be made the cathode. Should a steel needle be connected with the anode, indelible staining of the tissues will result.

Electrolysis for Angiomata.—Cavernous and subcutaneous capillary angiomata are best treated by the bipolar method. A convenient electrode is one which consists of a wooden handle provided with several needles, so connected with the binding screws on the handle that they are alternately positive and negative. A general anæsthetic is required. The needles are thrust into the tumour near its periphery, and kept parallel to the skin surface. If any large vessels are seen, they are if possible transfixed. The needles should be coated in their proximal parts with varnish, to insulate that portion which is in contact with the skin when the needles are *in situ*, otherwise sloughing of the skin will occur. The current is gradually turned on, and should not exceed 20 ma. per inch of positive needle inserted. The negative needles tend to become loose, while the positive are held tightly in the tissues. The tissues around the positive needles also become pallid, while round the negative lividity is produced and foam appears at the skin punctures. The first sign of any change in colour is the signal for the current to be turned off, the needles introduced into a fresh part of the tumour, and the treatment repeated.

Coagulation of the tumour is best shown by its becoming hard to the touch. As much as possible should be done at the first sitting, but only small tumours can be efficiently treated in one séance.

The larger tumours will require several applications, but at least three weeks should elapse between applications.

If too strong or too long an application be made, sloughing of the skin will result.

Cutaneous angiomata, or port-wine stains, are treated by the unipolar method.

The active electrode consists of a single platinum needle, connected with the cathode. With this a series of punctures are made, not too close together, and at each puncture 2 to 3 ma. are passed for twenty or thirty seconds. The treatment, even in small marks, requires to be repeated many times, and considerable scarring inevitably results.

Electrolysis for Hypertrichosis.—The method employed for the removal of superfluous hairs is as follows: The active electrode consists of a needle-holder armed with a fine but bulbous-pointed platinum or iridium needle. This forms the negative electrode. The patient is placed in a good light, and may hold the indifferent electrode, covered with sponge, in the hand. The needle is introduced down a hair-follicle, alongside the hair, to the extreme bottom of the follicle. The current is then turned on. A current of 2 ma. allowed to flow for 5 to 20 seconds will destroy the lining of the follicle. The best guide is the appearance of foam at the mouth of the follicle. The patient is then directed to release the sponge, and so cuts off the current. If sufficient action has taken place, the hair can be removed without any resistance by means of forceps. If any resistance is encountered, destruction of the follicle is incomplete, and the hair, even if pulled out, will certainly grow again. Each individual hair is treated in the same way. At each sitting hairs are dealt with which are not too close together; if a number of contiguous hairs are treated at one time, very unsightly scarring will result. The treatment is tedious, and when many hairs have to be removed may have to be continued over months. Even with the greatest care a certain proportion of the hair will grow again, but eventually the condition is cured.

This treatment may be employed in the treatment of hairy moles—if the hairs are removed the mole is usually sufficiently inconspicuous. Warts are best treated by transfixing their base with a negative needle, and passing a current of 2 to 4 ma. for 2 to 5 minutes. Large warts may require to be transfixed in more than one diameter.

Macroglossia, a lymphangiomatous condition, has been treated by electrolysis, either the unipolar or the bipolar method being employed, as in hæmangioma. Several sittings are commonly required.

Aneurysm.—This may be treated by introducing needles into the aneurysmal sac. The electrolytic effect is commonly augmented by scarifying the walls of the sac by moving the points of the needles along them. This treatment is not free from the danger of embolism.

Strictures of the Urethra, Œsophagus, and Lachrymal Canaliculi.—Strictures of the urethra are treated by means of a series of bougies, with olivary metal heads, and insulated stems enclosing a central metal core, by means of which the current passes to the olivary head. The bougie is chosen which is one size larger than that which will pass the stricture. The bougie is passed down to the stricture and the current turned on. The amount of current depends on the size of the electrode, and varies from 3 to 10 ma. The treatment lasts twenty minutes, during which tingling should be felt but no pain. At the end of that time the bougie will be found to pass easily through the stricture. After an interval of one or two weeks the treatment is repeated, the next largest size bougie being used; and this is continued at intervals till the stricture has ceased to exist. The treatment should be combined with dilatation by means of ordinary bougies.

Fibrous stricture of the œsophagus is treated in exactly the same manner, with, of course, the substitution of bougies suitable in size for this structure. Currents of 4 to 5 ma. are passed.

Stricture of the lachrymal canaliculi are treated by introducing a lachrymal sound, connected with the negative pole, and passing a current of 3 to 4 ma. for three minutes once a week. The stricture can be completely cured.

Malignant Growths.—Inoperable carcinomata of the breast and tongue have been treated by extensive electrolysis, the object being to coagulate the whole growth, which then sloughs away, leaving a healthy granulating surface. This method has been largely supplanted by surgical diathermy and X-radiation.

CHAPTER VII

SINUSOIDAL CURRENTS

The sinusoidal current used in electro-therapy is an alternating current, which differs usually from that supplied in the mains for commercial purposes in the following particulars:

1. The alternation is not abrupt, but gradual, the current rising from zero to its full positive potential, sinking to zero, rising to its full negative potential, and then returning to zero in a way which is diagrammatically represented in Fig. 7 (A). From *x* to *y* is one complete phase.

2. The periodicity, or number of phases per second, is generally not more than 20—sometimes considerably less. In the alternating current supplied in the mains the periodicity is rarely below 40, generally 50 or more. The current is obtained by means of an earth-free motor generator.

The sinusoidal current produces muscular contractions in both striped and unstriped muscles, but requires to be of much greater strength than faradism in the case of striped muscle, owing to the gradual rise and fall of potential. Muscular contractions can, however, be obtained with a mild sinusoidal current by placing a rhythmic interrupter in the circuit.

Sinusoidal currents are usually applied as a general treatment—*i.e.*, either in the full body bath, or in

Schnee baths (two or four). The effects of sinusoidal currents are:

1. General stimulating. Increase of metabolism produced.

2. Regulation of blood-pressure. This is raised in hypotension, lowered in hypertension.

3. The tone of the heart muscle is improved, and the pulse slowed.

4. The treatment is effective in insomnia.

5. There is marked improvement of muscular and articular pain.

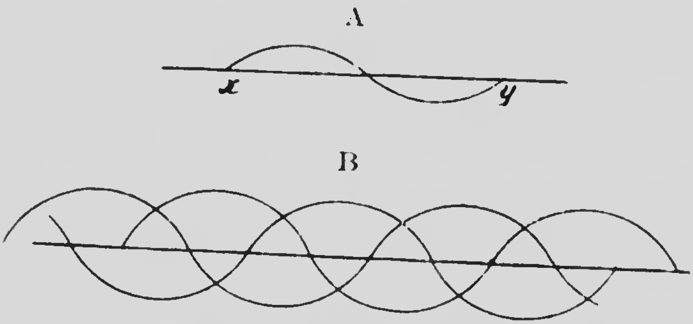

FIG. 7.—SINUSOIDAL AND POLYPHASE CURRENTS.
A, Sinusoidal; *B*, polyphase.

6. This current is more efficacious than any other in the treatment of anterior poliomyelitis.

7. The current is valuable in skin affections dependent upon disordered metabolism, such as chronic eczema.

Cardio-Vascular Disorders.—The full body bath, or four-cell Schnee bath, is of value in cases of uncomplicated cardiac insufficiency. Commencing dilatation is reduced, the pulse slowed, and the cardiac rhythm regulated. For these cases the current should be gradually increased from zero to 25 ma., or at most 30 ma. The treatment should last for fifteen to twenty minutes, at the end of which the current should be very gradually decreased to zero again.

Great cardiac feebleness and arterio-sclerosis are a contra-indication (Tousey). Sinusoidal currents administered by means of Schnee baths are sometimes successful in peripheral vasomotor disturbances, such as Raynaud's disease, and angioneurotic œdema.

Anterior Poliomyelitis.—This disease provides one of the most useful fields for the exhibition of sinusoidal currents. The full body bath is employed, and the electrodes placed, one near the nape of the neck, the other near the feet. Treatment should be started as soon as the acute symptoms have subsided and the patient is free from pain. The baths should, if possible, be given daily; if this is impracticable at least three times a week. They should last twenty to thirty minutes. It is as well to have a rhythmic interrupter in the circuit to excite muscular contractions, but this does not seem to be essential. The treatment should be persisted in for several months after all improvement has apparently ceased, and will therefore extend over a long period.

It is, of course, absolutely necessary that the affected muscles be kept relaxed at all times. No electrical treatment can be of avail where paralysed muscles are subject to stretching during the remainder of the day.

Arthritic and Muscular Pains.—The sinusoidal current has been advocated for the relief of pain in polyarticular rheumatoid arthritis. The author has failed to obtain any but the most transitory benefit from its employment, and in many cases no benefit whatever.

High-frequency currents are far more valuable.

Polyphase Current.—This is a modification of the usual sinusoidal current, and is obtained by taking tappings (usually three) from equidistant points on the generator of the sinusoidal current. The current in the cables is not synchronous as regards phases, and is best understood by reference to Fig. 7 (B), where it is diagrammatically represented. The action of the polyphase current is very similar to that of the simple sinusoidal. It is stated, however, to have a more definite effect in lowering arterial tension, and is therefore recommended in preference to the simple sinusoidal current in those cardiac conditions where production of low peripheral blood-pressure, together with stimulation of the cardiac muscle, is particularly desirable.

CHAPTER VIII

FARADISM

THE faradic current is what is known as an "induced" current, and the principles of electromagnetic induction must be briefly discussed here.

A, Fig. 8, is a coil of wire connected with a battery *E*, and having a key *D* in the circuit by which the current can be made and broken. *B* is another coil of wire, the ends of which are connected with a milliamperemeter *C*. If *B* is brought near to *A*, and the current is made in *A* by closing the key, a current will flow through *C* for a fraction of a second, as is shown by a movement of the milliamperemeter needle. After this the needle returns to zero, and no current flows through *B* so long as the key *D* is kept closed. If *D* be opened, and the current in *A* broken, another movement of the milliamperemeter needle will indicate a current in *B*, but this time flowing in the opposite direction to that when the current in *A* was made.

Similar currents can be produced in *B* by suddenly varying the strength of the current in *A*, or, while a steady current is flowing, by moving *B* nearer to or farther from *A*.

These secondary or induced currents in *B* result from the action of the electromagnetic field which surrounds a conductor through which a current is flowing. The induction effect is much increased if the coil *A* is wound upon a central core of soft iron.

The faradic current is made up of a series of induction currents following one upon another with great rapidity, and produced by mechanical making and breaking of the primary current.

The therapeutic faradic coil consists of a bobbin, upon which is wound one or two layers of coarse wire. This is the Primary coil. Another bobbin has many layers of fine wire wound upon it, the ends of which are led to terminals for connection with the patient. This is the Secondary coil.

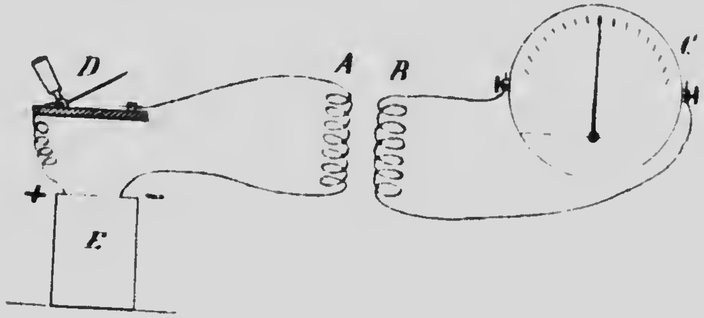

FIG. 8.—INDUCED CURRENT.
A, Primary coil; *B*, secondary coil; *C*, galvanometer; *D*, make and break key; *E*, battery.

The bobbin upon which the secondary coil is wound is hollow, and of sufficient size to enable it to be slipped right over the primary coil.

The primary coil is connected to the source of electrical supply, which may be one or more dry cells, an accumulator, or the direct current electric light main suitably modified by passage through a lamp or other resistance.

The primary current is made and broken by means of a ribbon interrupter placed in the circuit, and represented in Fig. 9. *A* is a core of soft iron, *C* is a flat steel spring which projects over *A*, and presses against a screw *D*. This screw regulates the distance between *C* and *A*. It is generally about $\frac{1}{16}$ inch. The screw *D* passes through a flat metal strip *F*, and the points of contact between *D* and *C* are armed with platinum to diminish the burning which tends to take place as a result of sparking on interrupting the circuit.

The current from a battery or other source is led to *C*, passes through the screw *D*, along the metal strip *F*, and then through a coil wound upon the iron core *A*. Thence back to the battery, completing the circuit.

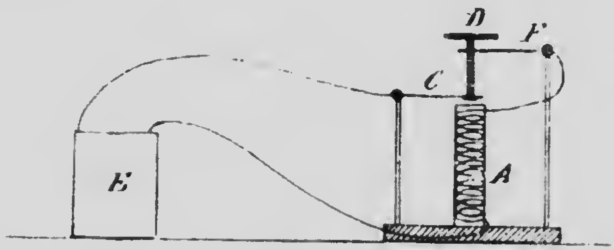

FIG. 9.—RIBBON INTERRUPTER FOR FARADIC COIL.
A, Core of soft iron; *C*, flat steel spring pressed against screw *D*; *F*, metal support for *D*; *E*, battery.

When the current is turned on *A* becomes an electromagnet, and attracts *C*. This draws *C* away from the screw *D*, and the current is broken. *A* then loses its magnetic force, and *C* returns to contact with *D*, making the current once more. The sequence of events is then repeated, and so continues automatically.

If the primary coil of the faradic battery has an iron core, this will form an electromagnet for the interrupter. If the coil is used without a core a separate electromagnet is provided.

Characteristics of the Faradic Current.—As has been stated above, both the make and the break of the primary current induce currents in the secondary, which are in opposite directions. The direction of the induced "make" current is opposite to, that of the induced "break" current the same as, the direction of the primary current. Moreover, the break current is much stronger than the make.

Each of these currents lasts only for a short time; the break current in a good therapeutic coil should last only about $\frac{1}{1000}$ second, and it rises to its maximum very rapidly. The make is several times longer in duration, and rises much more gradually to a maximum. The explanation of these differences is found in the consideration of the "extra" currents which arise in the primary. When the current is made, and starts to flow through the primary, induction currents are formed in the primary itself, opposed to the direction of flow of the galvanic circuit. The result of this "choke effect," as it is called, is that the rise of potential in the primary is gradual, and induction effect upon the secondary correspondingly small and gradual. When the primary current is broken extra currents are again induced in the primary, this time in the same direction of flow as the galvanic circuit; and these increase instead of retard the strong induction in the secondary caused by the sudden breaking of the primary circuit.

These "extra" currents are much increased if the primary is provided with a soft iron core. The "extra" current induced at the break may be led off to the patient, and produces effects very similar to the secondary current. It is, however, of very low voltage, and approximates in character to a rapidly interrupted galvanic current. It is unidirectional.

The strength of the *secondary* current is regulated by approximating to or withdrawing the secondary coil from the primary coil.

If the "*extra*" current from the primary coil (terminals labelled "Primary" or base-board) is used, a brass sleeve sliding over the iron core provides for regulation.

The above description applies to the currents obtainable from *any* faradic coil. It is found, however, that differences in the wire used, relative windings of the primary and secondary, presence or absence of iron core, and other details of construction, produce currents which vary fairly widely in their therapeutic properties.

The desideratum of a therapeutic coil is that the secondary current should produce strong muscular contractions with the minimum of discomfort.

It has been found that this is attained by constructing the coil so that (i.) The current induced at the break of the primary is of the shortest possible duration. This comprises a sudden rise to maximum, and equally sudden fall to zero. The current should not flow more than $\frac{1}{1000}$ second. (ii.) The interruptions should be rapid and regular. There should be 80 to 100 interruptions per second. Complete regularity is impossible to obtain with a mechanical interrupter of the electromagnetic type, owing to the occurrence of imperfect contacts; but the defect can be minimized by careful construction.

Many modifications have been devised, some of which approach within reasonable distance of the goal, but the painless faradic coil yet remains to be constructed.

The De Watteville, or galvano-faradic, current is produced by an apparatus consisting of a faradic coil, the secondary windings of which also form part of the circuit for a galvanic current.

The Leduc current is a rapidly interrupted galvanic current, the interrupter being constructed so that the relative times of flow and cessation of current can be regulated at will, as well as the actual rapidity of interruption.

Therapeutic Action of Faradism.—This is almost entirely dependent upon the property of exciting tetanic contractions in striped, or voluntary, muscle via their motor nerves. The stimulus may be applied to the nerve in any part of its course, in which case all the muscles whose branches of supply arise below the point of stimulus will contract. Or it may be applied to the muscle itself. In this case it will be found that for each muscle there is one area on the skin, localized in extent, and fairly constant in position, stimulation over which will cause a contraction with far weaker current than is necessary to produce contraction when the electrode is applied over any other part of the muscle. This is known as the "motor point," and marks the spot where the motor nerve enters the muscle. It is necessary that the motor points of the different muscles be carefully familiarized before attempting therapeutic or diagnostic procedures.

This reaction of voluntary muscle to faradism depends on the integrity of the motor nerve. Striped muscle fibres themselves are not stimulated to contract by faradism, but require currents of much longer duration than is possessed by the isolated induction shocks of a faradic coil. The importance of this fact is more fully discussed in the chapter on Electrodiagnosis.

Uninterrupted faradic currents should never be employed; continuous tetanization of any muscle injures rather than benefits it. A rhythmic interrupter should always be placed in circuit with the patient. The metronome is a good form to use for this current. If the Lewis Jones interrupter be employed, it must be adjusted so that the current is rhythmically reduced to a point at which it becomes too weak to produce any muscular contractions.

Application of Faradism.—The methods available are similar to those for galvanic and sinusoidal currents.

(i.) Two large electrodes may be bound in contact with different parts.

(ii.) One electrode may be of the ordinary type, while another is provided by a Schnee bath; or both electrodes may be formed by Schnee baths.

(iii.) There may be a large indifferent electrode, and a small active one.

Methods (i.) and (ii.) are useful when many muscles of one or more limbs are affected; the wasting of the thigh in chronic synovitis of the knee is a good example—the foot being in a Schnee bath, while the other electrode is bound round the upper part of the thigh, the current being interrupted by a metronome.

Method (iii.), by which individual muscles receive careful stimulation, is to be adopted in all but the mildest degrees of peripheral nerve injury. The active electrode is a small round padded metal plate, fastened to a wooden handle, which is held by the operator. This is applied to the motor point of each of the affected muscles, and then stroked down over the muscle to its insertion. This stroking movement provides for the interruptions of the current, and a mechanical interrupter need not be introduced into the circuit.

Indications for Faradism—*Lesions of Peripheral Motor Nerves.*—Faradism is invaluable in maintaining the nutrition of muscles whose motor nerve is not so damaged as to render this current incapable of producing contraction. If the muscles do not respond to faradism, galvanism must be substituted until such time as faradic excitability return. This is determined by periodic testing with the faradic current. Some observers have stated that faradism should *always* be used in preference to galvanism; but the author is convinced that the production of contractions is most necessary for the well-being of the paralyzed muscles.

The method of application is outlined above. The treatment should be given daily till voluntary power returns, then at increasingly longer intervals until full, or almost full, power is regained. The treatment may extend over two years or even longer, and great perseverance is required on the part of both patient and operator.

Lesions of the anterior cornual cells (*e.g.*, progressive muscular atrophy) sometimes show temporary improvement in their early stages from faradism. Sclerosis of the lateral tracts of the spinal cord (upper motor neuron) should not receive this treatment.

Paralysis resulting from hæmorrhage, embolism, or thrombosis of the cerebral vessels should be treated by mild faradic application as soon as symptoms of active mischief have subsided. Daily stimulation to all the affected muscles should be given and persisted in for one month after improvement has definitely ceased.

Secondary contractures are minimized by this treatment, but their appearance is a contra-indication for its continuance. Cerebral galvanism should also be given.

Functional paralysis, from whatever cause resulting, can frequently be cured by strong faradic stimulation. The stimulus should be sufficiently powerful to cause a considerable degree of pain, and the patient should be exhorted to voluntarily repeat the contraction produced by the stimulus.

It is essential to gain the patient's confidence before commencing treatment, and to convince him that his condition will be speedily cured by the methods which you are going to adopt.

The treatment may require to be repeated daily for some days, but it is important that some definite improvement be obtained on each day. The usual technique is to have a large indifferent electrode at some convenient part of the body, and apply the small active electrode to the motor points of the paralyzed muscles.

The aphonia, dependent upon functional paralysis of the adductors of the vocal cords, lateral electrodes may be applied to the sides of the larynx. In troublesome cases the intralaryngeal electrode should be used. This consists of a curved insulated rod, having a central conducting core which leads to the olivary metal terminal.

This is introduced with the aid of a laryngeal mirror, so that the olivary terminal rests directly on the vocal cords. A strong faradic shock is given, and usually results in immediate cure. The position of the indifferent electrode is unimportant.

Nocturnal Incontinence of Urine (*Enuresis*).—In approaching these cases it is necessary that a thorough examination be made to exclude all organic disease or exciting causes, such as urinary calculus, inflammatory lesion of the genito-urinary tract, hyperacidity of the urine, tight or adherent prepuce, intestinal worms, diseases of the central nervous system—*e.g.*, tabes dorsalis—etc.

If all recognizable causes are excluded, the case may be looked upon as true enuresis, and will then be found to fall into one of two classes:

Class 1: When the condition has persisted without intermission from infancy. This may be due to (*a*) some actual structural defect in the bladder or sphincter, not readily recognizable by clinical investigation; or, as is far more commonly the case, to (*b*) imperfect education of the centre in the brain whereby the reflex act is gradually brought under control as infancy is left behind.

Class 2: When the condition has appeared in early or in adult life, separated from the involuntary micturition of infancy by a period of perfect voluntary control. The causation in this class is generally obscure. In a certain proportion there is a history of preceding mental or physical shock. Usually the onset is gradual, and no definite cause can be assigned. Class 1 shows a preponderance of males over females of about 3 to 1; class 2 a much greater preponderance of males.

In either of these classes the nocturnal incontinence may be associated with frequency of micturition or actual incontinence during the waking hours. In Class 1, (*a*) is nearly always associated with frequency or incontinence in the daytime (*b*) is thus aggravated in about 30 per cent. of cases. In Class 2 about 20 per cent. are thus complicated.

The prognosis is different in these various types, and the proper classification of the case is therefore of value.

Class 1, (*a*), is of bad prognosis. This class is difficult to differentiate from (*b*); but the coexistence of severe daily incontinence is of some value in forming an opinion.

Class 1, (*b*), is of good prognosis in young subjects, and becomes progressively poorer as adult life is entered upon. In children and young adults a cure may be hoped for with reasonable confidence. In later life, and more especially if daily incontinence or frequency is present, a complete cure is unlikely; it is quite usual, however, to improve these cases to a degree which renders them happy and inoffensive to others, the actual incontinence being abolished, but the patient waking several times in the night to micturate.

In Class 2, the prognosis is generally good. The presence or absence of daily incontinence does not seem to be of much importance in estimating the prospects of this class of case.

The treatment in all these classes is the same, and is aimed at stimulating the higher centres to assume control over the reflex centre, strengthening and improving the tone of the sphincter vesicæ, and breaking the influence of habit. These ends are attained by (1) general, (2) local treatment.

General treatment consists in regulating the habits of the patient. He is allowed a light meal only in the evening, and takes with that meal a minimum of fluid. The bladder is thoroughly emptied immediately before going to bed, and he is awakened at regular intervals during the night and made to get up and micturate. At first these intervals should be two-hourly, or even, in severe cases, one-hourly. As the case improves the intervals are gradually lengthened.

Local treatment consists in producing active contractions of the sphincter vesicæ by means of an electrical stimulus which produces a moderate degree of discomfort, thus impressing the muscular contractions forcibly upon the cerebral centres.

Faradism is the method of choice. It may be applied by placing a flat electrode connected with one pole of a faradical coil upon the suprapubic region, and "stroking" the perineum with a small, round, well-padded electrode connected to the other pole.

Intermittent faradism may be given in this way for ten minutes daily, and may be followed for three minutes by galvanism, the perineal electrode being held stationary, and the direction of the current periodically reversed.

An alternative method, which should be employed with female cases and intractable male cases, is to use an intraurethral electrode having an insulated stem and bare metal olivary end. This is passed down to the external sphincter of the bladder, and the faradic stimulus thus applied directly to the muscle through the mucosa. Needless to say, the strength of current which can be borne is considerably less than with the perineal electrode.

Treatment should be given daily at first, then at increasingly longer intervals as the case improves.

Generally speaking, improvement should be noted within the first three weeks of treatment. Some inveterate cases have, however, been completely cured although no improvement took place until six weeks after treatment was commenced.

Relapses are not common in the case which is definitely cured, but they are not infrequent when the condition has stopped short of complete eradication.

Faradism in Simple and Reflex Muscular Atrophy.—Muscles which have become atrophied from disuse, as in a limb which has sustained a fracture, benefit markedly from faradic stimulation. In cases of fracture mild faradism can be advantageously applied as soon as massage is commenced—in other words, almost immediately. The fragments must, of course, be carefully controlled in these early stages, and the stimuli must not be of sufficient strength to cause any movement of the limb. In this way the absorption of effusion is hastened, adhesion prevented or minimized, and the muscular tone maintained.

In reflex atrophy the cause must be investigated carefully before prescribing treatment. In simple chronic synovitis faradic stimulation of the muscles about the affected joint should form a routine part of the treatment. Where any active inflammatory lesion of joints or bone exists, however, complete rest is vitally essential, and any stimulation of the muscles must be rigorously avoided.

The myopathies do not benefit from faradic stimulation to any marked extent.

Lesions of the Alimentary Tract.—Faradism applied by means of two large electrodes covering the abdomen and loins has been recommended as a means of stimulating gastric secretion. As the secretion produced under this stimulus, however, is not the specific gastric secretion, it is improbable that much benefit will result.

The motor functions of the stomach are favourably influenced by galvano-faradism and good results in atonic dyspepsia and dilatation of the stomach have been obtained by this means.

Diarrhœa, especially of the nervous variety, is much benefited by faradism with rather slow interruptions.

Obesity.—Faradism, applied by means of the Bergonié apparatus, is one of the best treatments for obesity. The patient sits or reclines in a special chair, and large electrodes are applied to both upper and under surfaces of the thigh, calves, and arms, and a large electrode covers the abdomen. The current is obtained from a faradic coil of low voltage in the secondary, and the interruptions of the primary are about 30 per second. This faradic current is interrupted 100 times a minute by means of a metronome. Rheostats are connected with every pair of electrodes, so that the current applied to each part can be regulated separately. The limbs may be weighted by sandbags, up to 200 lb. weight in all, so that the muscular contractions take place against considerable resistance. The patient is treated daily for periods varying from one-quarter to three-quarters of an hour. A permanent reduction in weight of $2\frac{1}{2}$ to [illegible] lb. per week is aimed at.

CHAPTER IX

HIGH-FREQUENCY CURRENTS

The high-frequency current is one in which very rapid reversals of flow take place—so rapid that the motor and sensory nerve-endings are not stimulated, and so no sensation of pain or muscular contractions are produced when the current is applied to the body. This is thought to be dependent on the fact that ionic movement cannot take place in either direction when the reversal of flow reaches this high rate. The current is better described as an oscillating than as an alternating one. A hot-wire milliamperemeter in circuit with the patient may show a reading of 500 to 600 milliamperes, while no sensation is produced but one of moderate warmth in the tissues.

The apparatus is best understood by reference to Fig. 10, which is a diagrammatic representation of the high-frequency apparatus invented by D'Arsonval.

A and *B* are two Leyden jars, the inner coats of which are connected with the secondary terminals of an X-ray faradic coil. There are also two adjustable terminals *C* and *D*, by sparking between which the inner coats of the Leyden jars are discharged.

The outer coats are connected together by means of a spiral of very thick copper wire *E*. The turns of this spiral are very close together. If the faradic coil be activated by means of the direct current from the mains and a mercury interrupter, the inner coats of the Leyden jars will be charged at each impulse and will discharge by sparking if *C* and *D* be brought close enough together. (Only the current produced at "break" is sufficiently powerful to produce discharge in this way under ordinary circumstances.) At the same time the outer coats of the Leyden jars will neutralize each other by discharge along the connecting wire *E*.

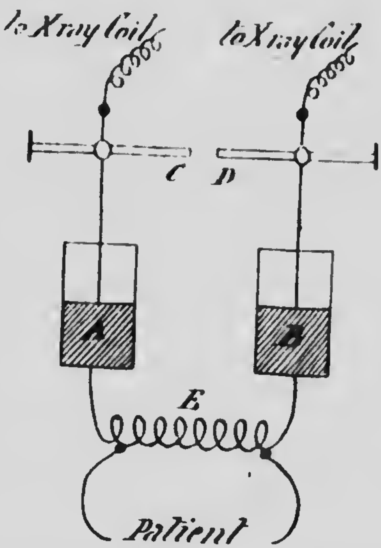

FIG. 10.—D'ARSONVAL HIGH-FREQUENCY APPARATUS.
A and *B*, Leyden jars; *E*, small solenoid connected to outer coats of *A* and *B*; *C* and *D*, electrodes connected to inner coats of *A* and *B*, and to secondary terminals of X-ray coil.

What actually occurs, however, is far more complicated than the above outline would lead one to suppose.

The discharge between the inner coats of two condensers in an arrangement as described above does not take place by one single spark, but by an alternating stream of sparks, which pass rapidly to and fro, gradually decreasing in volume until final equilibrium is established between the jars. They are then completely discharged. This stream of sparks forms an alternating current of high-frequency —about 500,000 alternations a second—but requires only a very small fraction of a second to completely discharge jars of the capacity used in this type of apparatus. Hence the current passing across the spark-gap consists of a series of high frequency oscillations, separated by intervals of quiescence. The rapidity with which the series of oscillations follow on one another depends on the rate of interruptions of the primary circuit, each break of the circuit producing a series of oscillations.

Exactly the same changes take place in the outer coats of the jars, and if the connection between them were formed of a single straight wire of large diameter the oscillations would flow backward and forward along this wire without further modification. The coil of heavy wire (*E*, Fig. 10) which connects the outer coatings of the jars, however, provides an enormous inductive resistance. To understand this, we must recall the fact that the commencement of flow of a current through a coil of wire induces a momentary current opposed in direction to the original one. This induced current is of very short duration, but in the circumstances under consideration, the "inducing" current has ceased to flow as soon as the induced current. The inductive resistance of such a coil is enormous, each turn of wire inducing a current of opposite direction in every other turn.

As a result, the alternating or high-frequency current will take an alternative path of high frictional but low inductive resistance, if such be provided, in preference to the path offered by the coil *E*.

The ends of *E* are therefore connected with terminals for leading the current to the patient, and nearly all the current will traverse the patient in preference to forcing its way through *E*.

The coil *E* is known as the small solenoid of D'Arsonval.

A modification of the high-frequency current is effected by introducing an Oudin resonator. This is a long spiral of wire (*F*, Fig. 11), wound upon a wooden framework, and terminating at its upper extremity by connection with a brass knob *G*, which

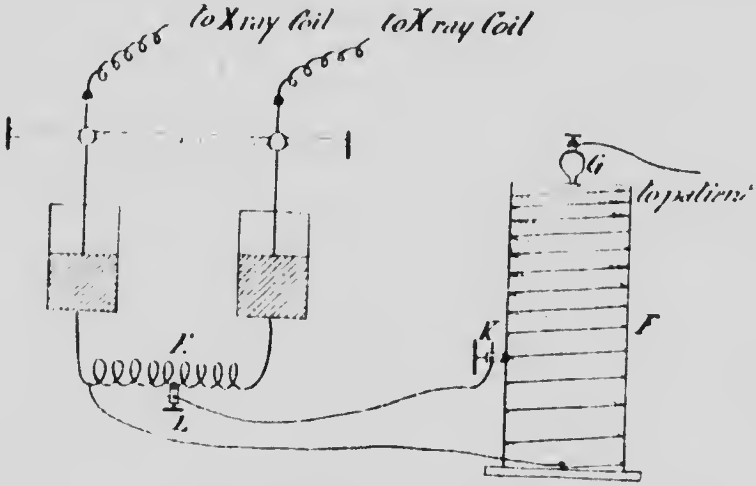

FIG. 11.—OUDIN RESONATOR CONNECTED TO HIGH-FREQUENCY APPARATUS.

E, Small solenoid; *F*, Oudin resonator; *L* and *K*, adjustable contacts; *G*, terminal at upper end of winding of resonator.

is provided with a binding-screw for the wire leading to the patient.

One end of the solenoid *E* is connected with the lowest turn of *F*.

A second connection is made between one of the turns of the solenoid and one of the turns of the resonator by two adjustable contacts *L* and *K*. The best position for *L* and *K* is found by experiment.

When the greatest efficiency is obtained the apparatus is "in tune," or in resonance. Usually the best position for *L* is about half-way along the solenoid, and for *K* about one-fifth of the way up the resonator.

The high-frequency current produced in the lower turns of the resonator acts by inductance upon the upper turns, so that a high-frequency current of greatly increased voltage is obtained from the terminal *G*.

If the main supply is an alternating current, a step-up static transformer can be used instead of the X-ray coil and mercury interrupter.

The static transformer consists of a closed magnetic ring of soft iron on which the primary wire, connected to the alternating mains, is wound. Over the primary coils, and insulated from them, are wound the secondary coils. Every alternation in the primary induces a current in the secondary. The voltage in the secondary varies directly as the ratio of turns of secondary to primary windings. If there are ten times the number of turns in the secondary to those in the primary, the voltage of the secondary is ten times that of the primary, and the amperage correspondingly diminished. This is a step-up transformer. A step-down transformer is constructed by having fewer turns in the secondary than in the primary.

The strength of the high-frequency current is regulated by altering the distance of the spark-gap between the inner coats of the Leyden jars—the longer the gap the more powerful the current. One-third to one-half an inch is an average spark-gap. When the resonator is employed the current can also be varied by selecting different points of contact between the solenoid and resonator windings.

Methods of Application of High-Frequency Currents to the Human Body.—Two methods are available:

1. General.
2. Local.

General applications take the form of auto-condensation and auto-conduction, and the solenoid is used without the addition of the Oudin resonator.

In auto-condensation the patient lies on a couch, holding a metal electrode, which is attached to one end of the solenoid. The couch is provided with a hair mattress for the patient to rest upon, and below this is a metal plate running the whole length of the couch. This plate is connected with the other end of the solenoid. When the current is turned on the patient forms one layer of a condenser, of which the other layer is formed by the metal plate. The mattress forms the insulation between the two layers. The patient is charged and discharged by every oscillation of the current, and the effect is greatly increased by the condenser action of the metal plate. No sensation is produced except one of slight warmth, but if the finger of the operator be approached to within a quarter or half an inch of any part of the patient's body, a stream of fine violet sparks is produced, accompanied by a sharp tingling sensation. The hot-wire milliamperemeter may show a current of 400 to 500 ma.

In auto-conduction the patient sits inside a large vertical coil of wire known as the auto-conduction cage, or large solenoid of D'Arsonval. This coil is connected by its two extremities with the outer coatings of the Leyden jars, and takes the place of the small solenoid described above. No direct connection is made to the patient, but he is charged with a high-frequency current by induction from the coil which surrounds him.

Instead of the large solenoid or cage, the patient may sit between two large flat spirals of wire, the innermost turn of one spiral being connected to the outermost turn of the other, and the free ends of the spirals leading to the outer coats of the Leyden jars.

Local applications of high-frequency currents are best made from the Oudin resonator, an electrode being connected to the brass knob. The effect can be increased by the patient holding a metal handle connected to the solenoid (bipolar application).

Three types of application are in common use:

1. The electrode is placed in actual contact with the skin or mucous membrane. There is very little sparking—a few short sparks passing from the edges of the electrode only if these are bevelled. No sensation is produced but one of mild warmth, unless the electrode is kept stationary for some time and heavy currents used. The electrode should generally be kept in fairly rapid motion over the area under treatment, except with mild currents; and to prevent it becoming sticky from accumulated fatty secretion, which will render contact imperfect, the skin should be dusted over with powder.

2. The electrode may be applied through the clothes. In this case a stream of fine sparks passes from the surface of the electrode to the skin. A burning sensation is produced, and, unless the electrode is kept in rapid motion, a temporary erythema ensues. This will be followed in prolonged heavy applications over a small area by vesication; but applications of this severity are not generally desirable.

3. The electrode may be held at a distance of 4 inches to 6 inches from the skin. An effleuve, or high-frequency breeze, then passes to the skin. The sensation is one of a cool or lukewarm current of air,

accompanied by analgesia and sedation. If the electrode be gradually brought nearer to the skin surface, sparks will pass to the skin, and produce a temporary vaso-constriction followed by vaso-dilatation, erythema, œdema, and vesication.

Electrodes for Local Applications.—These may be of metal or of glass. A common type of electrode is that which consists of a flat metal plate bearing a number of metal spikes or points on its surface. The metal plate is mounted on an insulated handle for the operator. This electrode is used for administering the high-frequency effleuve, or, by approaching it to the skin, strong sparks.

For application to the skin and mucous membranes glass vacuum electrodes are of great value. These electrodes consist of hollow glass bulbs, exhausted to varying degrees of vacuum. They are made in different shapes for convenience of application to special regions—*e.g.*, rectum, vagina, gums, scalp, etc. These electrodes are made for attachment to an insulated handle, or may have the handle incorporated in them, in the shape of a solid glass rod fused to the end of the vacuum electrode. The current may be led into the electrode by means of a wire passing through its side, or the terminal may consist of a brass collar surrounding the stem of the electrode, with no internal connection.

When the electrode is brought near to or in contact with the skin it becomes filled with a violet or greenish light, the colour depending on the degree of exhaustion. No current actually passes through the glass wall of the electrode to the patient, but the effect is one of induction, the oscillations in the gas remaining in the bulb inducing similar oscillations in the body.

These electrodes can also be applied through the clothes. Should the electrode perforate, it can be rendered serviceable by filling with strong salt solution and leading in a wire, if one is not already present, for conducting the current to the solution.

The electrodes have sometimes been filled with medicinal solutions, with a view to increasing the therapeutic action of the application; but, since no ionic movement takes place with high-frequency currents, it is difficult to see the rationale of this proceeding.

Electrodes of metal may be fashioned in similar shapes to the glass vacuum electrodes. They possess the advantage of being more durable, but tend to become unpleasantly hot when applied for any period of time to one part, such as the rectum.

Physiological Action of High-Frequency Currents.—The therapeutic value of this form of current probably depends largely on the fact that heat is generated in all the tissues through which the current passes. This results from the high frictional resistance of the tissues, and the heavy current which can be passed. Heat is, of course, generated in the tissues by the passage of the simple galvanic or low-frequency alternating currents, but in these instances the current that can be supported without great pain and risk of injury is so small that no appreciable heat is developed in any tissue except the skin. In the high-frequency current the voltage is so high that differences in resistance of the various tissues are almost negligible; and the heat developed is practically the same for all parts traversed by the current.

It seems probable that the beneficial action of the current does not depend solely on the production of physical heat, with its physiological sequelæ; but the subject is one which at present is very imperfectly understood.

Whatever the actual cause of production, the effects of this treatment are very varied, and of great importance.

The most marked effect, which is common to all methods of application, is an increase in metabolism. This is demonstrated by increased elimination of CO_2, increase of urea and phosphoric acid in the urine, with (in cases of gout and rheumatism) diminution or disappearance of uric acid.

Other effects vary somewhat with the method of application.

When general treatment is given by means of the couch or cage, the increased activity of metabolism is more marked than in local applications. This can be estimated by examination of the urine and expired air, as stated above. The increased metabolism is sufficient to produce loss of weight, more particularly in cases of obesity.

The result of general applications on the blood-pressure is to cause a marked fall in tension. This appears to be selective in action, and is confined to cases of hypertension, from whatever cause resulting—gout, rheumatism, asthma, Bright's disease, and even arterio-sclerosis. The fall of pressure is progressive, and can be rendered permanent by a course of treatment. In patients not suffering from hypertension this fall of pressure is not produced—in fact, a slight temporary rise may be noted.

As regards general sensation, many patients state that general high-frequency applications produce a feeling of exhilaration; others feel drowsy, and in a fair number neither of these effects is noted.

There is an increase of hæmoglobin, and, apart from this, there appears to be some increase in the oxygen-carrying capacity of the blood.

To produce these effects heavy currents are necessary—a hot-wire milliamperemeter should always form part of the circuit, and should register 600 to 1,000 ma. Failure can probably often be traced to an apparatus of poor efficiency or improper adjustment.

Local applications of high-frequency currents are somewhat different in their action, according to the presence or absence of spark-effect. Without spark-effect (*i.e.*, when the electrode is kept in close contact with the skin) there is very little sensation except with prolonged use of heavy currents. The sensation then is one simply of warmth. Sweat and mucous glands are stimulated to marked increase of secretion, moderate vaso-dilatation occurs, and local hyperæmia results. Painful conditions are greatly eased, and inflammatory exudates resolved.

If spark-effect is used the effect on the skin is to produce a marked erythema with heavy applications, and this is accompanied by tingling and smarting sensations. Prolonged application will produce vesication. The passage of sparks between the electrode and the body causes a considerable formation of ozone, and this is absorbed by the tissues. The analgesic effect of high-frequency is much increased by employing moderate spark-effect, owing probably to the counter-irritant element thus introduced, in addition to the specific action of these currents on the vital processes. Resolution of inflammatory exudates is also hastened by some spark-effect.

Muscular contractions are caused by large sparks. Local application up and down the spine will cause a rise of blood-pressure, especially where hypotension is present.

In inflammatory conditions, both acute and chronic, the most striking result of local high-frequency currents is the relief of pain. This often takes place so rapidly as to astonish both patient and operator, but, unfortunately, is not generally permanent. A course of treatment will, however, frequently produce permanent relief even in long-standing inflammation, such as chronic sciatica and lumbago. Generally speaking, when pain is the most marked symptom, some degree of spark-effect should be employed. An exception is provided by the case where superficial hyperæsthesia is too great to admit of any sparking being tolerated, as in acute articular gout.

A rough guide as to length and frequency of treatment will be of value.

General applications should be given at least three times a week, and each séance should last from twenty to thirty minutes. Local applications are best given daily at first, then at increasingly longer intervals. Without spark-effect each séance should last about ten minutes; with spark-effect, except with the mildest currents, five to seven minutes will be found sufficient.

Therapeutic Indications.—These are so numerous and so varied that only a brief classification can be given here of some of the more common complaints which may be successfully submitted to this treatment.

General applications:

- *Arterial hypertension*, from whatever cause resulting.
- *Neurasthenia*. May be combined with local applications to the spine.
- *Debility*.
- *Gout*. Best combined with local applications.
- *Diabetes*. General health much improved. Sugar sometimes diminished.
- *Polyarticular rheumatoid arthritis*. These cases are frequently relieved; they can never be cured.
- *Chorea*.

Local applications	*Respiratory system*	*Laryngitis*, from whatever cause.
		Bronchitis (especially acute).
		Asthma.
		Phthisis. Symptoms may be relieved. General condition improved.
	Alimentary system	*Pyorrhœa alveolaris.*
		Atony of stomach and intestines.
		Mucous colitis.
		Internal hæmorrhoids.
		Paralysis of sphincter ani, following stretching in rectal operations.
	Cutaneous system	*Acne.*
		Alopecia.
		Eczema—practically all forms of the disease.
		Impetigo.
		Lupus erythematosus.
		Pruritus, in any situation.
		Psoriasis.
		Seborrhœa.
		Ulcers, of any part, especially when chronic.
	Miscellaneous	*Arthritis, neuritis, neuralgia, fibrositis*, whether acute or chronic.
		Phlebitis and *varicose veins.*
		Trachoma.
		Tinnitus aurium, by effleuve to mastoid process.
		Ozena.
		Frontal sinusitis, by vacuum electrode over forehead

CHAPTER X

DIATHERMY

THE term "high frequency" is reserved for the current having the characteristics outlined in the preceding chapter, and produced by the D'Arsonval apparatus, or one which does not differ from it as regards essentials. There is, however, another form of current consisting of high-frequency oscillations, to which the name of "diathermy" has been given, in recognition of the marked property which it possesses of producing heat throughout the tissues. This current contrasts with the ordinary high-frequency of D'Arsonval in several particulars.

1. High-frequency currents are of very high voltage and relatively small amperage (50,000 to 100,000 volts, 500 to 1,000 ma. in a very efficient apparatus).

Diathermy is of comparatively low voltage, and of very high amperage (about 2,000 volts, and for ordinary applications 2 to 3 amperes; but higher amperage can be utilized when required).

2. High-frequency consists of a series of oscillations, each of the series corresponding to the breaking of the primary current and lasting a comparatively short time, to be followed by a considerable interval before the next of the series is produced. In diathermy the oscillations are continuous.

3. In high-frequency the oscillations are "damped" —that is, in each series the first oscillation is the largest, and those following grow gradually smaller until they cease completely.

In diathermy the oscillations are "undamped"—that is, they are all of equal intensity.

The apparatus for producing diathermy currents requires an alternating current from the main. If the main supply is direct, a rotary transformer must

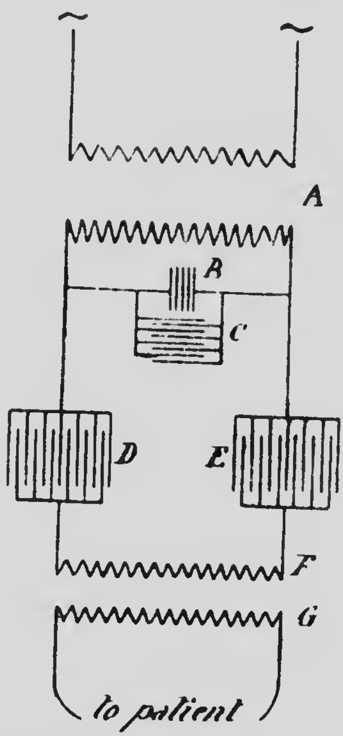

FIG. 12.—APPARATUS FOR PRODUCING DIATHERMY CURRENTS.

A, Step-up transformer; *B*, multiple spark-gap; *C*, condenser connected to spark-gap, *D* and *E*, large condensers.

be used to supply the alternating current. This is led to the primary of a step-up static transformer (*A*, Fig. 12).

This steps the current up to about 2,000 volts. The secondary alternating current from the transformer is led to two condensers, *D* and *E*. These consist of many plates of glass placed close together, on either side of which lead-foil is pasted, and correspond to the Leyden jars generally found on the high-frequency apparatus.

The condensers discharge across a spark-gap *B*, which consists of four plates of copper, coated on their opposing surfaces with silver and placed very close together; there is a third condenser, *C*, connected to either side of the spark-gap.

The other sides of the condensers, *D* and *E*, are connected by means of a coil of wire *F*, which corresponds with the small solenoid on the high-frequency apparatus. The patient is not connected directly to *F*, however, but to a second coil, *G*, which is in more or less close apposition to *F*, and in which high-frequency oscillations are induced.

The method of regulating the current applied to the patients varies in different makes. In some, the primary current in the static transformer is controlled by a rheostat; in others, control is established by varying the position of *G* in relation to *F*.

The diathermy apparatus is peculiarly apt to give trouble, which is nearly always referable to a breakdown of insulation of the two large condensers. This should be forestalled by filling the condensers completely with melted vaseline or paraffin wax, unless this has been done by the makers.

The plates forming the spark-gap also require to be cleaned at regular intervals, and occasionally renewed. They are easily removable.

Methods of Application.—Diathermy applications may be general or local. In the former case the auto-condensation couch is often employed, or the patient may hold the two electrodes in his hands; or one pole may be connected with two hand-pieces, while the other leads to two leg-baths.

For local applications, the same forms of electrodes are suitable as were described in the preceding chapter for local applications of high frequency, with this proviso—that the electrode be always kept in close contact with the skin or mucous membrane to which it is applied. Diathermy sparks are much too hot and painful to be utilized in ordinary therapy.

An excellent medium in many situations are the malleable electrodes used for galvanism and ionization. These may be covered with several layers of lint soaked in 10 per cent. saline solution, or may be applied direct to the skin surface if sufficiently good contact can be obtained in that way.

Local applications of diathermy are generally bipolar. Both electrodes may be active, or one may form an indifferent electrode (*e.g.*, a large indifferent electrode held in the two hands while a glass vacuum electrode is applied to some other part).

Other diathermy electrodes consist of small metal plates and cautery points, made to screw into an insulated handle for the operator. These are used for causing actual coagulation of the tissues.

Physiological Properties.—These are similar to those possessed by ordinary high-frequency, but are exaggerated in degree. In spite of this fact, diathermy often fails to produce the relief of pain which is such a marked characteristic of high-frequency. This is probably due to the absence of spark effect in the local applications.

The most striking property of diathermy is the production of heat throughout all the tissues traversed by the current. If the poles of the machine are connected to two metal electrodes held in the hands, and the machine turned on, a sensation of warmth is soon manifest. This is felt first of all in the wrists, which form the narrowest portion of the path traversed by the current, and in which,

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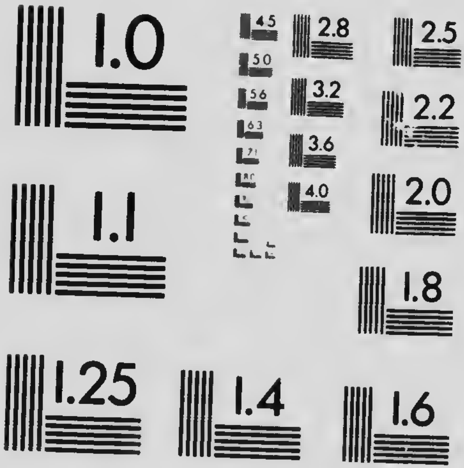
MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



therefore, the concentration of current is greatest. The sensation of warmth then spreads to the hands and up the arms, and is finally felt in the shoulders and thorax. It is still most intense in the wrists. The face becomes flushed, free sweating occurs, and faintness not infrequently supervenes if the application is at all prolonged. If too heavy a current is used the skin of the wrists may actually blister, and this blistering of the skin must always be guarded against when concentration of the current occurs at any part. It may take place very rapidly and without very much sensation of pain.

A hot-wire amperemeter always forms part of the diathermy circuit, and is a useful guide to the operator, but the patient's sensations are of even greater importance. A patient receiving diathermy must be under constant skilled observation, and any complaint of local pain or faintness should be an indication for immediately turning off the current. The length of time of the applications varies widely from five minutes to an hour.

Indications for Diathermy.—This form of treatment is rapidly attaining greater popularity, but up to the present it has not been tried very widely except in comparatively few conditions. Doubtless in time it will largely supplant ordinary high-frequency applications.

Cardio-vascular System.—Arterial hypertension is treated by the auto-condensation couch. The effect is somewhat doubtful. Cardiac hypertrophy and dilatation, and angina pectoris, are treated by means of electrodes on the front and back of the chest. One electrode at the upper margin and one at the lower margin of the sternum are also advised for angina.

Respiratory System.—The pain of pleurisy is often relieved by this current. Large electrodes cover the affected area. Asthma is markedly benefited by bipolar applications at the upper and lower margins of the sternum.

Pelvic Disorders.—Suppurative conditions are a contra-indication, but chronic inflammatory exudates and adhesions may be treated by means of an active vaginal electrode, and a large indifferent external electrode on the loins or abdomen.

In the male, chronic prostatitis and prostatic hypertrophy are treated by means of an active rectal electrode, and gonorrhœal epididymitis is said to respond rapidly to strong applications.

Diseases of the Joints.—Bipolar application is made by means of large electrodes on either side of the joint. Gouty deposits are absorbed, and improvement often results in rheumatoid and osteo-arthritis.

Neuritis.—The pain is greatly relieved and a permanent cure often achieved in obstinate cases of sciatica, brachial neuritis, and in some mild cases of trigeminal neuralgia. All parts of the affected nerve must be vigorously treated.

Surgical Diathermy.—This consists of actually destroying tissues *in situ* by producing coagulation. It has been largely used in the treatment of inoperable malignant growths, but can also be used for innocent growths, such as papilloma, fibroma, and zanthelasma.

The application is made with a large indifferent electrode and a metal active electrode, which is plunged into the tissue to be destroyed. In the case of growths the current is turned on and allowed to flow until bubbles of gas escape around the active electrode, and the surrounding tissues turn white.

The current is then turned off, the electrode thrust into another part of the growth, and the procedure repeated, until the whole of the diseased tissues are coagulated. The slough eventually separates, leaving a clean granulating surface. A general anæsthetic is required for this treatment. Diathermy is used with the most gratifying results in the treatment of papilloma of the bladder. The bladder is washed out and filled with boric acid solution, and an operating cystoscope is passed. Through this an electrode, insulated except at its tip, is introduced, and brought into contact with each part of the papilloma in turn, the coagulation taking place under observation through the cystoscope.

The strength of current is ascertained beforehand by applying the electrode to a piece of raw meat, and noting the current required to produce coagulation to the depth of about $\frac{1}{4}$ inch.

No anæsthetic is required for this treatment, which is painless.

A large indifferent electrode is placed under the loins.

CHAPTER XI

PHOTOTHERAPY

THE therapeutic action of light upon the tissues depends on rays having three different properties:

1. Luminous rays.
2. Heat rays.
3. Chemic rays.

The table on page 84 shows the distribution of these different rays throughout the spectrum, and it will be noted that certain rays possess more than one of these properties.

Generally speaking, the red end of the spectrum is richer in heat rays, and the violet end in chemic rays.

The ultra-red and ultra-violet rays are invisible to the human eye.

The methods employed in applying the different rays and combinations of rays are very numerous. The most important are briefly described here.

Radiant Heat.—Known also as light baths. These consist of a suitable number of electric-light bulbs arranged under a reflector; this is semicircular in shape.

The ends of the appliance are closed by wooden flaps provided with an aperture, the margins of which enclose the limb or portion of the trunk which is being treated, and so prevent escape of heat to the outside air. Light baths of suitable size and shape are made for the arm, leg, and trunk. Ten 16-candle-power lamps are usually sufficient for one of these baths, but it is convenient to have switches which control the number of lamps employed.

SPECTRUM OF LIGHT. (AFTER SATTERLEE).

Ultra-red.	Wave-length, 8 microns.
Red.	Wave-length, 0·71 micron.
Orange.	Wave-length, 0·66 micron.
Yellow.	Wave-length, 0·62 micron.
Green.	Wave-length, 0·53 micron.
Blue.	Wave-length, 0·49 micron.
Indigo.	Wave-length, 0·41 micron.
Violet.	Wave-length, 0·38 micron.
Ultra-violet.	Wave-length, 0·21 micron.

Heat rays

Luminous rays

Chemic rays

Finsen rays

General radiant-heat baths, for the treatment of the whole body, are made in the form of wooden cabinets. These are lined with reflectors, and provided with a folding top or curtain in which is an aperture for the patient's neck.

The patient sits or reclines on a slatted chair in the cabinet, and his head projects through the top. The curtain is far more comfortable than a rigid aperture round the neck. The temperature of the electric-light bath is generally about 80° C. or 177° F., but higher temperatures are sometimes employed.

A convenient form of local light bath consists of a single very high candle-power lamp (1,000 to 5,000) under a reflector. With this form of apparatus the part under treatment need not be entirely enclosed, as the heat generated is comparatively very great. The high-candle-power lamp should be 12 inches to 18 inches from the skin surface, and care should be taken that the patient is not burnt.

Patients undergoing general treatment in a cabinet also require constant supervision, as faintness is apt to ensue, and the patient, under these circumstances, is quite unable to help himself. The number of lamps in use should also be very limited at first, and gradually increased, so that the individual limit of tolerance of each patient may not be overstepped. A thermometer with blackened bulb should always be exposed to the direct rays at the same distance as the patient.

Physiological Effects of Radiant Heat.—In general treatment in the cabinet, the most marked effects are profuse sweating and superficial vaso-dilatation, with increased metabolism. There is slowing of the respirations, which are, however, of increased depth, so that the respiratory exchange is unaltered. The blood-pressure is lowered, and in cases of hypertension this change may persist for some time after a course of baths.

In some patients the pulse-rate is increased, in others diminished.

The heating of the tissues is only quite superficial, in contradistinction to that produced by diathermic currents.

The effect of these baths is chiefly due to the luminous and heat rays, but the chemic rays probably also play a small part.

The free sweating which occurs commences at a considerably lower temperature than if non-radiant heat were employed.

The action of local radiant-heat baths is confined almost entirely to the part under treatment, and consists of superficial vaso-dilatation, free sweating, and increased local tissue change.

Indications for Radiant Heat Treatment.—General applications are of great value in all conditions of auto-intoxication. Among these may be mentioned the toxæmias of acute and chronic uræmia, puerperal eclampsia, and the toxæmia resulting from suppression of urine due to any cause.

Patients suffering from the above conditions must generally be treated in bed by trunk and limb baths, and great care must be exercised that burns be not produced. General treatment in the cabinet is indicated in cases of arterial hypertension, chronic intestinal toxæmia and its sequelæ, gout, chronic polyarticular rheumatism, and rheumatoid arthritis. Chronic nephritis, apart from uræmic manifestations, is also markedly benefited.

Local treatment is indicated in sprains, synovitis, muscular rheumatism, mon-articular osteo-ar[illegible] fibrositis, sciatica, colitis, and pruritus vulvæ

Treatment by Coloured Light.—Red light ha[illegible] used in smallpox to prevent pitting of the face. Freckles, seborrhœic eczema, and rosacea seborrhœica, have been treated with ointment containing red pigment.

The value to be attached to these measures, as far as the action of the red light is concerned, is uncertain. It is worth a trial in smallpox.

Blue light is said to have a sedative and analgesic effect. It has been stated that gazing at a blue light for a few minutes will produce anæsthesia of the face, enabling small operations such as extraction of teeth to be painlessly performed. This effect would appear to depend far more on hypnotic influence than on any specific property of the type of light used.

Blue light has been applied locally with some apparent benefit in painful conditions of the joints and muscles, including tubercular arthritis, and general blue-light baths have been given in cases of widespread rheumatism. The benefit derived from this treatment probably depends to a large extent on the heat rays which are applied at the same time as the luminous rays.

Ultra-Violet Rays.—As has been stated above, the violet end of the spectrum is particularly rich in chemic rays, and the ultra-violet rays are better equipped in this respect than any others. Various appliances have therefore been made with the object of producing these rays for therapeutic purposes. The presence of ultra-violet rays can be detected by the use of Willemite, a substance which fluoresces when acted upon by ultra-violet rays. A piece of ordinary glass placed between the source of radiation and the Willemite will cause this fluorescence to cease, as ordinary glass, even of little thickness, cuts off practically all of these rays. Quartz glass, on the other hand, is very permeable to the ultra-violet ray.

Action of Ultra-Violet Rays.—These rays have many interesting chemical properties, but the action which most concerns us here is the bactericidal. Cultures of any organism are sterilized by exposure to these rays, the length of time necessary varying with the organism and the intensity of the radiation. Young cultures are more rapidly sterilized than old, and spores require about five times the exposure.

This bactericidal effect is quite independent of heat rays, which can be filtered out by a layer of water (as in the Finsen lamp).

Other beneficial effects of the rays are their stimulation of the tissues, causing inflammatory reaction with resultant formation of fibrous tissue.

There is also formation of ozone, hydrogen peroxide, and oxygen, in tissues exposed to the rays.

A moderate exposure to healthy skin causes some transient itching and erythema. A longer exposure will produce vesication. Repeated moderate exposures result in tanning of the skin.

The Arc-Lamp.—The ordinary carbon arc-lamp consists of two carbon electrodes, to which are led the terminals from the main, after passing through a resistance. The points of the electrodes are brought together to start the circuit, and are then separated to about ¼ inch. The distance which the electrodes are separated does not regulate the current passing between them. This must be done by the resistance mentioned above, and in therapeutic arc-lamps the current used varies between 2 and 60 amperes. The more modern appliances mostly take a moderate amperage (3 to 10 amperes).

The Finsen light consists of a carbon arc with automatic adjustment of the distance between the electrodes; a quartz condenser; and a metal tube closed at either end with quartz lenses, and containing water, which is kept in constant circulation, to absorb the heat rays. Only a small area can be treated at a time by this appliance, and the tissues radiated are generally compressed by a quartz compressor, through which water also circulates. Each exposure lasts from an hour to an hour and a quarter, and vesication is generally aimed at. The Finsen light has been and is still very largely used in the treatment of lupus. This method of treatment, when the disease is at all extensive, is exceedingly slow, but the ultimate results are excellent. It possesses no particular advan age over X-radiation in the treatment of this disease, and the latter is far easier to apply, and less tedic .s both for patient and operator.

The Simpson light consists of an arc-lamp the e ctrodes of which are formed of wulfram, an amalgam of metals of which tungsten forms the most important constituent. The pure tungsten arc appears to be equally beneficial.

The rays from this arc are exceedingly rich in ultra-violet rays. An exposure of three minutes at a distance of 12 inches to a tungsten arc taking 6 amperes will produce a slight transient erythema. The exposure may be repeated daily, and slightly increased in duration as tolerance is developed. The Simpson light is excellent for all skin conditions of microbic origin. When the inflammation is acute the treatment must be cautiously applied at first.

This treatment is also most successful in chronic ulcers and small infected wounds which show little tendency to heal. The beneficial effect is due to the bactericidal properties of the ultra-violet rays, combined with the stimulation of the tissues. The Simpson light has also been recommended for more deeply seated lesions, but can then only act by virtue of inflammatory reaction produced in superficial parts, with resultant increased blood-supply to underlying tissues. Practically none of the ultra-violet rays pass beyond the skin.

The ligh from the mercury vapour lamp is rich in rays a e violet end of the spectrum, and (when the lamp is made of quartz glass) possesses a fair quantity of ultra-violet rays.

The lamp in its simplest form consists of a ube exharsted of air, and containing at one end a reservoir of mercury. The tube is hence, of course, filled with mercury vapour. One terminal is led through the tube into the reservoir of mercury; another is led through the other end of the tube and is connected to an iron electrode. The electrode dipping into the mercury is connected to the cathode. The lamp takes about 3½ amperes. Mercury vapour, when cold, is a poor conductor of electricity, and the lamp is therefore started by tilting it so that the mercury flows from the reservoir to the iron positive electrode, making a metallic circuit. Once started, the current is transmitted by the mercury vapour, the tube being tilted back so that the metallic mercury returns to the reservoir.

The indications for this treatment, and methods of application, are similar to those for the tungsten arc, with the proviso that somewhat longer exposures should be given with the mercury vapour lamp. The tungsten arc will probably supersede this form of treatment, as it is far more efficient.

In using any form of arc-light the operator's eyes should be protected by dark-blue glasses.

The radiations should be localized by a suitable shield of thin metal. The effects of ultra-violet radiations upon the eye are very injurious, producing acute inflammatory changes and even temporary blindness. These changes are transitory, but should be guarded against. The operator is more liable to suffer than the patient. In treating the face, closure of the lids is sufficient protection for the patient.

CHAPTER XII

X-RAYS

The Crookes tube, the precursor of the modern X-ray tube, consists of a glass bulb exhausted of air to about $\frac{1}{1000000}$ of an atmosphere, and having two electrodes at the opposite ends of a diameter. These electrodes pass through the walls of the tube, where they are hermetically sealed, and project externally for attachment to the terminals of a source of high-potential electricity. When the tube is placed in such a circuit, and the current switched on, the tube is found to light up with an apple-green or bluish fluorescence. This is caused by the bombardment of the glass walls of the tube by the "cathode-stream"—a stream of minute negatively charged particles or electrons which are torn off from the cathode and flung out at right angles to every part of its surface. The electron is exceedingly minute, the estimated weight being $\frac{1}{1000}$ that of an atom of hydrogen.

Conflicting views are held as to the part played by this stream of negatively charged particles in conveying the current through a vacuum tube, but it is generally throught that the major part of the current is carried in this way. The cathode stream travels at the rate of 20,000 miles a second, and wherever it strikes a solid object two phenomena occur:

1. Secondary cathode streams are generated, mostly at right angles to the surface impinged upon, while

the original stream is partly absorbed, partly reflected, and partly diffused.

2. X-rays are generated. These are comparable to light and heat, and consist of transverse vibrations of the luminiferous ether, possessing, however, exceedingly short wave lengths, and a rate of vibration five to ten times as rapid as the most rapid vibration of visible light.

The cathode stream cannot be regularly refracted, but is deflected by either pole of a magnet. The stream will pass through a window of aluminium 0·00265 m.m. in thickness, let into the wall of the tube, losing 10 per cent. of its velocity in so doing, but otherwise retaining the characteristics of the stream. These extraneous cathode rays are called "Lenard rays," after their discoverer.

"Channel rays" are found behind a perforated cathode in an X-ray tube. They consist of a stream of positively charged particles, and have the property of causing fluorescence in certain substances. They are deflected by a magnet. They are thought to be generated by the combustion of gases in the substance of the cathode.

Since the cathode stream is flung off at right angles to the surface of the cathode, it is possible to focus this stream upon any desired point by making the cathode concave.

The ordinary X-ray tube (or gas tube) is provided with a concave cathode, focusing the stream upon a point on the positive terminal, or anti-cathode. The negatively charged particles making up the stream tend to dispel each other, so that the focus point is farther away than the actual focal point of the concave cathode.

The anti-cathode consists of a platinum or tungsten target (to withstand the great heat generated by the cathode bombardment), and is placed at an angle of 45 degrees to the long axis of the tube. The target is set in a solid block of copper (see Fig. 13).

The-X rays produced by the bombardment of the anti-cathode pass in every direction with equal strength from the surface of the target, and therefore fill a hemisphere of the tube. Their outstanding physical property is the penetration of solid substances. The degree of penetrability of any substance is closely related to that substance's atomic weight. The less the atomic weight the greater the penetrability. The X-radiation from any X-ray

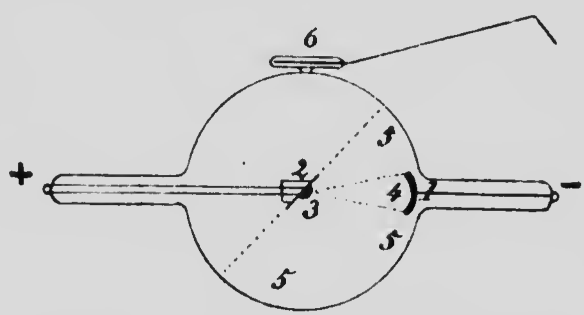


FIG. 13.—ORDINARY X-RAY TUBE.

1, Cathode; 2, copper anti-cathode; 3, platinum or tungsten target; 4, cathode stream; 5, hemisphere occupied by X-rays and reflected cathode stream; 6, regulator.

tube is not homogeneous, but consists of rays of many different wave-lengths, of which certain wave-lengths are predominant.

The type of ray which is predominant depends in practice chiefly on the degree of vacuum of the tube. A "soft" tube is one with a relatively low degree of vacuum, emitting rays whose predominant wave-length is comparatively long, with resulting low power of penetration. A "hard" tube is one with a high degree of vacuum, emitting predominant rays of short wave-length and great power of penetration.

A regulator for lowering the vacuum of the tube if this be too high is attached to all gas tubes. It consists of some substance (varying in different tubes) which gives off gas when a high-tension current passes through it. This substance is contained in a protrusion of the main bulb, and is connected with external wires. These can be approximated to the cables which pass to the main terminals of the tube. A series of sparks will leap across through the regulator, gas will be liberated, and the vacuum lowered. Great care must be exercised not to lower the vacuum too much.

The above brief description of a simple X-ray tube is applicable in general terms to all "gas" tubes. Modifications of these gas tubes and the modern Coolidge tube will be described later.

It will be best now to consider briefly the apparatus for activating an X-ray tube of whatever design.

Type of Current Necessary for Activating X-ray Tubes.—The current for this purpose must fulfil two conditions:

1. It must be of very high tension.
2. It must be unidirectional.

The first of these conditions is necessary on account of the very high resistance imposed to the passage of current by the vacuum tube. Roughly speaking, a voltage of from 100,000 to 250,000 is desirable. The lower voltage is adequate for most therapeutic purposes.

The second condition—unidirectional current—is obviously desirable, since, if the anti-cathode becomes negative, the cathode stream will be scattered over the walls of the tubes instead of being focused upon one spot. Moreover, the X-ray generated varies with the substance struck by the cathode stream, and has far less penetrating power when generated by the impaction of that stream upon glass than when the stream impinges upon the platinum or tungsten of the anti-cathode. The matter goes deeper than this, however, since it vitally affects the duration of useful life of the X-ray tube. The anti-cathode, as stated above, consists largely of copper, and if this terminal is subjected to negative potential the copper tends to disintegrate. Particles of metal are flung off and blend with the glass walls of the tube, and in so doing form an indissoluble union with the residual gases in the tube. The latter becomes progressively "harder" and finally unmanageable, owing to the increasingly high vacuum which results.

For practical purposes there are two forms of power unit which may be used for generating the activating current:

1. The Faradic coil.
2. The high-tension transformer.

The Faradic Coil Unit.—The faradic coil unit consists of a large coil, an interrupter, for making and breaking the primary circuit, and some form of rectifier for rendering the secondary or high-tension circuit unidirectional.

The *coil* should give a spark of 12 inches to 30 inches. A good coil for all-round therapeutic purposes is the 16-inch. No X-ray tube is made to back up a 16-inch spark-gap when working properly, but the long exposures of X-ray therapy put considerable strain on the coil, and it is therefore undesirable to work the latter at the limit of its capacity.

The X-ray coil is specially wound to produce the minimum of "make," or inverse current, and thus render the rectification of the current practicable. A good X-ray coil should generate a secondary current almost free of inverse when the amperage in the primary is low. Even the best coils, however, produce considerable inverse when heavy primary currents are used.

The *interrupter* for the primary current may be one of two types, the mercury interrupter, or the electrolytic interrupter. The trembler type used on small therapeutic faradic coils is quite unsuitable for heavy work, as the platinum contacts exposed to the air would be rapidly burnt away. The interruptions

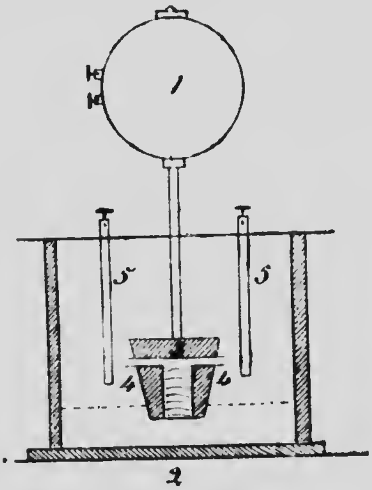


FIG. 14.—MERCURY JET INTERRUPTER.

1, Motor; 2, container; 3, hollow cone rotated by motor; 4, 4, jets; 5, 5, contact, connected to primary circuit.

produced by this appliance are, moreover, far too irregular for X-ray purposes.

The mercury interrupter is generally used for therapeutic applications. Many varieties of this interrupter are made, but the best are those fashioned on the mercury jet principle. This is diagrammatically shown in Fig. 14.

(1) represents a small motor mounted upon a container (2), which is shown in vertical section. This container is partially filled with mercury, the

upper level of which is indicated by the dotted line. The shaft of the motor passes through the top of the container, and is attached to a hollow cone (3), the blunt apex of which is immersed in the mercury. The cavity in the cone is T-shaped. The vertical limb of the T opens at the apex of the cone, and has a spiral ridge passing up round its walls. The horizontal limb of the T opens at the sides of the cone in two small orifices or jets (4, 4).

Two (sometimes four) platinum contacts (5, 5) are arranged at opposite ends of a diameter of the container. They do not reach to the level of the mercury. Their upper ends are connected to binding screws on the top of the container.

The primary circuit is divided, and the cut ends attached to the binding screws connected with the platinum contacts (5, 5).

If the motor (1) is started, the cone is rapidly revolved, mercury is forced up the inside of the cone by the action of the spiral ridge, and thrown out of the two jets by centrifugal action. When, in course of revolution, these two streams of mercury come into contact with 5, 5, the primary circuit is made, the current passing from one contact across the mercury to the other contact. When the two streams pass on, and cease to impinge on 5, 5, the circuit is broken.

To prevent arcing and rapid burning of the contacts at the moment the circuit is broken, the container has to be filled above the mercury with a dielectric, such as coal gas or the vapour of ether. Two taps are fixed in the upper part of the container for this purpose. If coal gas is the dielectric used (it is generally the most convenient) one tap is connected to the gas supply by a rubber tube, and opened. The other tap is then also opened, and a light applied and allowed to burn until the flame is pure white, indicating that no air is remaining in the container. The outlet tap is then closed. If ether vapour is used, a small quantity is inserted through one tap, and the motor run for a few moments with the tap open. The ether quickly vapourizes, and drives out all air. The tap is then closed.

If air is not completely expelled an explosive mixture of air and gas (or ether vapour) is left in the container. This will be ignited by arcing at the break of the primary circuit, and a small explosion will take place. A safety valve is provided to eliminate the possibility of damage from this source.

Whenever a mercury interrupter is used, a condenser forms an essential accessory. The two sides of this are connected to the primary circuit, one on either side of the interrupter. The condenser is an additional safeguard against arcing at the break of the current, and thus protects the contacts from burning, and also renders the break much more sudden and complete.

The motor driving the interrupter is regulated by a small rheostat, and the number of interruptions per second can in this way be varied at will. The most efficient rate of interruption will vary with individual units, and usually is about 50 to 60 per second. It may be as low as 30, or as high as 100.

The electrolytic interrupter is based upon quite a different principle. The most common type in use in this country is the Wehnelt interrupter. This consists of a glass jar nearly filled with a solution of sulphuric acid one part, water six parts. A large lead electrode, to which is connected the negative pole of the primary circuit, is immersed in this electrolyte. The positive pole is connected to a small platinum point, varying in diameter from 1 mm. to 3 mm. This projects from the apex of a cone-shaped porcelain sheath, the connection being made down the hollow centre of the sheath. The lower part of the sheath, with its platinum point, is immersed in the electrolyte.

When the primary circuit is closed the current flows from the platinum point to the lead electrode. Intense heat due to frictional resistance is generated in the path of the current where it is concentrated around the small point, with the result that the electrolyte surrounding the point boils, and is also converted into incandescent gas. The steam and gases thus produced form a layer around the platinum point, and break the continuity of the circuit. Immediately the circuit is broken the gases and steam resolve into their former liquid state, and the current flows again until the cycle of events is repeated. In this way a very rapid series of interruptions is produced. A screw device is attached to the positive electrode by means of which the depth of platinum point exposed to the electrolyte can be varied, and greater or lesser currents thus passed through the interrupter.

If the negative terminal is connected to the platinum electrode the interruptions are irregular, and the platinum is much more rapidly worn away.

Another type of electrolytic interrupter is the Caldwell, which consists of two large lead electrodes immersed in an electrolyte of Rochelle salt. They are nearly separated by a partition of porcelain, the only communication being a small hole in the partition. Hence, when the primary circuit is closed, concentration of current occurs at this hole, with resulting boiling, etc., of the electrolyte and interruption of the current.

Electrolytic interrupters are noisy, and give off unpleasant fumes. They should therefore be enclosed in a cabinet, and if possible placed in a separate room away from the remainder of the apparatus. Another disadvantage from the therapeutic point of view is the extreme rapidity of the interruptions, which cause undue heating and wear of the X-ray tube. The mercury interrupter is the appliance of choice for therapeutic work.

Rectification of the high-tension current to render it unidirectional is the next point to consider. Only with very small currents obtained from the best coils is the inverse, or "make," current sufficiently small to enable the outfit to be used without some form of rectifier. As modern methods of X-ray therapy frequently demand the use of heavy currents, some form of rectifier is an essential part of the treatment unit.

Rectification can be obtained in one of several ways. The most common method is to use valve-tubes. These are vacuum tubes whose exhaustion has not been carried very far. They usually back up a 1-inch or 2-inch spark-gap, so that the added resistance they impose in the circuit is not great.

The valve tube has two metal electrodes, the terminals of which pass through the walls of the tube, where they are sealed off.

One electrode is generally in the form of a point, or a small round plate, while the other is of large size, and generally forms a spiral of thick wire. It is found that the current readily passes through the tube when the spiral is connected to the negative pole of the coil and the point to the positive, but that great resistance is imposed to the passage of current if these connections are reversed. Hence, if one or more of these valves be inserted in the circuit with proper regard to polarity, the heavy break current will pass through with little difficulty, while the much smaller "make" current (or inverse current) will be suppressed.

The valves are connected in series if one is found inadequate to suppress the inverse current, and may be connected to either pole of the coil, or to both, as may be found more satisfactory.

According to the commonly accepted theory of the passage of current through a vacuum tube, the action of the valves is as follows: When the large spiral electrode forms the cathode, an extensive surface is afforded for the generation of electrons (or negatively charged particles), and a sufficient number of these will reach the anode to carry the current readily through the tube. When the small point or plate forms the cathode at the "make" impulse, a very small surface is offered for the emission of electrons, and the passage of the current is correspondingly obstructed.

Sir Oliver Lodge, however, thinks that the electrons (which, of course, constitute the cathode stream) only play a minor part in conducting the current through a vacuum tube, and that concentration of electrons may impede the passage of current by collision with the positive ions, which, according to this theory, pass from anode to cathode along the path of least resistance, and form the chief means for conveying the current through the tube.

Most valve-tubes are provided with regulators similar to those on an X-ray tube, by means of which the vacuum can be lowered when necessary. The regulator wires should be kept 1 to 2 inches from the terminals of the tube, so that automatic lowering of the tube takes place when the vacuum rises. Valve-tubes must never be used "hard," as in this condition they impose great resistance in the circuit.

Instead of valve-tubes, a *spintermeter* or small spark-gap may be placed in the secondary circuit, and is fairly efficient in eliminating inverse current for the lighter forms of work. The gap is usually adjusted to ¼ inch or ½ inch. One terminal is made in the form of a point, the other of a small round plate. The current will pass across the gap much more readily when the point forms the positive electrode.

A third, and probably the best means of eliminating inverse current, is to have some form of mechanical rectifier in the secondary circuit. This necessitates the use of a mercury interrupter.

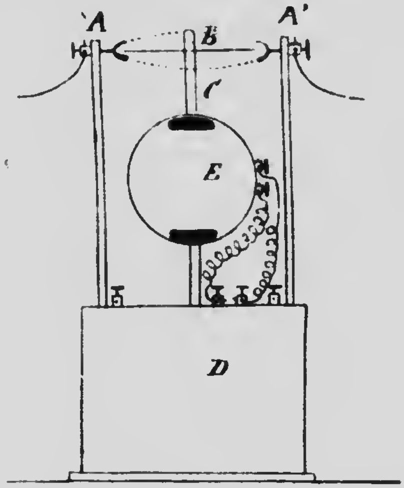


FIG. 15. MECHANICAL RECTIFIER.

A, *A'*, Terminals for secondary circuit; *C*, prolongation up of shaft of motor *E*; *B*, metal rod attached to *C*; *D* container of mercury interrupter.

A simple type of mechanical rectifier is shown in Fig. 15. The secondary circuit flows from terminal *A* to *A'*, when rod *B* is rotated to lie opposite these two terminals. This takes place when the primary current is broken by the interrupter. When the primary current is made the ends of the rod *B* lie some distance from *A*, *A'*, and so no current passes through the secondary circuit. This apparatus, once it is correctly set, cannot get out of tune. Many modifications are made with a view to increase of efficiency.

The detection of inverse current in the secondary circuit is rendered easy by the use of a small appliance called an *oscilloscope.* This consists of a small vacuum tube, into which are led two terminals. Inside the tube these consist of rods of aluminium, the ends of which are separated from each other by a very small interval. This tube is placed in the secondary circuit. The negative aluminium rod lights up with a violet fluorescence. Inverse current is indicated by the presence of violet fluorescence in the other rod. If there is as much inverse as direct current in the circuit both rods will fluoresce in their whole length. If very little inverse exists, one rod will fluoresce in its whole length, the other only in its terminal ¼ inch or so.

If this apparatus is not available, any considerable amount of inverse current is recognizable by inspecting the X-ray tube while the current is passing. The inverse current shows itself by irregular bands of light running transversely round the tube. The regular division into a light hemisphere in front of the surface of the anti-cathode, and a dark hemisphere behind that surface, is lost.

The High-Tension Transformer forms an alternative to the coil unit. It consists of a static transformer, the primary of which is supplied by an alternating current at the voltage of the electric light mains. This is transformed to a voltage suitable for activating an X-ray tube (*i.e.*, 100,000 to 250,000 volts). This high-tension current is of course alternating, and has to be rendered unidirectional by means of a high-tension commutator.

The apparatus is supplied to work off D.C. or A.C. mains. In the former case, however, a motor generator is added to the outfit. This is driven by the direct current of the mains, and generates an alternating current which is supplied to the primary of the transformer. If the main current is alternating the transformer is of course supplied direct.

Although a D.C. main supply thus adds to the expense and bulk (and also noisiness) of the outfit, there is, on the other hand, the great advantage

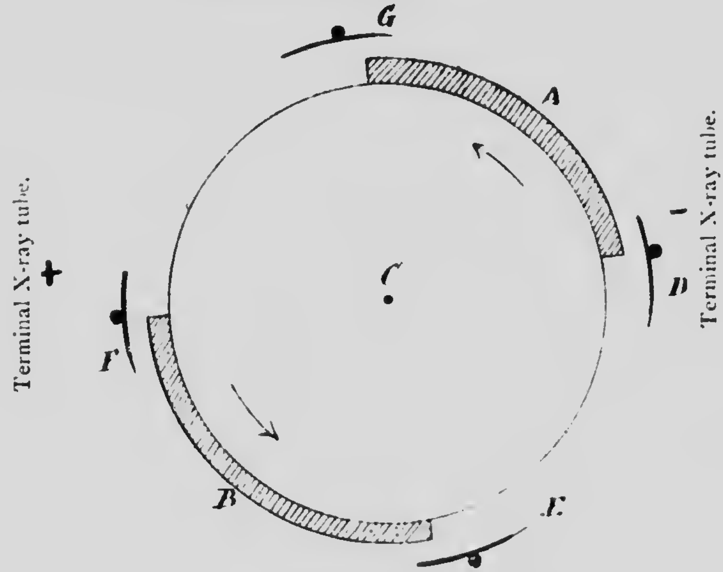


FIG. 16.—HIGH-TENSION COMMUNICATOR.

that with this outfit the high-tension commutator is mounted on the same shaft as the generator, and therefore cannot get out of tune; when the main supply is A.C. the commutator is driven by a small A.C. synchronous motor, and has to be carefully adjusted to remain in tune with the alternations.

The high-tension commutator is represented in Fig. 16. C is an insulated fibre disc, rotated by the motor-generator (D.C. supply) or a separate synchronous motor (A.C. supply). Projecting from its circumference are two metal strips *A* and *B*. At equidistant points around the disc are set four strips of metal, *D*, *E*, *F*, *G*, so that a very small space intervenes between them and the metal strips on the disc. *G* and *E* are connected to the two high-tension terminals of the transformer, and are therefore supplied with high-tension alternating current. *F* is connected with the positive pole of the X-ray tube, and *D* with the negative.

The commutator is timed so that when *A* is opposite *G* and *D*, *G* is in its negative phase. At the same time, *B* is opposite *E* and *F*, and *E* is in its positive phase. By means of sparking across the small air-gaps positive electricity flows from *E* along *B* to *F*, and negative from *G* along *A* to *D*, and the circuit is completed through the tube. The disc then revolves, so as to bring *A* opposite *G* and *F*, and *B* opposite *E* and *D*. By that time, however, *G* is in its positive phase, and *E* in its negative, and so a unidirectional current is supplied to the X-ray tube.

The chief differences between the high-tension current of the coil unit and that of the transformer unit are:

1. The current from the transformer is absolutely unidirectional. That from the coil unit, even under the best conditions, tends to show a little inverse.

2. The current from the transformer is much more nearly continuous than that from the coil.

So far as the first of these differences goes the transformer shows to advantage over the coil. In the case of the second difference the advantage lies with the coil—at any rate, for therapeutic work with ordinary gas tubes.

These tubes stand up to their work very much better if supplied with a current having considerable intermissions, such as that from a coil.

A current with short intermissions causes rapid overheating of the tube, with consequent lowering of vacuum, and the emission of soft rays.

Other more or less serious disadvantages of the transformer unit are its initial costliness, and the noise it makes all the time it is running, especially in the form for use off D.C. mains.

If the transformer is used it is well to have a mechanical interrupter in the primary circuit, which can be timed to interrupt the current every one, two, or three seconds as desired, the period of cessation of flow being variable, generally one second at each interruption.

Considering all things, the coil unit is probably preferable for therapeutic work.

Modifications of X-ray Tubes for Therapeutic Use.—The Coolidge tube will be separately considered later in the chapter. The modifications in the ordinary gas tube which are here discussed have all been introduced with the object of rendering the tube capable of supporting a fairly heavy current for some time without undergoing changes of vacuum. Modern methods demand a tube by which large doses of rays possessing a high degree of penetration can be administered. A tube which has been properly constructed and exhausted can become very hot without giving off much gas, and thus lowering the vacuum. There are limits, however, to the capacity of even the best tubes under these circumstances, and efforts have therefore been made to keep the temperature of the tube at a reasonable level.

The simplest modification is that known as the heavy anode type of tube. Here the target is made of tungsten, and this is set in a very massive block of copper which forms a large mass for the absorption of heat. This tube, when seasoned, will stand up well to moderate currents if the exposure is not too prolonged.

More important modifications are those tubes which are equipped with some more elaborate means of preventing overheating. Perhaps the best of these is the water-cooled tube. In this tube the anti-cathode consists of a hollow cylinder, to the outer end of which, outside the tube itself, is attached a hollow glass bulb. The lower end of the cylinder is closed by a sheet of platinum, which forms the target of the anti-cathode. The glass bulb is fitted with a screw stopper, perforated by a small tube. In use the bulb and hollow anti-cathode are nearly filled with water, a sufficient air-space being left in the bulb to assure that the inner end of the small tube is above the upper level of the liquid. This tube affords egress for steam when the water boils. These tubes stand up to a heavy current for a long time without alteration in vacuum. If the water boils vigorously, and the tube shows signs of softening, the current should be switched off, the water from the bulb emptied into a jug, and sufficient cold water added to render the mixture appreciably warm to the touch. The bulb is then filled again with the lukewarm water.

Another method where much heavy work is being done is to arrange a circulation of water through the bulb. For this purpose a second tube must be let in through the stopper. The two tubes are then connected by means of rubber tubing to two containers. One of these is filled with cold water, and fixed on a support at a slightly higher level than the X-ray tube; the other, empty, stands at a lower level. By means of a clip the passage of water from the upper container through the bulb to the lower container can be regulated.

Water-cooled tubes are made in two patterns, one for use above the patient only, the other for use in any position. The former has the anti-cathode set obliquely to the long axis of the tube, in the position usually occupied by the accessory anode. In the latter the anti-cathode occupies its usual position, and the small tube for escape of steam is semi-circular and movable, so that it can be twisted to have its end above the level of the water whatever the position of the tube may be.

These water-cooled tubes are exceedingly good. Only one word of warning is necessary: never run the tube, even for a few seconds, without water in the container. The anti-cathode is very thin, to allow of rapid absorption of heat by the water, and the tube may be ruined if worked when the container is empty. As, however, there is no need to empty the container from day to day, this accident is not very likely to occur.

Another tube designed especially for therapy is the radiator tube. Here a radiator of metal, connected with the metal of the anti-cathode, projects outside the wall of the tube. It can be played upon by an atomizer.

Management of X-ray Tubes.—To obtain the best service from a tube a certain degree of skill and care in handling is required. No tube when first obtained from the makers is at its state of maximum efficiency. Its vacuum is liable to sudden variations, and there is a tendency to rapid softening on the passage of a moderate current for any length of time. The tube requires "seasoning," and this is attained by using it at first for light work, when only small currents are required, and avoiding any unnecessary lowering of the vacuum by means of the regulator. It will be found that the tube soon gains in steadiness, and when it is quite steady for light work it can be tried with heavier currents. If at any period of its career a tube is overheated and suffers a serious fall of vacuum, it should be put aside for a fortnight, or preferably longer, and will probably then be found to have completely recovered. It will, however, require careful usage, approximating to reseasoning, before it can be considered thoroughly reliable.

A new tube subjected at its first trial to a prolonged heavy current may suffer such a fall in vacuum that no recovery takes place even after a prolonged rest, and nothing short of re-exhaustion will render it serviceable once more. Great strides have been made during the past few years in the manufacture of X-ray tubes, and much less care is now necessary than was formerly the case; but careful study of the behaviour of each individual tube is always well repaid by improved efficiency and diminished expenditure.

The Coolidge Tube.—This tube forms probably the greatest advance in X-ray apparatus that has been made since the X-ray was itself discovered.

The tube is made of much thicker glass than the ordinary gas tube, and is exhausted to a very much higher degree of vacuum by a special process. For practical purposes the vacuum may be considered a complete one (about $\frac{1}{1000000000}$ of an atmosphere). The anti-cathode is made of a solid block of tungsten, mounted upon a molybdenum stem. The cathode is set very close to the anti-cathode, and consists of a coil of tungsten wire wound in a slightly concave spiral (to take the place of the concave cathode of the gas tube). The terminals from the two ends of this spiral are led through the wall of the tube. They are connected with the terminals of a 12-volt set of accumulators, which are placed on an insulated stand, and one of them is also connected with the negative high potential terminal of the coil or transformer. The accumulator circuit is provided with a switch, a regulating rheostat, and an amperemeter.

If the tube is connected to the terminals of the high-tension circuit, and the current is switched on, the vacuum of the tube is so high that no current will pass, and no X-rays be generated. If, however, the accumulator circuit is made, the tungsten filament forming the cathode is lighted up like the filament of a lamp, and when thus heated will, under the influence of the high-tension circuit, provide a multitude of electrons to form the cathode stream.

This is focused upon the anti-cathode owing to the concave form of the tungsten filament, and X-rays are generated.

The vacuum of this tube never varies. The *penetration*, or *hardness*, of the rays generated varies directly with the potential of the high-tension circuit, and is therefore controlled primarily by the rheostat of the coil or transformer unit. The *quantity* of X-rays, or the *milliamperage* flowing through the tube varies directly with the heat of the tungsten filament, and is therefore controlled primarily by the rheostat in the accumulator circuit.

It must be remembered, however, that increased heat of the filament, by facilitating the passage of the current, will result in an immediate fall in potential in the high-tension circuit, with the production of correspondingly softer rays.

To increase the milliamperage passing through the tube without lowering the penetration of the rays, the voltage of the high-tension circuit must be maintained by readjustment of the rheostat or the power-unit, after increasing the filament current from the accumulators. In other words, the two controls must always be used in conjunction, any alteration in one necessitating a corresponding alteration in the other if the penetration of the rays is to remain unaltered by the change.

The advantages of the Coolidge tube are:

1. That it can be used continuously for an indefinite period, even with heavy currents, without any alteration in vacuum (and therefore of penetration).

2. That it can be adjusted to produce rays of any desired quantity and quality at will.

3. That similar adjustments will always result in precisely the same quality and quantity of rays being produced.

4. That rays of very great penetration can be utilized.

The disadvantages of the Coolidge tube, as far as therapeutic purposes go, are confined to increased initial cost and the extra complication of working. The former drawback is offset by the fact that a Coolidge tube carefully used will have a useful life of much greater duration than that of any gas tube. The increase in complication is of very slight moment once the principle of the tube is thoroughly grasped.

The heating circuit for the filament may be provided by other means than accumulators. An outfit for this purpose which is gaining rapidly in popularity consists of a small motor generator run off the mains and generating an alternating current which is stepped down by a static transformer to the necessary potential of 12 volts. It is immaterial whether the heating current is direct or alternating.

It must be remembered that the entire unit for heating the filament is raised to the potential of the high tension circuit when this is switched on. Hence the heating unit must be carefully insulated to prevent leakage of the high-tension current to earth.

Estimation of Quality of X-Rays.—It is most essential that the quality or penetration of the X-rays which are being produced should be constantly known to the operator. Various instruments are made for this purpose, and it is advisable that thorough acquaintance should be established with one of these, and reference made to it whenever necessary.

The Parallel Spark-Gap, and Bauer's Qualimeter. – These two methods of estimation may be considered together, since their value depends on the same physical law. It may be stated as a preliminary, however, that the parallel spark-gap is only a rough guide to penetration, while the qualimeter is very accurate.

The physical law upon which both these appliances depend is this: that the penetration of the rays produced by any tube is directly proportional to the voltage of the high-tension circuit activating that tube; and to understand this law it must be borne in mind that any variation in the resistance offered by the tube produces an immediate corresponding alteration in the voltage of the high-tension circuit.

The spark-gap consists of two metal rods mounted on suitably insulated pillars. One, for connection to the positive pole, ends in a sharp point. The other, for connection to the negative pole, has at its end a round plate. One of the rods is made to slide through its mounting, and the distance which separates the point from the plate in any position of the movable rod is indicated on a scale.

This spark-gap is connected to the high-tension circuit in parallel with the tube, and the maximum separation of the electrodes at which sparking will occur gives the "equivalent spark-gap" of the tube.

The *Bauer Qualimeter* is a unipolar appliance, which is suspended by its one terminal from the negative high-tension cable. No metallic object should be within 12 inches of the qualimeter. This meter is constructed on the principle of the gold-leaf electroscope. The high-tension current charges the electroscope, and causes the leaves to diverge, the degree of divergence varying with the potential of the

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charging circuit. This divergence is communicated to a needle, causing it to move along a scale on the outside of the meter. The scale is calibrated in numbers, 1 to 10.

The great advantage of the qualimeter lies in the fact that the penetration of the rays can be seen at a glance and from a distance at any time while the tube is running.

The Radiometer.—The other means of estimation of penetration is the employment of some form of radiometer. This depends on direct observation of the fluorescence produced by the rays after passing through substances of varying opacity.

The disadvantages of the radiometer compared to the qualimeter are:

1. Exposure of the operator to the rays.
2. The fact that the radiometer cannot be conveniently used without interrupting the treatment of the patient.

Several types of radiometer are obtainable. Those most commonly used must be briefly described here.

Benoist's Radiometer.—This consists of a central disc of silver foil, surrounded by ten pieces of aluminium of varying thickness, and numbered 1 to 10. The whole is covered with a small fluorescent screen, protected with lead glass. If now the room is darkened, and the radiometer is placed in the path of the rays, it will be seen that the fluorescent screen is unevenly illuminated. Even illumination occurs over the central silver foil, but varying illumination over each thickness of aluminium. The operator must determine over which thickness of aluminium the illumination is equal to that over the silver foil. Suppose that the thickness of aluminium marked " 7 " corresponds to the silver foil as regards illumination, then the rays which are being produced are said to be of penetration No. 7 Benoist.

The Walter Radiometer.—This consists of a sheet of lead in which are cut eight circular holes, which are filled in by platinum foil, varying in thickness from 0·005 mm. for the first hole to 0·64 mm. for the eighth.

The radiometer is placed in the path of the rays, and a small fluorescent screen is placed over each hole in turn. The hole with the greatest thickness of platinum which is visible on the screen gives the penetration of the rays—*e.g.*, if holes numbered 1 to 6 inclusive are visible, but No. 7 is invisible, the rays are stated to have a penetration of 6 Walter.

Wehnelt's Crypto-Radiometer possesses a means of finer adjustment and differentiation than the preceding instruments. It consists of an iron base, in the centre of which is a slit about 1 inch long and ¼ inch wide. In front of the slit is a small fluorescent screen. The lower half of the slit, behind the screen, is closed by a strip of silver foil; the upper half by some portion of a long wedge-shaped strip of aluminium. This wedge is controlled by a thumb-screw placed on the iron base, and is attached to a graduated scale which moves with it. The instrument is placed in the path of the rays, and the illumination of the screen over the slit is observed. The illumination will probably be found of different intensity in the two halves (the rays passing through silver in one half, aluminium in the other). The aluminium wedge is then moved backwards or forwards by means of the thumb-screw until the two halves of the screen are evenly illuminated. The reading on the scale for that position of the wedge gives the penetration of the rays. The Wehnelt scale is graduated 1 to 15.

Silver is used in the Benoist and Wehnelt instruments as a standard because its penetrability is little affected by the degree of penetration of the rays —soft rays pass through it almost as readily as hard.

COMPARATIVE TABLE OF THE QUALIMETER AND DIFFERENT RADIOMETERS.

	Soft.				Medium.					Hard.
Bauer's qualimeter ..	1	2	3	4	5	6	7	8	9	10
Benoist's radiometer	1	2	3	4	5	6	7	8	9	10
Wehnelt's radiometer	1·5	3	4·5	6	7·5	9	10·5	12	13·5	15
Walter's radiometer	1	1-2	2-3	3-4	4-5	5-6	6-7	7-8		

It will be noticed that Bauer's and Benoist's scales correspond. These graduations represent the absorption of the rays by lead foil varying in thickness from $\frac{1}{10}$ mm. to 1 mm. For example, rays of No. 1 Benoist or Bauer penetration are totally absorbed by $\frac{1}{10}$ mm. lead foil. Rays of No. 8 Benoist or Bauer penetration are totally absorbed by $\frac{8}{10}$ mm. lead foil, but not by $\frac{7}{10}$ mm.

Action of X Rays upon the Tissues.—The effect of X-radiation upon normal and abnormal tissues of the body is still a subject of considerable controversy as far as details are concerned. It can only be briefly outlined here.

The result of a moderate dose of X-rays upon normal tissues is the production of changes identical with a mild inflammatory reaction produced by any aseptic agent. This reaction involves all tissues radiated, gradually becoming less marked as the depth of the tissue from the surface increases. The relative effect of depth is much more marked when soft rays have been used than if the rays have been of the hard variety. If the rays are very soft the inflammatory changes are largely confined to the skin, and are much more intense in this tissue than is the case if a similar dose of hard rays be administered.

The inflammation induced by a single moderate dose of X-rays to normal tissues undergoes complete revolution, leaving the tissues unaltered in structure.

If a larger dose be given, the inflammatory exudation is correspondingly increased. There are, in addition, degenerative changes. The squamous cells of the skin swell up and lose their nuclei. The same change occurs in the sweat glands and hair follicles, and the hairs may be shed. In muscle fibres some loss of striation will occur, and there may be slight endothelial proliferation in the small bloodvessels.

These changes will be temporary only provided the dose has not been very large, the only permanent structural alteration being a certain amount of organization into fibrous tissue of the inflammatory exudation.

If a very big dose be given permanent destructive changes take place. Hair follicles and sweat glands will be irretrievably destroyed; there may be necrosis of the entire skin and of deeper structures, and the damage is repaired eventually by the formation of fibrous connective tissue, over which the skin may grow, but without any regeneration of specialized tissues.

When abnormal tissues are under consideration the subject becomes far more complex, and it is difficult to explain the changes which take place in terms of inflammatory reaction.

Certain tumour cells show inability to withstand radiation. Thus the cells of a carcinoma or sarcoma may undergo rapid necrosis as the result of a dose which has but little effect upon the surrounding healthy tissues. At other times, an apparently similar growth is stimulated to increased activity and cell proliferation by radiation. Some observers have claimed a selective action for X-rays upon certain tumour cells; but it appears possible that the reaction of any cell to radiation depends upon its vitality, apart from the actual nature of the cell. Looked at from this point of view, certain tumour cells may be considered to be of low vitality as compared to the surrounding tissues.

Generally speaking, the vitality of a cell, as shown by its reaction to X-radiation, is progressively less as the cell approaches more nearly to embryonic type. If the dose of X-rays administered be too small, however, many of these tumour cells are actually stimulated to increased activity, and their vitality appears to be enhanced.

The abnormal elements of the blood in the various leukæmias show marked susceptibility to radiation —unfortunately, however, not always with a beneficial result to the organism as a whole.

In the present state of our knowledge it is best to consider that X-rays produce their effects upon the tissues in virtue of the inflammatory reaction which they produce; that they have no selective action upon abnormal tissue-cells; and that when these cells succumb readily to radiation it is on account of their deficient vital activity.

Further research may alter these views.

Estimation of Dosage.—It will be obvious from the foregoing brief account that great care is necessary in administering X-radiations. Too small a dose may make matters worse than before, while a too large one will lead to damage to the healthy tissues. Various methods of measuring dosage have been elaborated; they fall into two classes:

1. The Direct Method.
2. The Indirect Method.

The largest single dose of X-rays which can safely be given is one which will produce a slight transient erythema of the skin. A full dose, therefore, is one which produces this effect, and it is necessary to measure this dose accurately, and also any fraction of a full dose where less vigorous application is desired.

Direct Methods of Estimating Dosage.—These depend on actual measurement of the quantity of X-rays during the application. The quantity is indicated by colour changes in various substances when acted upon by the rays, and comparison of these changes with a standard.

The Sabouraud Pastille.—This consists of a small pastille coated with barium-platino-cyanide. The original colour of the pastille is yellow; it turns brown on exposure to X-rays, getting gradually darker as the length of exposure is increased. In practice, the pastille is placed at half the distance between the anti-cathode of the tube and the skin of the patient. It must rest upon a lead backing, be shielded from strong light, and be at least 1 inch from the wall of the tube, to eliminate the action of heat. Two standard tints are supplied with each book of pastilles. Tint A is the colour of a pastille before exposure; tint B is the colour of the pastille after exposure to the maximum dose which can be administered to the skin without the development of an erythema. This is commonly called a "full pastille dose."

The comparison of the pastille with the standard tint B must be made by the light of a carbon-filament electric lamp—never by daylight. The pastille must be compared several times during the exposure, at increasingly shorter intervals as the full dose is approached, to avoid exceeding the margin of safety.

No intermediate tints are provided with the book of pastilles, but fractions of a pastille dose can be estimated by the use of an appliance such as Lovibond's tintometer. This consists of a number of standard tints representing fractions of a pastille dose, varying from tint A to tint 2 B, the latter being twice the full dose.

The higher grades are useful when the same pastille is used more than once. Exposure to daylight restores the colour of the pastille to a considerable extent, but never completely to tint A. Supposing it is restored to tint $\frac{1}{3}$ B, then if a full pastille dose is to be given the pastille must be turned to tint $1\frac{1}{3}$ B, or nearly so. As the darker tints are difficult to differentiate accurately, it is best not to use the same pastille more than three or four times.

It must be remembered that if a filter is used for the rays (see below) this filter must be placed between the tube and the pastille, otherwise a totally erroneous estimate of the dose administered to the skin will be made.

The Sabouraud pastille provides a very reliable means of measuring dosage, and is widely used in this country.

The Holzknect Quantimeter.—This also consists of pastilles coated with barium-platino-cyanide. The standard tints are, however, provided by unexposed pastilles covered by a strip of celluloid film, gradually increasing in intensity of colour. The exposed pastille is matched against these, and the fraction of a dose is given by the pastille of similar shade. An erythema dose is known as 5H, one-fifth of an erythema dose as 1H, and so on.

The Kienböck Quantimeter.—In this method strips of paper, coated with silver bromide and enclosed in light-tight envelopes, are exposed to the rays during treatment. They are placed actually in contact with the skin, and it is advisable to start the exposure with at least two strips on the skin.

The paper has to be developed and fixed before comparison with a standard scale of tints, which is graduated 0 to 10. Tint No. 1 is known as 1X, and so on. Tint No. 10 corresponds to the colour assumed by the developed strip after exposure to an erythema dose. Thus, comparing these three methods of estimation we have:

1B – 5H – 10X – an erythema dose.

The disadvantages of the Kienböck system lie in the fact that the strip has to be developed and fixed before comparison with the standard; hence the necessity of exposing more than one strip, so that one can be developed and compared when it is judged that exposure is nearly complete, and the other left on the skin for development after further radiation. It is obvious also that considerable difficulty may be experienced in gauging the correct time at which to develop the strip. It has been suggested that the method should be controlled by means of a Sabouraud pastille, but if this is done there is obviously no necessity to use the Keinböck paper.

Where a number of small doses are to be given, however, the method is of value, as the same strip may be used for all, and the total dose administered measured at the conclusion of the séance.

Development is carried out by means of a stand holding four test-tubes. The first tube contains developer, the second water, the third fixer, and the fourth water. Development may be performed in the dark-room or in a light-tight box. It is essential that scrupulous cleanliness be observed in making up and keeping the developer and fixer. The developer should not be used when stale.

The exposed strip is immersed in the first tube for one minute, transferred to the second for a few seconds, then immersed in the third for one minute, and finally washed in the fourth. The strip can be compared with the standard tints while still wet.

Indirect Method of Measuring Dosage. When the operator has become thoroughly familiar with his apparatus and with the particular tube which he is using for therapy, it is possible to estimate the dose of X-ray administered within fairly narrow limits by observation of the milliamperage passing through the tube, the penetration of the rays, and the time of exposure. A most important factor is also the distance from the anti-cathode to the skin, since the intensity of X-rays, like light, varies in inverse proportion to the square of the distance. When using filtered rays (see below) this indirect method of estimation has largely superseded the direct methods in routine treatment. With unfiltered rays, unless very small doses are to be given, one of the direct methods should invariably be employed, otherwise grave risk is run of burning the patient. Even with the greatest skill and care accidents will occasionally occur when using unfiltered rays, possibly owing to an individual idiosyncrasy of the patient. X-ray burns in modern practice should be limited to this category, and should never be attributable to negligence on the part of the operator.

Primary and Secondary Rays. The primary rays emanating from a tube are those produced at the anti-cathode by the bombardment of the cathode stream. These rays cannot be reflected, but wherever any solid body is impinged upon a fresh set of radiations is started from the surface of the body. These are known as secondary rays. Their existence is easily demonstrated by exposing a photographic plate to the X-rays, the glass being turned towards the rays, and strips of zinc, iron, lead, and aluminium being placed in contact with the film inside the light-tight envelope. After a short exposure the plate is developed in the ordinary way, and will then be found to show various gradations of darkness. The lightest part of the plate will be that with which there has been no metallic contact. The part which has been in contact with the aluminium will be slightly darker, while the parts corresponding to the iron, lead, and zinc will show considerable increase in darkness. This is not due to reflection of the rays, but to secondary rays generated by the impact of the primary rays upon the metals. It also demonstrates that the secondary rays produced by aluminium are very few compared to those produced by the other metals mentioned.

The secondary rays which are produced from any metal are of two varieties:

1. Heterogeneous. These are of the same wave-lengths as the rays of the primary beam.

2. Homogeneous. The wave-length of these varies with the metal in question, and is a constant for that metal.

The Use of Filters.—The primary rays emanating from any X-ray tube are heterogeneous—that is, the beam is made up of rays of many different wave-lengths.

The predominating wave-length gives the characteristic quality of the radiation.

The action of X-rays upon the skin is largely due to the soft rays which are absorbed by that tissue, and as the quantity of radiation given to any part is limited by the maximum dose which may be given without damage to the overlying skin, it is obvious that some means of eliminating the soft rays is desirable in treating any tissue deeper than the skin itself.

For this purpose various substances are interposed in the path of the rays to absorb the soft radiations, and so prevent them reaching the patient.

The filters in common use are aluminium, boiler felt, tanned leather, chamois leather, and compressed paper.

Aluminium, in thickness of ½ mm. to 6 mm., is probably the best of all filters. It not only absorbs the soft rays, but actually increases the hardness of the rays which penetrate it.

As aluminium itself gives off secondary rays it should be placed at some distance from the skin, and three or four layers of boiler felt be placed between it and the skin.

With a thick filter (3 mm. of aluminium is sufficient for ordinary purposes) heavy doses can be given repeatedly to the same area without any skin reaction beyond the development of a gradual bronzing, and large doses of X-rays can thus be administered, by means of hard tubes, to the deeper tissues.

Filters should always be used in X ray therapy except in a few cases where the action is required upon the skin alone, and even in these instances a filter of ½ mm. or 1 mm. of aluminium is probably an advantage.

Use of Hard Tubes.—The great advance which has been made in recent years in the treatment of deep structures by X-rays has been largely due to the manufacture of tubes having a high degree of penetration, and capable of maintaining that penetration for considerable periods while in use. It is unquestionable that much better results are obtained with hard than with medium or soft tubes, and it is a fairly safe rule always to employ as hard a tube as possible except in the treatment of cutaneous lesions. Here a medium penetration is best—*e.g.*, 4 to 5 Benoist. Very soft tubes should never be used for therapeutic purposes.

Distance of Anti-cathode from Skin.—This is a matter of great importance. It must be remembered that the intensity of X-rays varies inversely with the square of the distance, and that the duration of exposure to give any particular dose is much increased by lengthening the distance between the patient and the tube. On the other hand, soft rays are absorbed by the air in greater proportion than hard rays, and increasing the distance of the tube therefore has the effect of causing a larger proportion of the rays which reach the skin to be of the hard variety. With modern therapeutic tubes, which will maintain their vacuum unchanged for long periods, this latter advantage outweighs the disadvantage of increased time of exposure. Ten centimetres from the anti-cathode to the skin will be found a good distance to work at. It should be measured—never guessed. If repeated exposures over the same area are given, it will be an advantage to increase the distance as the series progresses.

Repeated Doses of X-Rays.—Determination of the limit of safety in giving repeated doses of X-rays to the same skin area requires, above all things, experience on the part of the operator. Certain rules can, however, be laid down as a guidance.

The first fact to recognize is that X-rays have a cumulative effect upon the skin if given in several doses at short intervals. For example, if one-sixth of a full pastille dose be given unfiltered to the same area of skin every day for six days, the reaction will be practically the same as if a full pastille dose were given at one sitting. This cumulative effect applies equally to filtered rays; but, as will be explained later, more latitude is permissible under these circumstances.

This cumulative effect must never be lost sight of. By increasing the intervals between doses the cumulative effect is lessened, and finally to some extent (but probably not entirely) eliminated.

For unfiltered rays, the time which must elapse after a full pastille dose before further radiation is contemplated is four weeks. If the second dose is to be given through a moderately thick aluminium filter, two weeks is sufficient.

If, as is generally the case, no unfiltered rays are given, and very hard tubes only are used, the frequency of treatment can be greatly increased. A pastille dose given through a filter of 3 mm. aluminium and four layers of boiler felt will produce no skin reaction whatever; and if repeated two or even three times a week, with gradually increasing thickness of filter, will generally result in no acute reaction, but only a gradual bronzing of the skin. If any erythema develops after several doses it will be of a subacute nature. In such cases it is best to suspend radiation for ten days or a fortnight. In the treatment of inoperable carcinoma, where the preservation of the skin is often of secondary importance, radiation need not be suspended on account of such an erythema. The usual result of continuing radiation in these cases is merely that the erythema is maintained without exacerbation. In some cases, however, actual X-ray burns have been produced by this prolonged treatment. The possibility of such an occurrence should be explained to the patient before carrying the treatment to this extreme.

The surrounding healthy skin, in this as in all instances, should be carefully protected by means of sheet-lead, or heavy lead rubber, cut to leave the necessary aperture.

In many cases it is desired to apply a very heavy dose of X-rays to deep structures, either at one séance, or at two or more séances on consecutive days, so as to obtain the maximum cumulative effect on these structures. In this case the cross-fire, or multiple ports-of-entry method is adopted.

This method consists of giving a number of heavy doses of X-rays, all directed towards the structure to be treated, but entering the body through different areas of skin. For example, in producing an artificial menopause by radiation of the ovaries, the skin of the abdomen and loins may be divided into a number of "ports of entry." Through each of these in turn the rays are directed towards the ovaries, all the other ports of entry being protected by sheet-lead. The technique adopted for treating various lesions by the cross-fire method will be more fully described below.

Indications for X-Radiation.—The following table includes the more common diseases in which X-radiation has been found beneficial. It is followed by a description of the special methods adopted in some of the more important of these diseases:

I. *Parasitic Diseases:*
  Ringworm and favus.

II. *Chronic Inflammations:*
  (*a*) Of the skin and mucous membranes—
    Eczema.
    Psoriasis.
    Syphilides.
    Lupus vulgaris.
  (*b*) Of the neuro-muscular system—
    Idiopathic neuritis.
    Neuritis due to involvement in scar-tissue.
    Myositis.
    Fibrositis.
  (*c*) Of the bones and joints—
    Tubercular arthritis and osteitis.
    Syphilis.
    Osteo-arthritis.
    Chronic rheumatic arthritis.
  (*d*) Of the lymphatic glands—
    Tubercular adenitis.
  (*e*) Scar-tissue, wherever occurring.

III. *New Growths:*

(*a*) Innocent—

Papillomata.

Uterine myomata.

(*b*) Malignant—

Primary { Carcinoma. Sarcoma. Rodent ulcer.

Secondary { Carcinoma. Sarcoma.

IV. *Miscellaneous:*

(*a*) Diseases of the blood-forming organs—

Pernicious anæmia.

Lymphadenoma.

Myelocytic leukæmia.

Lymphocytic leukæmia.

(*b*) Pruritus ani and pruritus vulvæ.

(*c*) Exophthalmic goitre.

(*d*) Hyperidrosis.

Treatment of Ringworm of the Scalp.—The technique described below is that evolved by Adamson, and is now almost universally adopted. It aims at complete epilation of the scalp. All hair, diseased and healthy alike, is shed, and the fungus thus eliminated. After a varying interval (usually about six weeks) the hair commences to grow again.

The greatest care must be taken in giving this treatment, and the precautions here set forth rigidly adhered to. Under these circumstances epilation by X-rays is probably the best treatment for ringworm. Any neglect or carelessness may result in a permanent alopecia, and even with all precautions faithfully observed a very small proportion of cases will be met with in which a partial permanent alopecia ensues. Such cases are presumably those mentioned above, in which there exists a hypersensitiveness to X-rays.

Before submitting the patient to radiation inquiry must be made into the previous treatment. If iodine, mercurials, or ointments containing any irritant have been employed, treatment must be postponed until all reaction has entirely subsided.

The day before the radiation the hair should be clipped short over the whole scalp, and the head washed with a non-irritating soap.

The next preliminary to treatment is to mark the scalp out into areas for radiation

Five points are chosen, as follows:

A, in the mid-line, 1½ inches to 2 inches behind the frontal margin of the hairy scalp.

B, in the mid-line, 1 inch to 1½ inches above the centre of the flat area forming the upper portion of the occiput.

C, in the mid-line, just above the lower border of the scalp on the occiput.

D, on the right side, just above and in front of the ear.

E, on the left side, just above and in front of the ear.

These five points should all be equidistant, the distance between any two being 5 inches. The points are joined by lines, which should cut each other at right angles.

The X-ray tube is contained in a shield having a circular aperture 3 inches in diameter, and 3¼ inches from the anti-cathode of the tube.

Three pegs of soft wood are arranged around this aperture, and converge at their free extremities to within ¼ inch of each other. They are of such a length that their extremities are 6½ inches from the anti-cathode of the tube.

A Sabouraud dose (unfiltered) is given to each of the five areas—vertex, occiput, lower occiput, right and left side—taking the points A, B, C, D, and E as the centre of each area. The parts surrounding the hairy scalp are protected with lead. The radiation of each area is *directed at right angles to the radiation of adjacent areas*, and the points aimed at are at the outer margins of the areas, half the rays falling on the scalp, and half on the protective lead. In this way the overlapping of the radiations of adjacent areas (owing to obliquity of the rays and greater distance of the scalp at the margins) results in exactly one pastille dose being given to every part of the scalp.

The hair commences to fall about the fourteenth day, and is complete in three or four weeks. A slight erythema may appear, but is of short duration.

After treatment the head should be washed every other day till all hair has fallen out. A linen cap should be worn, and the head smeared with vaseline. The case is not free from infection till all the hair has fallen.

Favus.—This condition may be treated on similar lines to the above. Epilation is effected over the diseased area by administration of a pastille dose. The precautions regarding previous treatment, etc., must be rigorously observed.

Treatment of Eczema and Psoriasis.—Eczema is chiefly amenable to X-radiation in its chronic form, and especially in the dry type. This condition, and also psoriasis, are best treated with small stimulating doses given through a thin filter of aluminium (½ to 1 mm.). The results in chronic eczema are often astounding, small localized lesions which have resisted all treatment for years often clearing up after three or four exposures. Each exposure should consist of about half a pastille dose, and treatment should be repeated once a week for four to six weeks. Any reaction is best avoided. If it should appear treatment should be suspended for three weeks.

Small areas of psoriasis are treated in the same way. When the disease is widespread it obviously presents difficulties to this form of treatment. The more resistant patches may, however, be treated, and it will often be found that remote patches, which have received no radiation, show improvement. This remote effect of X-radiation is seen in other diseases also, and points to a general systemic effect of X-radiation, the nature of which is not at present understood.

Lupus Vulgaris.—This chronic tuberculous infection of the skin is usually amenable to X-radiation. The treatment is apt to be prolonged, but not to such an extent as with other forms of treatment. The effect to aim at in the treatment of this disease is a mild skin reaction. This is obtained by a series of exposures (usually six is sufficient, at intervals of four days), given through a filter of 1 mm. to 2 mm. aluminium and three layers of boiler felt. Each dose should be about half to two-thirds of a pastille dose. The filter is necessary, as the deeper layers of the skin must be acted upon more th... the most superficial. After the mild reaction has been produced treatment is suspended for four to six weeks. By that time considerable improvement is generally noticeable. The treatment is then repeated, and this sequence of events is continued as long as necessary. A final course of radiation should be given after the lesion is completely healed. The scar resulting from this treatment is quite as good as that from Finsen light treatment, and the X-radiation method is far less tedious and prolonged.

Chronic syphilitic lesions of the skin which resist ordinary medicinal treatment are sometimes stimulated to heal by small doses of X-rays.

Tuberculous lesions of joints, bones, and glands a... very greatly benefited by heavy doses of filtered

X-rays. This is especially the case in "closed tubercle"—*i.e.*, before the formation of sinuses. This method of treatment deserves far more extensive trial than it is at present receiving, as the results are most encouraging.

Treatment of Uterine Fibro-Myomata and Fibrosis Uteri.—This is an alternative to operative measures, and in suitable cases is equally efficient. The treatment produces an artificial menopause, which is generally permanent. The symptoms resulting from this are not so severe as those produced by operative removal of both ovaries.

Indications and Contra-indications for X-Radiation.—1. Patients should be at least forty years of age, but the ordinary menstrual flow should not have ceased.

2. Interstitial myoma is the only variety which should be treated by this means.

3. The myomatous condition should be uncomplicated by suppuration, diseased appendages, etc.

4. Radiation is obviously especially suitable for patients who are unlikely to withstand an operation well.

5. Cases of fibrosis uteri, without myomata, are very amenable to X-radiation.

Freiburg Technique.—The method consists of giving a large dose of X-rays through multiple ports of entry at one sitting. The exposures are repeated at intervals of three weeks till three or four treatments have been given. This is usually sufficient.

A hard tube is used (a Coolidge is excellent; if gas tubes are employed several will be required for each sitting to prevent undue softening).

A filter of 3 mm. aluminium is employed, with satrap paper, loofah sponge, and lint on the skin surface. Kienböck paper is used to estimate the dosage, and the anti-cathode should be 20 cm. from the skin.

The skin of the abdomen below the umbilicus is divided into ten or twelve rectangular areas. Six areas are marked on the back. Each area receives a dose of 10 to 20 X (one to two pastille doses), the rays being directed towards the pelvic organs. All areas except that acting as the port of entry are protected by thick sheet-lead.

It is important that the series should all be given on one day, or, if that is impracticable, should be spread over two or three consecutive days, otherwise time is given for recovery of the ovaries to take place.

After three weeks' rest the series is repeated, and third and fourth repetitions will probably be necessary.

Bordier's Technique.—Three ports of entry are used one medium and two lateral. Series of exposures are given at intervals of three weeks. Each series consists of nine irradiations, each of the three areas being irradiated on three consecutive days. A thick aluminium filter is used.

It was formerly held that, whatever technique was adopted, the time of radiation should be midway between two menstrual periods. It is now generally considered that the relation of radiation to the menses as regards time is unimportant.

Treatment of Carcinoma.—This falls under two categories:

1. Where the growth is operable.
2. Where the growth is inoperable.

X-radiation has, up to the present, failed to *cure* carcinoma. It should therefore never be adopted as an alternative to surgical removal in operable cases unless the condition of the patient from some cause absolutely precludes operation. Radiation is, however, a most valuable adjunct to operation. A course of radiation should be given *before* operation (it can be compressed into one day, if necessary), making use of hard tubes, multiple ports of entry, and filters. The latter should vary in thickness according to the depth of tissue which it is desired to treat. *Heavy doses* must be given—small doses may stimulate the growth to greater activity. Besides the growth itself, all lymphatic paths draining the affected area, and the glands to which they lead, must be irradiated.

After operation the course should be repeated at least twice (more often if operative findings indicate a probability of recurrence). The first post-operative course should be commenced as soon as the patient is up; an interval of four weeks can then elapse between this course and the next. The keynote of success in this post-operative radiation is the employment of many ports of entry and the thorough irradiation of all areas where recurrence may take place.

Inoperable growths may sometimes be rendered operable by a course of radiation. Apart from this possibility, however, X-rays, sometimes combined with radium, are far the best means at our disposal for treating inoperable cancer. After vigorous treatment the primary growth may greatly diminish in size, ulcerated areas heal, and secondary deposits disappear. The patient may live in comfort for months if treatment is persisted in. Eventually the disease is invariably fatal.

The technique is the same as for operable growths, with the proviso that it is permissible in these cases to push the treatment to the very uttermost.

It must be continued regularly, and new manifestations dealt with as they arise.

Treatment of Sarcomata.—These growths usually respond well to heavy doses of X-rays, and may entirely disappear for a time. They invariably recur. The more active, round-celled type are the most amenable to treatment temporarily. As these nearly always recur after operative removal, X-radiation would appear to be a possible method of choice even in apparently operable cases.

Rodent Ulcers.—These generally do very well with X-ray (or radium) treatment up to a certain point. It will often be found that a small nodule persists after the remainder of the ulcer has been apparently cured. This nodule will resist all treatment, and will eventually spread and break down again, especially if treatment is relinquished.

Other cases will entirely clear up, and a few will be permanently cured. The majority, however, will sooner or later show a recurrence.

The treatment of rodent ulcer therefore would appear to conform to that of carcinoma—*i.e.*, if the growth is operable without severe disfigurement it should be removed, the extirpation being combined with pre-operative and post-operative radiation. If operation is impossible or inadvisable, radiation should be adopted.

It is usual to give one unfiltered exposure of a full pastille dose, and follow this with a prolonged course of filtered radiation. It is essential that treatment should be continued for several weeks, or even months, after the ulcer has been apparently completely cured (should this result be attained).

Treatment of the Blood and Blood-forming Organs.—X-radiation has been widely adopted in the diseases which fall into this category. As is to be expected, the results obtained vary in the different diseases, and also in individual examples of any one disease. One word of warning is applicable to all of them, however: X-radiation *may* result in rapid progression of the disease, and must always, therefore, be applied with great caution at first, until an idea can be formed as to how the patient will react to treatment. Apart from this general exacerbation which is sometimes seen, it is not at all uncommon for X-radiation to be followed by symptoms of an acute toxæmia, which may:

1. Clear up without any after ill-effects, rendering it possible cautiously to attempt further treatment.

2. Clear up leaving the patient considerably and permanently worse.

3. Prove rapidly fatal.

Lymphatic leukæmia is especially liable to furnish examples of this toxæmia following X-radiation.

Pernicious Anæmia.—Marked improvement often results from small stimulating doses of X-rays to the ends of the long bones and the spleen. The bones are irradiated in turn, and when all have been treated the cycle recommenced again. Medicinal treatment should be energetically employed at the same time. Toxæmia is not very common if small exposures only are given, but may occur.

Lymphadenoma (Hodgkin's Disease).—This disease responds more readily than any other blood disease to X-radiation. The enlarged glands and spleen are irradiated. Toxæmia, beyond a possible transient malaise, is unusual. Treatment may be fairly energetic, and usually results in complete disappearance of the enlargements. Even when the patient is keeping apparently well occasional courses of treatment should be given. Sooner or later the disease nearly always manifests itself again. The second and subsequent attacks are generally less amenable to treatment, and ultimately the disease is nearly always fatal. This termination may be postponed for a long time as the result of treatment, however; after the course of radiation has been completed patients sometimes are free from any manifestation of the disease for as long as five years.

The blood-count rarely becomes quite normal. Children respond much less readily than adults.

Myelocytic Leukæmia.—Treatment is here directed towards the ends of the long bones and the spleen. If any glands become enlarged they are also irradiated. Temporary improvement is to be expected, and the patient may be relieved of his symptoms for some months. A fatal termination is inevitable.

Lymphatic Leukæmia.—This is the least amenable of all the blood diseases to X-ray treatment. In the acute form of the disease occurring in children and young adults X-radiation is contra-indicated. It never does any good, and very frequently exaggerates the progress of the disease.

In the chronic form, treatment may be given to the ends of the long bones and glands with great caution, and if, after several weeks of this treatment, no untoward effects are observed, small doses may be given to the spleen.

This organ should never be treated at the commencement of the course of irradiation. A frequent examination should be made of the blood, and the advisability of continuing treatment decided by this, and by the improvement or otherwise of the patient's general condition. In favourable cases marked temporary relief is obtained, but in many instances treatment has to be abandoned.

Pruritus Ani and Pruritus Vulvæ.—X-ray treatment is a specific for these disorders, provided that they are not secondary to some other lesion. No case of this type should be accepted for treatment until all possible causative lesions have been excluded by thorough examination.

Doses of about half a pastille are given through a filter of 1 mm. of aluminium, and repeated twice weekly up to three or four doses. By that time the condition is generally cured; but if not, treatment should be continued, after a rest if any skin reaction has appeared.

Exophthalmic Goitre (Graves' Disease).—This disease, both in its acute and chronic forms, can be markedly relieved and often symptomatically cured by irradiation. The enlargement of the thyroid tends to persist, at any rate for a long time, and the exophthalmos usually remains to a greater or lesser extent.

The course of treatment is best extended over six weeks, two exposures being given a week, one to each side of the thyroid gland. The region of the thymus should also be irradiated.

Filters are employed (2 mm. to 3 mm. aluminium), and about two-thirds to three-quarters of a pastille dose given at each exposure. The patient generally shows progressive improvement, and this continues after the course of treatment is concluded. Relapses are uncommon.

Hyperidrosis.—This condition is best treated by giving a series of doses through a thin filter. In this way the effect can be best regulated, as it is inadvisable to completely destroy the functions of the sweat glands.

CHAPTER XIII

RADIUM THERAPY

Physics of Radium.—In any quantity of radium a certain proportion of the total number of atoms at any one time are in a condition of instability, and it is this instability, and the changes which result from it, which constitute radio-activity. The unstable radium atom provides four phenomena:

1. It gives off an atom of helium, carrying a positive charge. These positively charged particles form the α-rays.

2. It gives off a stream of negatively charged particles, or electrons, which are much smaller than the helium atom. These electrons constitute the β-rays, and are comparable to the cathode stream of the X-ray tube.

3. It gives rise to vibrations in the luminiferous ether, known as γ-rays, which appear to be identical with the X-rays.

4. The radium atom, when it has parted with the atom of helium, ceases to exist in its former state, and becomes gaseous. The gas thus given off by radium is known as radium emanation.

The α-rays have little penetrating power. They are absorbed by 3·5 cm. of air, and do not pass through the wall of the tube containing the radium.

The β-rays are more penetrating than the α-rays, but are all absorbed by 4 mm. of lead. The γ-rays have great penetrating power, and about 10 cm. of lead is required to absorb them.

It is therefore the γ-rays which are of most therapeutic value at the present time. It is, however, thought that the β-rays may have speci' 'herapeutic properties which further improvement of technique may cause to be utilized more fully.

Radio-activity is not confined to pure radium, but is a property of radium salts, and also of the gas " radium emanation."

The salts most commonly used are the bromide, chloride, and sulphate. The loss of efficiency, or " decay " of radium and radium salts, takes place so slowly that for practical purposes it may be considered negligible.

Radium emanation, however, loses its radioactivity fairly quickly, a very large percentage of its efficiency being lost in ten or fourteen days. For practical purposes radium emanation is only of value during the first few days of its liberation from radium.

Radium emanation is soluble in water, and this solut known as Radium Water.

Quantity of radium salts is expressed as weight of the salt.

Quantity of radium emanation is expressed in curies.

To understand this important unit, the curie, it is necessary to describe very briefly the processes taking place in radium emanation.

Any given quantity of radium or radium salt gives off radium emanation at a constant rate, the quantity depending directly upon the quantity of radium or radium salt present.

As the gas collects, however, it undergoes processes of disintegration, and the proportion of gas disintegrating in any specified time is a constant fraction of the quantity present. Thus, the larger the collection of gas, the larger will be the quantity disintegrating in every second. Hence, if all the gas being given off is collected in a receptacle exhausted of air, it is obvious that when a certain quantity has collected, the gas disintegrating will equal the new gas being formed. This is known as being "in equilibrium," and it forms the basis for the unit of radium emanation.

The quantity of radium emanation which is in equilibrium with 1 grm. of radium 1 curie.

Therapeutic Action of Radium on the Tissues.—The action of radium radiations appears to be identical with that of X-rays, and does not require any separate description.

The γ-rays are of a high degree of penetration, and are practically homogeneous; they therefore have very little effect upon the skin. If a superficial action is required, the β-rays are employed as well as the γ-rays, otherwise the former are cut off by means of a filter.

Comparative Advantages of Radium and X Rays.—1. Radium can be conveniently applied in the patient's own home.

2. It can be buried in the substance of a tumour, or placed in parts not readily accessible to X-rays (*e.g.*, in the uterine cervix or œsophagus).

3. Some lesions yield more readily to radium than to X rays (and vice versa), while some are best treated by both these agents in combination.

On the other hand:

4. The quantity of radium and its salts available is exceedingly small, and the cost prohibitive to the majority of private electro-therapists.

5. Radium can only be applied to a very small area at a time, and the treatment by radium of widespread lesions is, therefore, far more tedious than their treatment by X-rays.

6. Improved technique of X-ray treatment, the use of hard tubes, and their increased stability, and the invention of the Coolidge tube, are gradually eliminating the superiority of radium in those instances where such formerly was held to exist.

In general, it may fairly be stated that at the present time the results attainable by radium-therapy can usually be attained equally well with X-rays at much less cost to the patient; but that a few lesions, such as cancer of the uterus, œsophagus, etc., are still more readily amenable to radium than to any other therapeutic agent, and that some superficial lesions, of which rodent ulcer is the most prominent example, sometimes react much better to radium treatment than to X rays.

Methods of Application of Radium.—The forms in which radium is commonly applied are:

1. As radium emanation.
2. In the form of a solid radium salt.

1. Radium emanation can be pumped under pressure into a platinum tube, which is then hermetically sealed. These tubes can be obtained of various shapes and sizes to suit the purpose for which they are required. They can be applied to the surface, buried in a tumour, or placed in the uterus, œsophagus, etc.

Radium emanation can also be inhaled, or can be dissolved in water and drunk. The strength of this "radium water" is usually 1 millicurie per litre, but higher concentrations are sometimes used.

2. Radium salts can be placed in platinum tubes in the same way as the emanation, and applied to any desired part.

The only important difference between these two methods is that the emanation rapidly loses its radio-activity, while the salt remains unchanged indefinitely.

Filtration of Radium Radiations.—As stated above, the γ-rays have very little effect upon the skin, while the β-rays are nearly all absorbed by that tissue, and therefore cause a reaction which, as in the case of soft X-radiations, may vary from a mild transient erythema to an actual necrosis of the skin.

These β-rays are entirely absorbed by 1 mm. of lead or 4 cm. of aluminium.

Where a deep action only is required, a thick lead filter is used, to exclude all the β-rays. When skin reaction is desired varying thicknesses of aluminium can be employed.

These filters (as also the platinum tube containing the radium) give off secondary radiations, which must be excluded by 3 mm. of rubber (sheet or tubing round the platinum tube) between the filter and the skin.

Dosage of Radium Radiations.—This is a far more difficult question to decide than that of X-ray dosage. No hard-and-fast rules can be laid down, and in fact nothing but practical experience will enable the operator to judge the correct exposure for any particular case.

Even when armed with this experience, however, the operator requires to base his dosage on:

1. The quantity of radium salt or emanation which he is going to use.

2. In the case of a salt, the radio-activity of that salt.

The activity of a salt depends on the percentage of pure radium salt present. The unit of activity is obtained by comparison with the activity of uranium. The radio-activity of uranium is taken as unity.

If *pure* radium bromide is compared with an equal quantity of uranium, it will be found to have 2,000,000 times the radio-activity of uranium. If the salt contains only 1 per cent. of pure radium bromide, its activity will be 20,000, and so on.

The other salts of radium in common use have a somewhat higher activity than the bromide.

A tube containing 5 mg. radium salt of 50,000 activity, and with no filter except a rubber tube for secondary radiations, may produce a skin reaction if placed on the surface of the body in less than half an hour.

As in X-ray therapy, repeated doses of filtered radium radiations may be given, with occasional intervals of rest to permit of the subsidence of any skin reaction.

Indications for Radium Therapy.—These are, for practical purposes, the same as the indications for X-ray therapy, and need not be again enumerated here. Radium is best utilized for the treatment of deep-seated malignant disease, and for superficial neoplasms which are found to respond imperfectly to X-radiation. Of the latter, rodent ulcer is by far the most common example, and in this condition radium therapy may be looked upon as the method of choice.

CHAPTER XIV

ELECTRO-DIAGNOSIS OF NERVE LESIONS AND MYOPATHIES

The electrical diagnosis and prognosis of these lesions depends upon the deviation from the normal reaction to electrical stimuli which may be manifested by the muscles and nerves, and the degree of abnormality present.

Before proceeding to a description of the methods employed, it is necessary to insist upon the fact that the electrical reactions *alone* are utterly insufficient for the formation of a useful opinion as to the condition of the nerves and muscles under examination. The electrical reactions merely form one link in the chain of evidence, and not always a very reliable link at that. The electro-therapist who intends to undertake this branch of diagnostic work must therefore possess a thorough clinical knowledge of the lesions with which he will be brought in contact.

This is especially the case with peripheral nerve lesions, and a brief summary of the method of examination of these cases is given below.

Every case should be submitted to the same routine examination, otherwise the operator, working without a fixed plan in his mind, will sooner or later omit some essential step in the procedure.

Before making any actual examination of the part a careful history must be elicited from the patient. This should include the nature of the accident, and its date; if a wound was sustained, the length of time which it took to heal, and the nature of its healing (first intention, suppuration, etc.); the time of onset of symptoms referable to nerve injury—whether this coincided with the accident, or followed after an interval; the symptoms first noticed, and the subsequent development of others, if any; the course of the case—whether improving, stationary, or getting worse; the presence or absence of pain, and its distribution; the occurrence at any time since the accident of blisters or sores on the affected part.

This history must be carefully recorded. The next step is inspection.

The general condition of the part should be noted for wasting or deformity. The scar, if any, should be examined, particular attention being paid to its situation—whether overlying any nerve-trunk—and its appearance as suggesting suppuration or not.

The skin of the affected part must be carefully inspected; it may be normal in appearance, blue, and atrophic, with loss or irregular growth of hair, covered with heaped-up, imperfectly shed epidermal scales, or red and shiny. The nails may be overgrown, and much curved, or ribbed. There may be an appearance similar to onychia around the nail-beds.

Trophic sores, or the scars remaining from them, should be noted.

The part should next be palpated. First the scar, if any, to ascertain whether it is adherent to underlying tissue, or tender. Then the affected part, to ascertain tenderness, heat, or cold.

This concludes the general examination, from which a large amount of most useful information, negative or positive, is generally obtained.

The special examination follows. It deals with:

1. The sensory condition—
   (*a*) Epicritic sensation.
   (*b*) Protopathic sensation.
   (*c*) Deep sensibility.
2. [Motor] condition—
   (*a*) Passive movements.
   (*b*) Active movements.
   (*c*) Electrical reactions.
3. The condition of the nerve trunk—
   (*a*) Conductivity.
   (*b*) Tinel's sign, or distal tingling on percussion.

The Sensory Condition.—The areas supplied with sensation by the different peripheral nerves must be carefully studied in the illustrations of textbooks devoted to the subject. It may be stated here that epicritic sensation is the perception of light touch. It is tested with cotton-wool, which must not be made to deform the skin, otherwise deep sensibility is involved. Discrimination of two points of a compass at distances apart varying with the area examined is also a function of epicritic sensation, as is also discrimination between small differences of temperature. The area supplied with epicritic sensation by every peripheral sensory or mixed nerve is very constant in extent—there is practically no overlapping.

All sensory examination must be made with the patient's eyes closed, and he should be told to say "Yes" whenever he feels anything.

Protopathic sensation is the perception of painful stimuli, and of considerable differences of temperature. It is best tested with a hat-pin, the head and point being used irregularly, and the patient told to answer "head" or "point" according to the sensation invoked.

The area of loss of protopathic sensation in peripheral nerve lesions varies considerably in different individuals, owing to overlapping by protopathic fibres of contiguous areas. In peripheral nerve lesions the area of protopathic loss is always less than that of epicritic loss. In a lesion of the posterior roots of the cord the reverse is true.

Deep sensibility is the sensation invoked by firm pressure which dimples or deforms the skin. It appears to be dependent on fibres accompanying the motor fibres, and forming sensory endings in the muscles and ligaments. It is rarely completely lost unless many tendons have been divided.

If there is no actual loss of epicritic, protopathic, or deep sensibility, the patient must be tested for "changed sensibility." This is done as follows: The point of a pin is drawn over the skin from the normal on to the (suspected) abnormal part, and the patient asked to state at once if he feels any change in sensation at any point. In this way an area can often be mapped out over which sensation is of a tingling nature. This is due to slight injury of epicritic fibres, and is also found after regeneration of a nerve lesion. In the latter case "changed sensibility" will be found over the area of epicritic supply long after actual perception of light touch has returned.

The Motor Condition.—Passive movements are employed to ascertain whether the full range of movement is still possible, or whether this has been modified by contractures resulting from persistent over-action of the unparalyzed muscles.

Active movements require very careful observation. The operator must thoroughly familiarize himself with the action of the individual muscles, and the way in which these actions may be counterfeited by other muscles. Mistakes in this matter are easily made, and may prove completely misleading.

Electrical Reactions of Muscles.—For carrying out these tests the following appliances are required:

1. A good therapeutic faradic coil of the Sledge type.

2. A source of constant or galvanic current. This may be provided by a battery of dry cells, a pantostat, or similar instrument; or, with suitable resistances, the D.C. mains may be utilized. Whatever source of current is adopted it must include a milliamperemeter in the circuit, and be provided with a pole reverser and a make-and-break key.

3. Instead of the galvanic current an apparatus for supplying condenser discharges may be used. This will be more fully described below. It may be stated here that condenser discharges should not be used alone in testing, as was formerly advocated, but in combination with faradism.

An indifferent electrode of the flat type and of fair size—at least 6 inches by 4 inches—should be used. It should be covered with half a dozen layers of lint thoroughly soaked in warm normal saline solution.

The active electrode should consist of a small round metal disc mounted on a handle. The disc should be covered with three or four layers of lint also soaked in the saline solution, and a make-and-break key should be mounted on the handle.

It is essential that the part to be examined should be warm, and the skin thoroughly wet with saline solution. In the case of the extremities it is well to immerse in a bath of the warm solution for ten or fifteen minutes to insure these conditions.

Normal Electrical Reactions.—These depend upon the intact state of the lower motor neuron (the only exceptions to this rule are provided by the myopathies, where the primary incidence of disease is on the muscles; the myopathies are discussed in a later paragraph).

Faradic stimulation of a normal motor nerve in any part of its course produces a tetanic contraction of all the muscles supplied by that nerve whose branches of distribution are given off from the parent trunk below the point of stimulation.

If the faradic stimulus be applied to the individual muscle, a tetanic contraction of that muscle will again be obtained. It will be found, however, that in every muscle there is a small area, stimulation over which produces a contraction with a much weaker current than when the active electrode is placed over any other part of the muscle.

This is known as the "motor point," and corresponds with the entry of the motor nerve into the muscle-sheath. The position of this motor point is very constant for each muscle, and must be memorized by the operator.

Galvanic Stimulation.—If a galvanic current is allowed to flow through a motor nerve no muscular contraction takes place while the flow is constant. At the moment the current is "made," however, and again when it is "broken," a contraction occurs in the muscles supplied in the form of a single brisk twitch.

The strength of current required to produce this contraction in any one nerve varies according to whether the stimulus is provided by the make or the break of the current, and also according to the polarity of the active electrode. The normal relations of these different stimuli are:

K.C.C.	A.C.C.	A.O.C.	K.O.C.
(Kathodal closing contraction.)	(Anodal closing contraction.)	(Anodal opening contraction.)	(Kathodal opening contraction.)

It may be stated that if a response is obtained to 1 ma. at kathodal closure, then 2 ma. will be required at anodal closure, $2\frac{1}{2}$ ma. at anodal opening, and 15 ma. at kathodal opening, to obtain a similar contraction.

All the above remarks on galvanic stimulation of nerve trunks apply equally to galvanic stimulation of the motor points of muscles.

Tetanic contraction of a normal muscle can be obtained by a rapid succession of galvanic makes and breaks applied to the motor nerve trunk or motor point of the muscle. The interruptions must be at least twenty per second—often a higher frequency is necessary.

Stimulation by Condenser Discharges.—The condenser apparatus for muscle testing was elaborated by the late Dr. Lewis Jones. It consists of a series of condensers, varying in capacity from 0·01 microfarad to 2 microfarads.

There are usually ten intermediate condensers between these two extremes.

The condensers are provided with a selection board, so that any one condenser can be utilized as required.

A metronome or other form of two-way rhythmic interrupter causes the condenser selected to be charged from the mains (usually at a voltage of 100), and then discharged through the patient.

The theory upon which this apparatus is based is that the duration of the stimulus required to produce a muscular contraction depends on the condition of the muscle and its motor nerve. If the condensers are charged at 100 volts potential, the duration of discharge of the smallest (0·01 microfarad capacity) through the resistance of the body (taking this as 1,000 ohms) will be about $\frac{1}{100000}$ second. The duration of discharge of the largest (2 microfarads capacity) will be about $\frac{1}{500}$ second.

Normal muscles should respond to one of the lower condenser discharges, but, as will be seen later, great differences occur with different muscles and in different individuals.

Condition of the Nerve Trunk.—Two important tests must be applied to the trunk of the nerve.

1. It must be stimulated with the faradic and galvanic currents *above* the point of injury, and observations made on the muscles supplied by branches given off below the point of injury. This may help to determine whether any fibres are passing intact through the lesion.

2. The skin over the nerve trunk must be firmly percussed, starting at the point of injury, and proceeding downwards towards the periphery.

It may be found that percussion over a certain part of the nerve produces a sensation of tingling in the part normally supplied by the nerve with sensory fibres.

This is Tinel's sign, or Distal Tingling on Percussion (usually written D.T.P.). It depends on the presence of young, imperfectly medullated sensory nerve fibres.

The normal growth of new fibres after division takes place at the rate of 1 mm. a day, and three months elapse before the new fibre becomes perfectly medullated. Hence, in a case of normal regeneration after division, at the end of three months D.T.P. will be elicited from the site of injury to a point on the nerve trunk about 9 cm. nearer the periphery. This area of 9 cm. will gradually move down the trunk of the nerve, corresponding to the downgrowth of the axis cylinders on the one hand, and the perfection of the process of myelinization on the other. At the end of another three months, therefore, the first 9 cm. of the nerve below the injury will give no D.T.P., but the next 9 cm. will do so. In this way the course of the new fibres can be traced.

Two fallacies have to be guarded against in this test:

(*a*) A certain number of new fibres always spring from the proximal end of a divided nerve, though they may form no connection with the distal end, but merely ramify in the tissues.

D.T.P. in the immediate neighbourhood of the scar, therefore, cannot be looked upon as a sign of regeneration.

(*b*) If an incompletely divided nerve is the subject of *neuritis*, D.T.P. will be elicited. In this case, however, the D.T.P. will not be localized to 9 cm. of the nerve, but will be obtained over the whole nerve trunk distal to the injury.

Wallerian Degeneration.—After division of a peripheral nerve a series of changes occurs in the distal portion of the nerve: the same changes occur in the proximal portion, as far as the first node of Ranvier, above the point of division. These changes constitute what is known as Wallerian Degeneration. They do not progress from the region of the section, but take place simultaneously in all parts of the nerve affected.

The first change is visible at the end of twenty-four hours after the section of the nerve. The myelin sheath is then found to be somewhat irregular in outline. Later the axis-cylinder process becomes irregular and ruptures, the myelin sheath undergoes fatty degeneration, and the nucleated sheath shows active nuclear and cellular proliferation.

Cellular proliferation also occurs in the surrounding tissues, and these cells break through the nucleated sheath. The débris formed of fat droplets, nuclei, and fragments of axis-cylinder is eventually removed by leucocytic ingestion. Eventually the nerve fibre is represented by a multinucleated fibre formed by the proliferated nucleated sheath.

This is known as a "band fibre," and down between its interstices grows the new axis-cylinder from the proximal end of the divided nerve in those cases where regeneration occurs.

Changes in Muscular Reactions after Complete Division of the Motor Nerve.—For the first two or three days no great change in the reactions is noticeable, except that stronger stimuli are necessary to excite contraction than upon the uninjured side. Some time between the fourth and seventh days after the division the muscle ceases entirely to respond to faradism.

About the tenth day important changes occur in the nature of response to stimulation with the galvanic current. Instead of the contraction being a brisk twitch, affecting all parts of the muscle simultaneously, it takes the form of a sluggish wave, proceeding along the muscle from the point of stimulation. The motor point of the muscle is no longer the most suitable spot for stimulation, but contraction is often most readily obtained by applying the active electrode to the muscle at a point near its junction with the tendon of insertion. With the appearance of this alteration in the character of contraction, the strength of current necessary to produce any response is much increased. In addition, "polar reversal" may occur. This term is used to indicate that anodal closure will produce a response with a weaker current than cathodal closure, or, as it is usually written, A.C.C. > K.C.C.

Polar reversal is by no means an invariable occurrence in complete division of a nerve.

The changes described above—loss of reaction to faradism; sluggish, wave-like response to galvanism; and possibly polar reversal—constitute the

"Reaction of Degeneration," usually termed R.D.

It may be described as "Complete R.D.," to distinguish from lesser changes, which are sometimes described as "Partial R.D." It is advisable, however, to restrict the term R.D. to the complete form described above.

The length of time after complete nerve division for which the muscles retain their power of response to galvanism varies in different cases. It may persist for many years, but not infrequently is lost within a year or two.

It was formerly held that R.D. was found only in those cases where complete division of the nerve had occurred, and that, on the other hand, it was invariably found in cases of complete division. It is now known that neither of these premises is correct.

Testing by Means of Condenser Discharges.—This method is of comparatively recent adoption, but has had sufficient trial to prove that it does not fulfil the expectations which it aroused.

Generally speaking, response to condensers of 0·01 to 0·1 microfarad capacity may be taken as normal to weak normal, the latter indicating a very incomplete lesion.

Response to condensers of 0·1 to 1 microfarad capacity indicates incomplete division of increasing severity, while response to condensers of 2 microfarads capacity, or no response at all, indicates complete division. These guiding principles are, however, liable to very great variations. A negative finding—*i.e.*, response by a paralyzed muscle to a low condenser discharge—may safely be taken as indicating that the nerve is incompletely divided, but the reverse does not hold.

Cases are seen where no response to even the highest condenser discharges is obtained, and yet the limited anæsthesia is positive proof that complete division has not taken place. In other words this method, like all other reaction methods, must take its place as subsidiary to the evidence obtained by other means. So long as this is remembered, the condenser method, combined with faradism, is probably of more value than galvanism combined with faradism.

The Diagnosis of Complete or Incomplete Division.—From the above statements it will be seen that this must not be made on the electrical reactions alone. The following data must be collected and carefully weighed:

1. History of the case.
2. Sensory condition.
3. Muscular condition as regards voluntary action.
4. Electrical reactions of muscles.

As regards 2, it must be borne in mind that some peripheral nerves (notably the musculo-spiral in its lower third) may be completely divided without producing any sensory change.

Prognosis of Peripheral Nerve Lesions.—Three classes of case must be considered:

1. That seen immediately after the injury.
2. That seen within a few weeks of the injury.
3. Old cases—those not seen for months or even years after the injury.

1. *Cases Seen Immediately after the Injury.*—In this class of case no change in the electrical reactions will have developed. The prognosis for practical purposes depends on whether or not the injury to the nerve is due to violence which produced a wound of the skin and subcutaneous tissues (and possibly the nerve trunk itself). If the injury is subcutaneous—*e.g.*, pressure produced by the head of the humerus on the cords of the brachial plexus in a subcoracoid dislocation—the prognosis is good. Complete spon-

taneous recovery will probably ensue if the paralyzed muscles are kept relaxed.

If the injury produced a wound leading down to the region of the nerve, the prognosis is doubtful, and immediate exploratory operation should always be advised.

2. *Cases Seen some Weeks after the Injury.*—In this class, as in Class 3 (see below), the observer should, if possible, avoid giving a definite prognosis on one examination alone. Two or three, at fortnightly intervals, should enable him to form an opinion, and at this stage a little extra time is not generally of paramount importance. An exception to the above is formed by the case which is fairly obviously one of complete or nearly complete division as the result of a wound. Here immediate operation is always advisable (provided the wound has healed by first intention, or has been soundly healed for at least six weeks if suppuration occurred).

In such a case complete recovery without operation is exceedingly unlikely.

Where the lesion is obviously incomplete, the process of regeneration should be studied at several examinations, as stated above. It is evidenced by diminishing anæsthesia, growth of new fibres down from the site of injury (as shown by D.T.P.), improvement in electrical reactions, and return or improvement of voluntary muscular action. So long as the process of regeneration *continues unchecked*, conservative methods should be advised. The examinations should be then continued once a month. The prognosis should be guarded. At any time progress may cease, owing to ingrowth of fibrous tissue into the nerve, general infective neuritis, or pressure from bony callus or scar-tissue. The condition may then remain stationary, in which case the advisability of operation will depend on the degree of recovery which has been attained, and the likelihood of improving matters by operative procedures; or the condition may retrogress, with possibly additional symptoms, such as pain and trophic sores, in which case operation should always be advised.

3. *Cases Seen Months or Years after Injury.*—It must be remembered, in dealing with this class of case, that after complete division of a peripheral nerve, even if operative measures have been at once resorted to, and uncomplicated regeneration takes place, still many months will elapse before complete recovery ensues.

The operator must therefore decide—

(*a*) If normal regeneration is taking place.

(*b*) If regeneration never took place to any appreciable extent, or has ceased after partially repairing the damage done.

In the case of (*a*) the prognosis is good or fair. The same lines must be followed as those laid down for recovering lesions in Class 2—*i.e.*, conservative methods must be adopted, and periodical examinations made to follow progress.

In the case of (*b*), the prognosis as regards complete recovery is bad. In many old-standing cases the muscles, as such, have ceased to exist. This can be determined by their failure to respond to any form of electrical stimulus. In other cases, though response to stimuli still remains, the muscles have become so overstretched by unopposed action of their antagonists, and so much deformity has resulted, that it is obvious no useful purpose can be served by attempting to re-establish innervation.

At any time after the lapse of two years since the injury it is doubtful if much improvement in the muscular condition can be obtained.

On the other hand, a certain improvement in anaesthesia is generally attainable by operation. In most cases protopathic sensation can be restored, and this, although an uncomfortable condition in the absence of epicritic sensation, will relieve the patient of the risk of injury and of trophic sores.

In another class of old case, it will be found that regeneration and recovery have taken place to a very considerable extent, but have then stopped. It is then necessary to consider the cause of cessation of regeneration. If the cause is remediable (*e.g.*, involvement in callus), and the cessation of regeneration recent, a fairly hopeful prognosis may be given of the result of operative interference.

Conservative Treatment of Nerve Lesions.—The operative treatment of these injuries concerns the surgeon, and need not be dealt with here.

The conservative treatment rests largely with the electrotherapist, and frequently the entire responsibility for the care of these cases is borne by him.

As regards the actual electrical treatment, no great difficulty is met with. The paralyzed muscles should each in turn receive systematic stimulation with whichever current they will respond to, remembering that faradism is the current of choice when a response to it can be obtained.

This stimulation should be carried out for 15 to 20 minutes daily, at least, until voluntary power has returned; if possible for some little time after.

In stimulating the muscles, care must be exercised not to put the damaged nerve trunk on the stretch, otherwise the new axis-cylinders may be damaged.

Massage and movements are of great benefit, keeping in mind the necessity for not stretching the nerve trunk.

The most important part of the treatment of these cases, since without it all other administrations are valueless, is to assure complete relaxation of all the paralyzed muscles by means of proper splinting. The splint must be worn night and day until voluntary power commences to return, and may then be left off for increasingly longer intervals *during the day*, until in a short time it is discarded entirely in the daytime. But it must still be worn at night until the recovering muscles have attained sufficient tone to exclude their overstretching by their antagonists during sleep.

Lesions of the Upper Motor Neuron.—Lesions of the upper motor neuron in the brain or cord are generally followed by increased excitability to faradism with normal response to galvanic stimuli. In old cases the response to both forms of stimuli will gradually diminish. R.D. never occurs in lesions of the upper motor neuron.

Electrical Reactions in the Myopathies and in Functional Disorders.

Pseudo-hypertrophic Muscular Paralysis and Idiopathic Muscular Atrophy.—In both these conditions irritability to faradic and galvanic stimuli is gradually diminished. There is no R.D.

Thomsen's Disease (Congenital Myotonia).—In this disease contraction to strong galvanism, both K.C. and A.C., is much prolonged beyond the duration of the actual stimulus. Reaction to faradism may be normal, or contraction may persist after the stimulus has ceased. This is known as the "Myotonic Reaction."

Family Periodic Paralysis.—In the intervals between the attacks the electrical reactions are normal. In an attack the response to both faradism and galvanism becomes weaker and weaker, until it is finally lost entirely. As the paralysis passes off the excitability to these stimuli gradually returns.

Myasthenia Gravis.—The muscles at first contract normally to faradism. If the application is prolonged, they quickly become exhausted and cease to respond. A short interval of rest will restore faradic excitability.

Galvanic stimulation produces a continuous contraction, which does not relax if the stimulation is prolonged. This is known as the "Myasthenic Reaction."

Chorea.—There is increased excitability to faradism and galvanism in both nerves and muscles.

Hysterical Paralysis.—The electrical reactions are normal, and form an important diagnostic aid in cases of difficulty. In *Paralysis Agitans* and *Writer's Cramp* the reactions are also usually normal.

INDEX OF TREATMENT

Brief indications of the lines of treatment to be adopted are given here. For particulars of technique reference should be made to the appropriate chapters in the preceding portion of the book.

Acne Vulgaris. High-frequency and diathermic currents may be given by means of the vacuum electrode, kept in motion and in direct contact with the skin. Each application should last long enough to produce slight redness of the skin.

Large comedones may be treated by electrolysis 2 to 4 ma. being applied by means of the electrolytic needle for 3 to 5 minutes. Care must be taken to avoid scarring from overtreatment.

Salicylic ionization to the whole affected area is sometimes successful.

X-radiation gives good results. Repeated small doses should be administered, care being taken to protect all hair (eyebrows, etc.).

The static breeze is of value in conjunction with any of the above methods.

Adenitis.—Chronic suppurative adenitis is best treated by means of zinc or copper ionization. Great care must be taken to bring the electrolyte into contact with every part of the area to be treated. Treatment should be repeated once a week.

Tubercular adenitis, before softening has occurred, often yields rapidly to X-ray treatment. Filters should be used, and repeated doses with hard tubes given.

When sinuses have formed, X-radiation, possibly combined with zinc ionization, tends to promote rapid healing.

Alopecia Areata.—This may be treated with high-frequency currents, the glass vacuum electrode being employed with sufficient spark-effect to produce considerable reddening of the scalp. Treatment should be repeated two or three times a week.

Small stimulating doses of X-rays are also excellent.

Zinc ionization will sometimes produce good results, and faradization of the scalp is a useful adjunct.

Anal Fissure.—The following method is advocated for this condition: the fissure is first rendered insensitive by application for several minutes of a pledget of cotton-wool soaked in stovaine, or some similar preparation. A zinc rod, around which is wrapped a little cotton-wool soaked in zinc sulphate solution, is then laid in the fissure and connected with the positive pole. A current of 15 ma. (if the patient will bear as much) is passed for 10 minutes. The treatment is repeated weekly. The author has failed to obtain good results in these cases.

Amenorrhœa.—Cases of this condition, where no local causative factor can be discovered, have been benefited by light baths with the mercury vapour lamp (Nogier). See also **Uterus (Imperfect Development of).**

Anæmia (Pernicious).—Small stimulating doses of X-rays to the ends of the long bones and spleen may produce a marked temporary improvement.

Diathermy, one large electrode being placed between the shoulder-blades and the other over the precordium, is also of considerable value.

Aneurysm.—Bipolar electrolysis has been employed with success in some cases of saccular aneurysm. The needles are introduced into the sac, and the current gradually turned on and allowed to flow for 10 to 15 minutes.

The needles are generally used also to scarify the lining of the sac-walls, the treatment thus being a combination of electrolysis and scarification.

The object of the treatment is to produce coagulation, and the risk of embolism must not be forgotten.

Angina Pectoris.—Light baths are successful in relieving many of these cases. The treatment should be pursued as vigorously as possible.

Aphonia (Functional).—See **Hysteria.**

Arthritis.—For purposes of electrical treatment the following very brief classification is useful—

I.—Infective	(*a*) Suppurative	Pyogenic. Gonorrhœal.
	(*b*) Non-Suppurative	Rheumatoid and allied conditions Gonorrhœal.
	(*c*) Tubercular.	

II.—Osteo-Arthritis.

III.—Neuro-Arthropathies; Syringomyelia.

Suppurative Arthritis.—The treatment of this condition in its acute form is, of course, essentially surgical. If incision and drainage has been adopted, however, attempts may be made to combat the infecting organism by means of—(1) Ionization; (2) Ultra-violet radiation; (3) Diathermy.

If ionization is attempted, every effort must be made to bring the electrolyte into contact with all parts of the joint.

Zinc and copper are the best medicinal agents to employ. The joint should be thoroughly irrigated, and then immersed in a bath of the electrolyte, into which the positive pole is led. If long, narrow sinuses are present about the joint, they should be lightly filled with a wick of gauze, which will soak up the medicinal fluid and so bring it into contact with the sinus wall.

As heavy a current as can be borne should be passed for $\frac{1}{2}$ to $\frac{3}{4}$ hour, and the procedure should be repeated weekly.

Ultra-violet rays, especially those obtained by the tungsten arc, or Simpson light, have an excellent effect on all infected surfaces. The light may be applied daily for 5 minutes or longer at a distance of 12 inches, the skin being protected.

Unfortunately, in these conditions only a small proportion of the infected area is exposed to the rays, and as these have no penetrating power the application is only of limited value.

Diathermy is of value in gonorrhœal arthritis, whether suppurative or non-suppurative. It should be applied transversely through the joint daily for half an hour.

Rheumatoid Arthritis and Allied Conditions.—General high-frequency applications on the auto-condensation couch are of value. They should be given daily for half an hour. General diathermy given in the same way is possibly preferable.

In acute exacerbations affecting individual joints, salicylic or lithium ionization may do good. General and local light-baths are generally productive of marked relief of pain and stiffness.

Permanent improvement can only be obtained by eradicating the source of infection, whatever this may be.

Tubercular Arthritis.—Repeated heavy doses of filtered X-rays produce marked effects on this condition, even after sinuses have formed. This method of treating tubercular infections of the joints deserves far wider application than is at present the case.

Where sinuses have formed and have sustained a mixed infection, ionization of the sinuses with zinc may be used in combination with the X-radiations.

Osteo-Arthritis.—Local and general light-baths, salicylic ionization, diathermy, and X-radiation are all of some value. Various combinations of treatment should be tried, as individual cases will be found to vary in their response to the different methods.

Where any advanced structural changes in the joint have taken place, it is obvious that electrical treatment can have little effect beyond the relief of symptoms.

Arthropathies in Syringomyelia.—These, together with the other manifestations of the disease, often show considerable improvement after a series of X-ray exposures to the affected portion of the spinal cord. Thick filters should be used, and the exposures repeated twice a week. After ten or twelve exposures no further treatment should be given for 4 to 6 weeks.

Asthma.—Diathermy, with one electrode applied to the upper and the other to the lower end of the sternum, often gives considerable relief.

Galvanism may be tried. The active electrode is the anode, and is applied to the sides of the larynx and to the insertions of the sterno-mastoids and scaleni. The indifferent electrode is stationary at the nape of the neck. The current should be rhythmic, varying from 0 to 15 ma.

General high-frequency on the auto-condensation couch will be of value in lowering hypertension in these cases.

It should be given daily for half an hour for some weeks.

Atrophy of Muscles resulting from disuse, whether local, as after a fracture of a long bone, or general, as after confinement to bed by illness, should be treated by rhythmic faradic stimulation.

In general atrophy the treatment is given most easily, and with great comfort to the patient, in a full-body bath. It should be repeated daily for 10 to 15 minutes.

Bronchitis.—An expectorant effect may be produced by the galvanic current. The cathode is placed at the nape of the neck, the anode first at one side, then the other over the scaleni. A current of 2 to 3 ma. for 3 minutes is passed.

Chronic bronchitis is benefited by high-frequency applications to the chest-walls by means of the vacuum electrode.

Bipolar applications of diathermy, given through the chest from side to side, are excellent in both acute and chronic bronchitis.

In the early stages of acute bronchitis, exposure of the chest-wall to the mercury vapour-lamp or Simpson light for a sufficient time to produce an erythema will afford marked relief.

Cancer.—See **Carcinoma.**

Carcinoma.—Squamous-celled carcinoma, if situated on the surface of the body, is best treated by X-rays. Repeated doses must be given through a thin filter, or the first dose may be unfiltered. When situated in one of the body cavities, such as the vagina or mouth, radium is more easily applied than X-radiation.

Spheroidal- and columnar-celled carcinomata require repeated doses of X-rays, heavily filtered to avoid damage to the overlying skin, unless this has become involved, when the earlier exposures should be given through a thin filter ($\frac{1}{2}$ to 1 mm. aluminium).

In some situations, such as the uterus and œsophagus, these growths are better treated with radium.

Superficial growths can also be treated by electrolysis or surgical diathermy.

In electrolysis the bipolar method is employed. A number of needles are thrust into the growth, and a current of 40 to 60 ma. gradually turned on and allowed to flow until the whole growth is coagulated, with a margin of surrounding healthy tissue.

The entire mass separates in course of time as a slough.

In diathermy, either unipolar or bipolar applications may be made (generally the former). The active electrode consists of a blunt metal electrode, which is thrust into the tumour. The current is turned on until the tissues surrounding the electrode whiten from coagulation. The current is switched off, the electrode withdrawn and inserted in a fresh place, and the current again switched on. This is repeated until the whole tumour is coagulated.

Diathermy may be used in operable growths as a prelude to operation.

Cardio-vascular Disorders.—Sinusoidal and polyphase currents given in the full-body bath are of value in cardiac dilatation and hypertrophy, early cases of myocardial insufficiency, and arhythmia.

Cardiac dilatation is benefited by general electric-light baths, as are also the palpitation and dyspnœa of valvular lesions. Galvanic and polyphase currents by means of Schnee baths are of value in relieving the paroxysms of pain in *Raynaud's Disease.*

If galvanism is employed, a positive plate electrode should be applied to the nape of the neck, while the limbs are immersed in negative baths.

High-frequency currents by auto-conduction may be of help in producing peripheral vaso-dilatation. *Arterial Hypertension,* with whatever condition it may be found associated, can generally be reduced by a course of auto-conduction or auto-condensation with high-frequency currents. General electric-light baths are a useful adjunct.

Arterial Hypotension in neurasthenia, and sometimes in other conditions, is corrected by high-frequency applications to the spine with the vacuum electrode. The electrode should be applied through the clothes, so as to obtain considerable spark-effect.

Chilblains.—Rhythmic sinusoidal and faradic currents, given by means of Schnee baths in which the affected extremities are placed, are followed by good results.

Small doses of X-rays, and application of the high-frequency vacuum electrode, also procure rapid relief from the redness and pain of this disorder.

Chorea.—The static breeze applied to the spine is of value; so also are diathermy applied by the vacuum electrode to the spine, and the four-celled Schnee bath with sinusoidal current. Cerebral galvanism is deserving of a trial.

Cicatrices.—The adherence of scars to underlying tissues may be satisfactorily treated by means of a prolonged course of chlorine ionization. Heavy currents and long applications should be employed. The treatment is slow, but the results obtained are good. The more usual method of treating adherent scars is by means of X-rays.

Repeated exposures with a thin filter should be given, the object being to initiate and maintain a mild degree of reaction. This method of treatment by X-radiation is also of great value in cheloid scars, providing that they are not of too long standing. The cheloid scar which responds best is the pink, soft scar which is showing signs of active increase in size. A scar of this nature usually reacts well to treatment, which should not be finally abandoned until all signs of hypertrophy have disappeared.

Several courses of radiation may be necessary for large scars.

Coccygodynia.—Hydro-electric sitz baths with the sinusoidal current should be given three or more times a week.

Colitis.—Membranous colitis may be treated by static bath and static breeze applied to the abdomen.

Chronic dysenteric colitis is benefited by the high-frequency vacuum electrode applied to the abdomen and loins.

Mucous and chronic ulcerative colitis have been successfully treated by means of ionization with zinc and silver salts.

For this treatment the colon and rectum are first washed out with distilled water by means of a long rectal tube. The anode is then passed into the rectum and as far up the colon as possible. This consists of a wire spiral enclosed in a rubber tube provided with side openings. Two large negative electrodes are applied to the abdomen and back. The electrolyte, consisting of warm zinc sulphate or silver nitrate solution, is then run into the rubber tube, and, passing out through the side openings, fills the rectum and colon. A current of 15 to 20 ma. is gradually turned on and allowed to flow for 20 minutes; it is then slowly turned off. Treatment may be repeated in ten days or a fortnight.

It is hardly necessary to insist on the need for great gentleness and care in inserting the rectal electrode.

Comedones.—See **Acne.**

Congestion, from whatever cause arising, is benefited by electric-light baths. If the congestion is the result of infection by micro-organisms, the treatment is still of great value provided that pus has not already formed. In the latter case the treatment produces increase of pain, and indicates that the case is one for the surgeon.

Constipation.—Atonic constipation is treated with static sparks applied to the abdomen over the course of the colon. An alternative method is to apply heavy galvanic stimuli to the colon. The patient lies on a large plate electrode connected to the anode. A round disc electrode, the cathode, is applied rhythmically to the anterior abdominal wall, the successive applications following the course of the large gut from the cæcum to the rectum; 40 to 60 ma. should be passed. The vigorous contractions of the abdominal muscles produced undoubtedly contribute to the success of the treatment, which should be repeated at first daily, and then at gradually increasing intervals as improvement shows itself.

In cases of urgency the hydro-electric douche may be given. The electrodes and general technique are similar to those described under Ionization for Colitis.

The galvanic current is employed, but should undergo *sudden* reversals every two or three minutes; 30 to 40 ma. should be passed, and the treatment continued for half an hour. It will probably be followed by immediate action of the bowels. This method is not suitable for repetition, but is a method for cases of emergency.

Spasmodic constipation is treated by the static breeze and galvano-faradism. The latter is maintained at constant strength during the application, two large electrodes being used, one to the back and the other to the front of the abdomen.

Cornea, Ulceration of.—Zinc ionization after the application of a local anæsthetic (*e.g.*, cocaine) is suitable. The active electrode consists of a thin zinc rod, round the point of which is wrapped a small wisp of cotton-wool soaked in zinc sulphate solution. This must be brought into contact with all parts of the ulcer. One ma. should be passed for 5 minutes.

The treatment may be repeated after 7 to 10 days have elapsed.

Corneal Opacities may be improved by chlorine ionization. The active electrode (cathode) consists of a small plate placed on the closed eyelid, the sodium chloride in the lachrymal secretion supplying the requisite chlorine ions. Treatment requires to be repeated once a week for a considerable period.

Corns.—Salicylic or zinc ionization relieves painful corns. The corn must be thoroughly soaked with the solution to be used by wearing a compress of cotton-wool, wet with the solution and covered with oil-silk, for twenty-four hours before the ionization is attempted. The active electrode must not come into contact with the surrounding healthy skin.

Cystitis.—Acute cystitis is not amenable to electrical treatment.

Chronic cystitis, when the infection is of a mild type, may be treated with high-frequency currents by means of a vacuum electrode shaped like a catheter. This is introduced into the bladder, and applications of 15 to 20 minutes given daily. There is often speedy relief of symptoms.

The more serious forms of chronic cystitis may be treated with zinc or silver ionization. The bladder is washed out, and then filled with the electrolyte by means of a rubber catheter with side openings near its closed extremity. A metal stilette is then passed down the catheter. This forms the active electrode. The indifferent electrode is placed in the suprapubic region. A current of 10 to 15 ma. may be passed for 15 minutes, and the treatment repeated in a week's time.

Deafness.—See **Eustachian Catarrh** and **Otitis Media.**

Diabetes.—There is no established electrotherapeutic method for this disease.

The following are stated by various observers to be beneficial:

High frequency by means of the auto-conduction cage. It has been claimed that a course of this treatment is followed by improvement in general health, and reduction in the quantity of sugar excreted in the urine. These claims have not been generally substantiated, but the method is deserving of a trial.

X-radiation of the upper abdomen, so as to include the liver and pancreas, has been advised.

The static wave may be used to reduce arterial tension and improve the general nutritive condition.

Diarrhœa.—The high-frequency vacuum electrode applied over the front of the abdomen frequently relieves this condition, once the exciting cause has been eliminated.

Mild faradism to the abdomen is also useful.

Dupuytren's Contraction.—This contraction of the palmar fascia may be treated by X-radiation in the same way as scar-tissue, combined with splinting to put the fibrous tissue continuously on the stretch. Repeated doses through a medium filter must be given. Only early cases can be cured in this way, but a good deal of improvement may be obtained in more advanced cases.

There is a tendency to relapse, but this is found after all forms of treatment for this condition.

Dyspepsia.—Atonic dyspepsia is treated with galvano-faradism and static sparks applied over the stomach.

The dyspepsia of neurasthenia is treated with the high-frequency vacuum electrode applied over the abdomen.

The method of intra-gastric electrization by means of an electrode passed into the stomach via the œsophagus has not proved of any great value, and is very unpleasant for the patient.

Eczema.—Chronic eczema often yields to small doses of X-rays in a most satisfactory manner, one or two exposures often clearing up a case which has resisted all other treatment for months or even years.

High frequency by means of the vacuum electrode or the effleuve is of considerable value. If the vacuum electrode is used the affected skin should be covered with a dry, smooth bandage. Very little spark effect is desirable.

Endometritis.—Zinc ionization gives good results. A zinc rod, wrapped round with ribbon-gauze soaked in zinc sulphate solution, is passed into the uterus. One end of the gauze is allowed to project from the external os, so as to insure easy removal should the rod be withdrawn without its covering. The zinc rod is connected to the positive pole, and a current passed for 10 to 15 minutes; 20 to 30 ma. is sufficient. Removal of the intra-uterine electrode is facilitated by passing a weak current in the reverse direction for a couple of minutes.

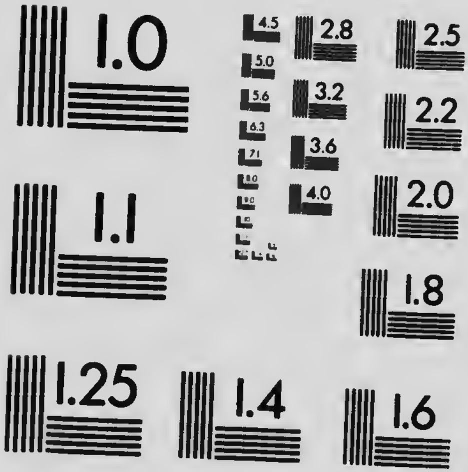
The treatment may be repeated in 14 days if necessary.

Epididymitis.—Bipolar applications of diathermy, one electrode being on either side of the affected testicle, should be given in acute gonorrhœal cases. It is essential that the application should be as strong as the patient can bear, and should last for 20 minutes to ½ hour. Treatment may be repeated daily. Rapid improvement commonly results, and the incidence of occlusion of the seminal ducts is greatly diminished.

Epilepsy.—Applications of high frequency to the head and spine, combined with X-radiation of the head (heavily filtered to avoid epilation), produce

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



a temporary improvement in a fair proportion of cases. Cerebral galvanism has produced some very encouraging results in cases where it was commenced within a few months of the first epileptiform seizures, and continued at frequent intervals over a period of many months.

Epithelioma.—See **Carcinoma.**

Erysipelas.—Exposure to red light is of value, as is also the static breeze.

Eustachian Catarrh.—Zinc ionization may be given by means of a zinc rod shaped like the Eustachian catheter. Currents of 1 ma. for 5 to 7 minutes are passed, and the treatment repeated at intervals.

Exophthalmic Goitre, both in its acute and chronic forms, yields well to X-radiation. A fairly prolonged course of treatment is required (see Chapter XIII.).

Diathermy has also been advised in this condition, but X-radiation is far more reliable.

Favus, where this occurs on the scalp or other hairy parts, is best treated by means of epilating the affected area with X-rays. Suitable treatmens will then produce complete cure of the condition before the hair commences to grow again.

Fibroids (Uterine) and **Fibrosis Uteri.**—The indications for X-ray treatment, and the methods employed, are discussed in Chapter XII.

Fibrositis.—In its acute form this is best treated by local or general electric light baths combined with high frequency with a vacuum electrode, the latter being applied through the clothes so that considerable spark effect is obtained.

Chronic fibrositis often yields to the same methods; should it prove obstinate, a few X-ray exposures will frequently be of value. These should be combined with, not take the place of, the high-frequency applications.

Diathermy may be found more effectual than high frequency in some instances, but the latter form of treatment is usually highly satisfactory.

In very obstinate cases salicylic or iodine ionization should be tried. Heavy currents and prolonged applications three or more times a week are necessary.

Fistula-in-Ano.—This condition sometimes yields to zinc ionization, a zinc rod being passed up the fistula to its extreme end. The large proportion of failures which are met with are probably due to the difficulty of obtaining contact of the zinc rod with every part of the fistulous wall. When the fistula can be demonstrated to be multilocular or very tortuous, electrical treatment is not advisable, as it can only lead to disappointment.

Frostbite.—Diathermy is a useful form of treatment. Great care must be taken not to damage the skin by too strong an application.

Recovery from frostbite of the extremities (and also from trench-foot) is greatly accelerated by rhythmic faradic currents given by means of Schnee baths.

The current should be strong enough to produce vigorous contraction of the muscles of the hands and feet. Treatment should be given for 10 to 15 minutes, and repeated daily.

Furunculosis.—An attempt may be made to abort isolated boils early in their development by inserting a zinc needle into the middle of the swelling, and passing a current of 4 to 6 ma. for 5 minutes, the needle being, of course, connected to the anode. This treatment is painful. The healing of boils after incision or bursting, and separation of the slough, is accelerated by zinc ionization of the granulating cavity.

Prevention of recurrent crops of boils is attempted (and very often with complete success) by daily zinc or salicylic ionization of the affected area.

The high-frequency effleuve is a useful adjunct to ionization both in the treatment and prevention of boils. Another admirable method of treatment is provided by ultra-violet radiation, the Simpson light being the best form to employ. Exposures should be given daily at first, and continued at increasingly longer intervals for several weeks after healing of the last boil.

Gangrene.—Cutaneous and Symmetrical. Both forms may be treated with some hope of amelioration by means of hydro-electric baths, the galvanic current being employed. Cerebral and spinal galvanism may also prove of value.

Goitre—See **Exophthalmic Goitre.**—The parenchymatous form of goitre does not yield to electrical treatment. Malignant goitre may be treated with X-rays on the lines laid down under the heading of **Carcinoma.**

Gonorrhœa.—Considerable advances have been made of late in the treatment of both the acute and chronic forms of this disease by copper ionization.

Copper electrodes in the form of sounds are used. The urethra is thoroughly irrigated before the introduction of the electrode. Two to 5 ma. are passed, and the application repeated weekly if necessary.

In very early cases, before the discharge has become purulent, one application may effect a cure. In this, as in all forms of treatment for gonorrhœa, it is essential to avoid overtreatment. Diathermy has also been applied for uncomplicated anterior gonorrhœal urethritis. (See also **Epididymitis.**)

Gout.—The pain of an acute attack of gout may be relieved by the passage of a fairly heavy galvanic current through the affected joint; or salicylic ionization may be substituted for simple galvanism.

Recurrent and chronic gout is treated by salicylic and lithium ionization, general and local electric-light baths, and high frequency by means of the auto-condensation couch or the auto-conduction cage.

Diathermy is often effectual in causing absorption of the deposit in joints which have been the subject of repeated attacks of gout.

Habit Spasm.—Local electrical treatment is contra indicated. Cerebral galvanism should be given a trial, but not persisted with unless definite improvement manifests itself after two or three applications.

Hæmorrhoids.—These may be transfixed by a zinc needle, connected to the positive pole, after application of a local anæsthetic. The current is gradually increased to 20 to 25 ma. and allowed to flow until the pile becomes greyish-yellow in colour.

Only one hæmorrhoid should be treated at a sitting, and ten to fourteen days should elapse between each treatment, so the method is tedious when many piles are present.

An excellent method of dealing with piles is by surgical diathermy. A general anæsthetic is advisable The piles are drawn outside the anal margin after stretching of the sphincter, and each is in turn coagulated by application of the diathermic current from a suitably shaped metal electrode.

The coagulated piles are left *in situ*, and separate in the course of a few days, leaving a clean, dry, granulating surface.

Headache.—Headache for which there is no exciting cause may be treated by cerebral galvanism; this form of treatment is also of value in cases of persistent or severe intermittent headache following injuries to the head, including fractures of the base and fissured fractures of the vault of the skull.

Mild faradism is sometimes effectual in relieving frontal headache, and the same is true of the high-frequency vacuum electrode applied directly to the skin of the forehead.

Hemiplegia.—See **Paralysis.**

Herpes Zoster is treated by means of mild galvanism (8 to 10 ma.). A large positive electrode covers the origin of the affected posterior roots from the spinal cord, and a large negative electrode covers the lateral and anterior distribution of these roots.

This treatment is of value in all stages of the disease, including the after-effects of intercostal neuralgia often met with. Applications should last 15 to 20 minutes.

Hodgkin's Disease (Lymphadenoma).—The treatment of this disease by X-radiation is described in Chapter XII.

Hyperidrosis.—This is effectually treated by means of X-radiation. Thin filters should be used, and several doses given, so that the effect (which consists of atrophy of the sweat-glands) is attained gradually. It is inadvisable to produce entire cessation of sweating, as in this case the skin becomes dry and ill-nourished, and irritation ensues.

Hyper- and Hypo-tension (Arterial).—See **Cardio-Vascular Disorders.**

Hypertrichosis.—The only safe and reasonably sure means of destroying superfluous hair is by means of electrolysis. For description of technique see Chapter VI.

Hysteria.—Generally speaking, the hysterical patient does not derive any benefit from electrical treatment. In fact, electrical treatment, directed towards the general condition of hysteria, is strongly contra-indicated. Certain hysterical manifestations, however, will be found to respond well to suitable electrical treatment, *combined with suggestion.* The latter factor is most essential. Hysterical amaurosis, or contraction of the field of vision, is treated with the faradic current, a small electrode being placed over the eyelid.

Hysterical paralysis of the limbs is treated with strong faradism (to which the hysterically paralyzed muscle always reacts). The current should be sufficiently powerful to cause a vigorous and painful contraction, and after each application the patient must be exhorted to repeat the contraction voluntarily. The treatment must be intensive; it is very advisable to persist at the first séance until definite improvement has been obtained. Treatment may be repeated daily, but should be abandoned at the earliest possible moment. When anæsthesia is present, the stimulus must be sufficiently powerful to produce pain. If the faradic current is not successful in this, a wire brush will always succeed if used with sufficient vigour.

Hysterical aphonia, depending on paralysis of the adductors of the vocal cords, will nearly always yield to faradism applied through the larynx from side to side. Severe cases respond much more rapidly to the current applied by means of the intra-laryngeal electrode.

Hysterical contractures are treated with galvanism to the contracted muscles, and faradism to their antagonists. Some of these cases of contractures are exceedingly difficult to deal with. Hypnotic suggestion, if available, should be recommended in preference to electrical treatment.

Ichthyosis.—Hydro-electric baths with the galvanic current appear to have been beneficial in some cases. The prognosis of the results of treatment should be very guarded.

Impetigo.—The static breeze and the high-frequency effleuve are useful adjuncts to the ordinary treatment of this condition. The ultra-violet light, preferably by means of Simpson rays, is excellent, and will frequently effect a cure unaided.

Incontinence of Urine.—See Chapter VIII.

Insanity.—The fully developed case of insanity, of whatever form, is not amenable to electrical treatment. The incipient or border-line case, especially of the depressed type, sometimes shows improvement with general hydro-galvanic baths and general high frequency. Cerebral galvanism, though but little used in this type of case, has shown a certain number of encouraging results. It is deserving of more extensive trial, and until this has been given no definite statement of its value can be made.

Insomnia generally yields to general high frequency on the auto-condensation couch. Insomnia, associated with neurasthenia, may be treated by means of the static breeze to the head.

Intermittent Claudication.—Faradism applied by means of two Schnee baths, in which the legs are immersed, sometimes relieves this condition.

Keloid.—See **Cicatrices.**

Lachrymal Obstruction.—This is treated by electrolysis of the lachrymal canaliculi. A platinum probe, connected to the negative pole, is passed into the canaliculus, and a current of 3 ma. passed for 30 seconds. The treatment is repeated at intervals of a week or ten days. The ultimate result is good.

Laryngitis.—Simple laryngitis is treated with high frequency by the glass vacuum electrode. In tubercular laryngitis high frequency combined with X-radiation is given; or X-radiation alone often gives good results. Moderately heavy doses and thick filters should be employed.

Leuchæmia.—See Chapter XII.

Leuchorrhœa.—This is treated by means of high frequency with a vaginal vacuum electrode, or a similar electrode filled with water is probably equally effective, and possesses the advantage of not becoming unpleasantly hot. Treatment should be given three times a week, except during the menstrual periods, when it is suspended. It is important that the electrode should be of sufficient size to fill the vagina, otherwise painful sparking will occur.

Lichen Planus.—Small doses of X-rays or radium are of considerable value. The static breeze may be used in conjunction with one of the above.

Lipoma.—The common encapsuled lipoma is not amenable to electrical treatment, though Nogier states that the tumour is reduced in size by X-radiations.

The pain of lipomatosa dolorosa is relieved by heavy doses of X-rays, but the disease does not appear to be affected otherwise by this treatment.

Lumbago.—Acute cases are generally quickly cured by means of high frequency with the glass vacuum electrode, given through the clothes to obtain considerable spark effect.

Chronic cases should receive the same application combined with local light-baths, and an occasional dose of X-rays.

Obstinate cases will sometimes yield to diathermy, and salicylic or iodine ionization may be tried. Ionization, however, is generally disappointing in these cases. Heavy currents for a considerable period are essential.

Lupus.—See Chapter XII.

Lymphadenitis (Hodgkin's Disease).—See Chapter XII.

Lymphangioma.—These are treated by electrolysis on the same lines as capillary angiomata. The technique is described in Chapter VI.

Lymphosarcoma.—Heavy doses of filtered X-rays will diminish the size of the tumour in most cases, and produce temporary relief of pressure symptoms. When the growth is situated in the thorax multiple points of entry should be employed, with the hardest rays available. The Coolidge tube is of great value in treating these deep-seated neoplasms.

Maxillary Antrum (Empyema of).—Chronic empyemata of the antrum of Highmore, which do not clear up in spite of efficient drainage, etc., may be treated by zinc ionization. The patient lies with the head on its side, the affected antrum downwards. The antrum is washed out and then filled with a solution of zinc sulphate, and a zinc rod, insulated except for its terminal ½ inch, is inserted into the antrum through the opening which has been made for drainage. A current of 3 to 5 ma. is passed for 10 minutes. Treatment can be repeated in a week's time.

Melanosarcoma.—This very malignant growth is little amenable to any treatment. It may be held in check for a time by repeated heavy X-radiation.

Menorrhagia and Metrorrhagia, occurring without any discoverable pelvic lesion, are benefited by hydro-electric sitz baths with the sinusoidal current.

Moles.—These are treated by electrolysis if hairy, or by zinc ionization if non-hairy.

The technique is described in Chapter VI.

Morphœa.—Static sparks give good results in many cases.

Myalgia.—Acute cases generally yield readily to high frequency, with the glass vacuum electrode applied through the clothes to insure considerable spark effect. When the affection is very widespread the auto-condensation couch is preferable.

Ionization with salicylic salts or iodine give good results in some cases, and the constant galvanic current without medicinal electrolytes is also useful.

In chronic cases light-baths and high frequency should be combined, with occasional doses of X-rays if the condition prove obstinate.

Mycosis Fungoides. Thorough X-radiation should be employed in the treatment of this very intractable disease. When the skin is already involved the first dose should be given through a thin filter (½ to 1 mm. aluminium). This should be followed by radiation through a thicker filter on subsequent occasions.

Myopathies. Faradic stimulation may help to retard the progress of the various muscular dystrophies.

It does not, any more than any other method of treatment, permanently arrest the disease.

In the other myopathies electrical treatment is of no value, and in myasthenia gravis it is actually contra-indicated.

Myxœdema.—Electrical treatment is, of course, entirely subsidiary to medicinal treatment. Given in conjunction with the latter, high frequency or the auto-condensation couch is of value in producing increased activity of metabolic processes.

Nævus.—This is treated by electrolysis. For technique see Chapter VI.

Nasal Polypus.—Monopolar or bipolar electrolysis may be employed. A current of 15 to 20 ma. is passed until the polyp is coagulated.

Nephritis.—Acute nephritis often calls for treatment with the electric-light bath. A portable bath shaped for the trunk is employed, and is, of course, used in the patient's bed.

Chronic nephritis is benefited by general electric-light baths and general high frequency. The high blood-pressure is reduced, and many of the symptoms depending upon this are abated. Whether the quantity of albumen in the urine is diminished as a result of this treatment is questionable.

Neuralgia (Cephalic, see **Headache).**—Trigeminal neuralgia [illegible] form is sometimes relieved by [illegible]zation, by the constant galvanic current (positive pole to the affected area), or by repeated small doses of X-rays.

In severe forms only the last-named can be attempted.

Neuralgia in other situations—brachial, deltoid, intercostal, etc.—should be treated by the electric-light bath combined with the constant galvanic current (positive pole over the most painful areas, 5 to 10 ma. for 20 minutes daily). Salicylic and iodine ionization is sometimes effectual and diathermy often gives rapid relief.

If the condition does not show fairly quick improvement under any one form of treatment, this should be abandoned and some other form given a trial. In the author's experience the constant galvanic current is the most reliable method in these cases.

Neurasthenia.—Cerebral galvanism and high frequency on the auto-condensation couch are most useful adjuncts to general treatment directed against this disease.

Neuritis.—Idiopathic neuritis is treated by the electric-light bath, salicylic and iodine ionization, diathermy, and high frequency with the vacuum electrode. The constant galvanic current, positive pole to the area of greatest pain, and direction of flow towards the periphery of the nerve, is also most useful.

In infective and toxic neuritis the essential procedure is to remove the cause, and the same applies to neuritis resulting from pressure, etc. When this has been done, the above methods may be utilized to accelerate the recovery of the nerve. When paralysis forms an important manifestation, as in alcoholic and lead neuritis, the paralyzed muscles should receive faradic or galvanic stimulation as soon as the part is free from pain.

In the neuritis which sometimes occurs as the result of an infected wound which exposes the nerve trunk, the pain is often relieved with [illegible] rapidity by the constant current, positive pole to the affected portion of the nerve, 5 to 10 ma. for 20 to 30 minutes.

Obesity.—Faradism by means of the Bergonié chair is the best electrotherapeutic method for treating these cases. (See Chapter VIII.)

Slighter reductions in weight are obtained by high frequency on the auto-condensation couch, and by cerebral galvanism.

Osteitis.—Tubercular osteitis often responds in a remarkable manner to X-ray treatment. This is not only the case in "closed tuberculosis" of bones, but also after the formation of sinuses. It is needless to say that the appropriate surgical treatment must not be omitted. This method of treating tubercular osteitis should be far more widely practised than is at present the case.

Osteo-Arthritis.—See **Arthritis.**

Otitis Media.—Chronic otitis media is treated by zinc ionization. The patient reclines with the affected side uppermost, and the middle ear and external auditory meatus is filled with warm solution of zinc sulphate (1 per cent.).

The external auditory meatus is then filled loosely with cotton-wool soaked in the same solution, and the irregularities of the concha are levelled in the same way. On top of this is placed a round or oval electrode cut to the appropriate size, and connected to the positive pole.

The indifferent electrode may be held in the hand A current of 3 to 5 ma. is passed for 15 minutes. Some transient vertigo commonly results. Treatment is repeated twice a week.

A similar technique may be employed in cases of dry otitis media (otitis sicca). The ions are then driven through the membrana tympani. Good results have recently been reported by this method in this very intractable disease.

Ozœna.—High frequency given by means of a small nasal vacuum electrode is of considerable value in arresting the progress of the disease.

Papilloma.—Cutaneous warts may be treated by electrolysis. The base of the wart is transfixed with a negative needle (or a positive needle if the zinc needle is used), and a current of 1 to 2 ma. passed for 2 to 4 seconds. If the wart is more than $\frac{1}{4}$ inch in diameter it must be transfixed two or more times in different diameters. In treating big warts by several transfixions, considerable inflammatory reaction will be found to develop; this can be allayed by boracic fomentations.

When multiple warts are present, X-radiation affords an easier means of treatment. Two or three doses through a thin filter will cause the warts to disappear.

Papilloma of the bladder is treated by diathermy. For technique see Chapter X.

Paralysis.—Paralysis resulting from lesions of the upper motor neuron (cerebral hæmorrhage, etc.) should be treated with faradic stimulation of the paralyzed muscles as soon as signs of active mischief have subsided. The treatment should be continued daily for one month after improvement has definitely ceased. This stimulation appears to expedite and increase the degree of recovery, and to diminish the occurrence of secondary rigidity. Should secondary rigidity appear, the treatment should be discontinued.

Old cases of central paralysis which have become stationary derive no benefit whatsoever from electrical treatment.

Paralysis resulting from disease or injury of the lower motor neuron should be treated with whatever form of current the paralyzed muscles will react to, bearing in mind that faradism is the method of choice in most cases.

Acute anterior poliomyelitis should be treated in the full-body bath with rhythmic sinusoidal currents. Chronic anterior poliomyelitis (progressive muscular atrophy) is treated by faradic stimulation. For treatment of peripheral nerve injuries see Chapters V., VIII., XIV.

Paralysis Agitans.—The constant galvanic current benefits some cases.

Periostitis.—Simple traumatic periostitis in its recent state is treated with diathermy.

The pain of chronic periostitis is relieved by diathermy, the high-frequency effleuve, or X-radiations.

Peritonitis.—Chronic tubercular peritonitis is treated with repeated filtered X-radiation, or with diathermy, or both may be used alternately.

Many ports of entry should be adopted for the X-ray exposures. Diathermy should be given through the abdomen, one large pad covering the front, another the back.

Each diathermy treatment should last $\frac{1}{2}$ to $\frac{3}{4}$ hour.

Phlebitis.—High frequency with the vacuum electrode may be given as soon as the acute symptoms have subsided. Pain is relieved and nutrition improved. The electrode should be kept moving in direct contact with the skin.

Pleurisy.—The pain of acute pleurisy without effusion is relieved by applications of diathermy through the chest. These must be given with caution, as diathermy applied through the thorax is very liable to produce a feeling of faintness, or an actual attack of syncope, owing to action on the heart. Chronic pleural effusions and pleural adhesions are stimulated towards absorption by the same treatment.

Heavy galvanic currents passed through the affected side of the chest from large electrodes also stimulate the absorption of pleural effusions.

Poliomyelitis (Anterior).—See **Paralysis.**

Prolapse of Rectum.—Mild examples of this condition are much improved by high frequency given with a rectal electrode—preferably a glass tube filled with saline to prevent overheating. The treatment is most effective in those cases where the mucous membrane only enters into the protrusion. It should be repeated at least three times a week. Mild rhythmic faradism given in the same way is also very useful, especially when there is considerable weakness of the external sphincter of the anus.

Prostatic Hypertrophy.—As an alternative to operation, heavy filtered X-radiations may be given via the perineum. The scrotum and testes must be carefully protected. At the present time the treatment is little used, but improved technique will probably demonstrate that it possesses considerable value.

Hypertrophy of the middle lobe of the prostate may be treated by the diathermic cautery, in a similar manner to papilloma of the bladder.

Pruritus Ani.—This condition is nearly always secondary to some lesion of the anus or neighbouring parts, or of the rectum. Cases should therefore always be referred to the surgeon for thorough examination before electrical treatment is undertaken. When the pruritus is primary, it can always be rapidly cured by X-radiation. Three or four fairly heavy doses through a thin filter usually suffice to effect a permanent cure. A convenient technique is for the patient to sit on the X-ray couch, with the tube below. This flattens out the parts, insures free access to the anus and peri-anal skin, and renders protection of the testes a matter of ease. The latter is a very essential point to bear in mind.

Pruritus Vulvæ is treated on similar lines to the above. Here again an exciting cause must be eliminated before proposing treatment.

Pulmonary Tuberculosis.—Exposure to the ultra-violet light and X-radiation of the thorax are the means suggested for the treatment of this disease. Some observers report good results, but more extensive trial is necessary before forming an opinion on the value of this treatment.

Pyorrhœa Alveolaris.—This condition should only be treated in conjunction with a dental surgeon, and after radiography of the affected teeth. If the latter show any considerable absorption of the alveolus, it is improbable that the electro-therapist will effect much improvement. The mildest forms of the disease are treated by X-radiation of the gums, small stimulating doses being given once or twice a week. The lips and face must be carefully protected.

X-radiation may be supplemented by high frequency with a special oral vacuum electrode. If pockets have formed about the teeth, these should be subjected to zinc ionization, a fine zinc rod being inserted into the pocket. Only a mild current (½ to 2 ma.) can be borne. The treatment may be repeated once a week.

Raynaud's Disease.—See **Cardio-Vascular Disorders.**

Renal Colic.—This is frequently relieved by the passage of a heavy galvano-faradic current through the affected loin, one electrode being placed on the front of the abdomen and one covering the loin.

Rheumatism (**Muscular,** see **Myalgia**).—Articular rheumatism, in its acute form, may be treated by salicylic ionization of the affected joints. The degree of benefit derived is doubtful. Chronic articular rheumatism is treated by electric-light baths, high frequency on the auto-condensation couch, and salicylic, chlorine, or iodine ionization of the affected joints.

So-called gonorrhœal rheumatism is treated by diathermy and salicylic ionization.

Rheumatoid Arthritis.—See **Arthritis.**

Rickets.—Hydro-electric baths with the rhythmic sinusoidal current are very useful in improving the general condition.

Ringworm (Scalp).—Small circumscribed patches may be treated by zinc ionization. The most satisfactory treatment for ringworm of the scalp is complete epilation by X-rays (see Chapter XII.).

Ringworm of non-hairy parts does not require electrical treatment.

Rodent Ulcer.—See Chapters XII. and XIII.

Sarcoma.—These growths usually show rapid and marked diminution in size as the result of X-ray or radium treatment. The effect is only temporary, but may be maintained by continuance of treatment for a good many months. Sometimes the tumour disappears entirely (to clinical examination) for a time. In the very malignant forms of sarcoma this treatment compares fairly favourably with more radical surgical procedures.

Sciatica.—See **Neuritis.**

Scleroderma.—Heavy doses of X-ra[ys] unfiltered, or through ½ mm. aluminium, som[eti]mes produce marked improvement. No cures have been reported.

Scleroses (Spinal).—Improvement sometimes follows on X-radiation of the spine in the various spinal scleroses. Treatment must be continued over a considerable period. At the best it can only be palliative.

Sebaceous Cysts.—These may be treated by electrolysis. A negative needle is thrust into the centre of the cyst, and a current of 8 to 10 ma. passed for 2 or 3 minutes. Three days later the negative needle is thrust through the small cutaneous slough which has formed, and a current of 10 ma. again passed. Three days later the cutaneous slough will have separated, leaving a small opening, and through this a softened mass consisting of cyst contents, plus lining of cyst wall, may be expressed. Except in rare instances this procedure possesses no advantages over surgical excision.

Seborrhœa Capitis.—High frequency by means of a special comb-shaped vacuum electrode is excellent treatment for this condition. It should be applied for 15 minutes daily. A slight amount of spark effect is advisable.

Sinusitis (Frontal).—High frequency by the glass vacuum electrode applied over the affected frontal sinus is useful in subacute and chronic inflammation.

Sterility in the female, resulting from atrophy or small imperfections of development of the uterus, is treated with rhythmic undulatory galvanic currents with reversals of polarity. One electrode is placed on the abdomen; the other is intra-vaginal or intra-uterine. High frequency with a vaginal vacuum electrode also sometimes yields satisfactory results in these cases.

Sycosis.—This is treated by epilation with X-rays. The results are excellent.

Synovitis.—Acute synovitis is treated by the electric-light bath, and the galvanic current of maximum strength bearable passed through the joint for 20 to 30 minutes. This aids in absorption of the effusion.

Chronic synovitis is usually associated with muscular wasting, which again reacts upon the stability of the joint. Faradic stimulation of the affected muscles is here the line of treatment to pursue. The case should also be referred to the masseur for massage and exercises.

Syringomyelia.—Considerable improvement in this condition may be attained by X-radiation of the affected part of the spinal cord. Repeated exposures with a hard tube and thick filter should be given.

Tabes Dorsalis.—Treatment directed against the pathological condition takes the form of X-radiation of the dorsal and lumbar spines. Sometimes marked improvement results, but this is by no means invariable, and the treatment sometimes appears to be even injurious. It should therefore be discontinued if the patient shows any signs of going down-hill.

Symptomatic treatment is chiefly directed against the "lightning pains" in the lower limbs. These pains are often relieved by the galvanic current, the negative pole being led into two Schnee baths in which the legs are immersed, while the positive electrode is passed up and down the spine.

Teno-synovitis.—Diathermy is very useful in this affection. In teno-synovitis of the wrist the patient may hold one electrode whil the other surrounds the forearm or upper arm.

Tinea Capitis.—See Chapter XIII.

Tinnitus Aurium.—This may be treated by galvanism. A bifurcated positive electrode, shaped like the binaural stethoscope, is adjusted so that the two terminals rest on the mastoid processes immediately behind the conchæ. The negative electrode is held in both hands. A small curren —2 to 5 ma.—is gradually turned on, allowed to flow for 10 minutes, and gradually turned off. Considerable vertigo may result. An alternative method is the high-frequency brush-discharge applied to the mastoid process for 3 to 6 minutes three times a week. When the condition is associated with chronic otitis media improvement rarely results, but of other cases a fair proportion are relieved, and some completely cured, according to many observers. Treatment should be continued for several weeks after the symptoms have subsided.

Torticollis.—Only the rheumatic variety of this condition is amenable to electrical treatment. Electric-light baths, together with the high-frequency vacuum electrode or salicylic ionization, generally lead to rapid relief of pain and speedy cure.

Trigeminal Neuralgia.—See **Neuralgia.**

Ulcers.—Chronic ulcers nearly always respond well to zinc ionization and the ultra-violet rays; the exceptions are those large, very chronic ulcerations which present great induration of tissues around their margins.

Ionization is given once a week, all irregularities in the floor of the ulcer being carefully filled up with pledgets of cotton-wool soaked in the zinc sulphate solution. The active electrode is cut to the shape and size of the ulcer.

Ultra-violet radiation may be given daily, and the surrounding skin should be protected, especially if this is already inflamed. If the ulcer does not show signs of healing at the end of the first week, a few stimulating (small) doses of X-rays will frequently initiate the healing process.

Varicocele.—When this condition is really causing pain (a very small proportion of cases) diathermy applied to the scrotum will generally be found to give relief.

Warts.—See **Papilloma.**

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