the beating is arrested in diastole in both warm- and cold-blooded animals, that the action is probably directly upon the heart muscles, that the automatic centres are first affected and then the muscles are greatly weakened, although they still respond to artificial stimuli.

Clinical Tests for Phosphorus.—Expose to the vapors given off from the warmed material to be tested two strips of filter paper, one of which has been moistened with silver-nitrate solution, the other with lead-acetate solution. If phosphorus is present, the silver paper blackens while the lead paper should remain unchanged. If both papers blacken, hydrogen sulphide is present and must first be removed before testing. In such an event add to the material to be tested sufficient lead acetate solution to precipitate all the hydrogen sulphide as lead sulphide, and test with the two papers as before. The blackening of the silver-nitrate paper is due to the formation of silver phosphide and metallic silver.

A less satisfactory test consists in boiling the material to be tested with a small piece of roll sulphur. After a few minutes the piece of sulphur, which has taken up most of the free phosphorus present, is removed, washed, and examined in a darkened room. On being gently warmed and rubbed with the finger the sulphur will shine with the peculiar glow of phosphorus, if this latter element is present.

If possible the suspected material should always be tested in the laboratory by the Mitscherlich distillation method.

There are reasons for believing that phosphorus can exist in the body in the free state for about eight weeks. After twelve weeks it can still be detected in the form of phosphorous acid, but after about fifteen weeks it is probable that all the elemental phosphorus has been eliminated or oxidized to phosphoric acid. As regards the detection of free phosphorus after death, it is safe to say that chemical tests usually fail after four weeks; but there are instances in which it has been possible to obtain undoubted proof fifteen weeks after burial.

Emile Monnin Chamot.

PHOTOMICROGRAPHY.—DEFINITION.—The process of obtaining a macroscopic photograph of a microscopic object. It is sometimes incorrectly termed microphotography, which is the reduction by photography of landscapes, portraits, or other gross photographs to collodion positives of minute size, which are subsequently mounted beneath a small convex lens, in watch charms, paper knives, pencil handles, and the like. It is to be noted that this distinction is not universal on the continent of Europe. The above title in German is Mikrophotographie; in French, Photomicrographie.

HISTORY.—The first photomicrographs and probably also the first photographs were taken by Wedgewood and Davy. The record of their experiments, published in 1802, some time after the death of Wedgewood, show that they used a solar microscope and obtained images upon paper and leather which had been washed with a silver solution. They were, however, unable to fix the images so obtained and, when exposed to daylight, the entire surface became uniformly dark.

The Rev. J. B. Reade, of England, in 1837, with a solar microscope photographed entomological specimens and sections of vegetable tissues upon paper coated with nitrate of silver solution and fixed the images with an infusion of galls. In 1839, at a soirée given by the Mar-

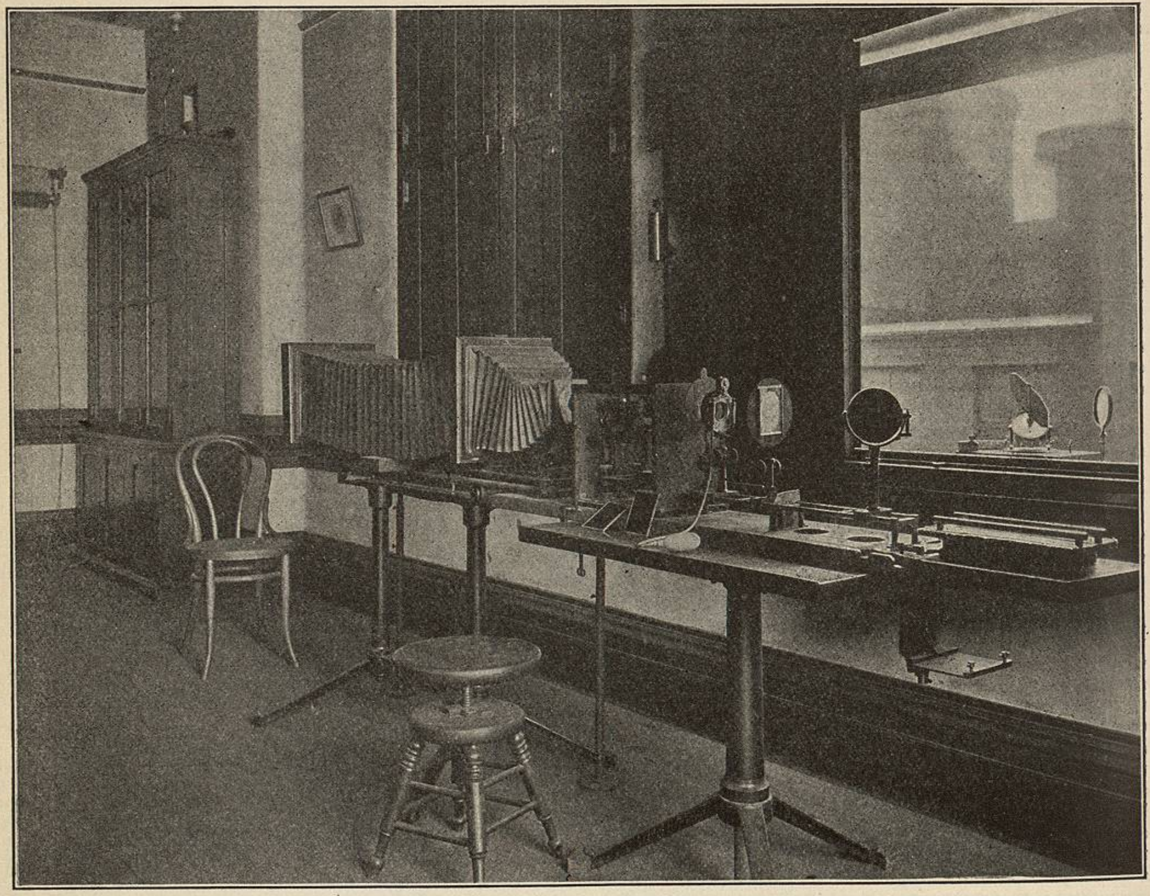

FIG. 3805.—Installation for Photomicrography with Heliostat. The objects are arranged, from left to right, in the following order: camera, microscope, screens, shutter, and mirror; outside the window, on a levelling stand: heliostat and a second mirror.

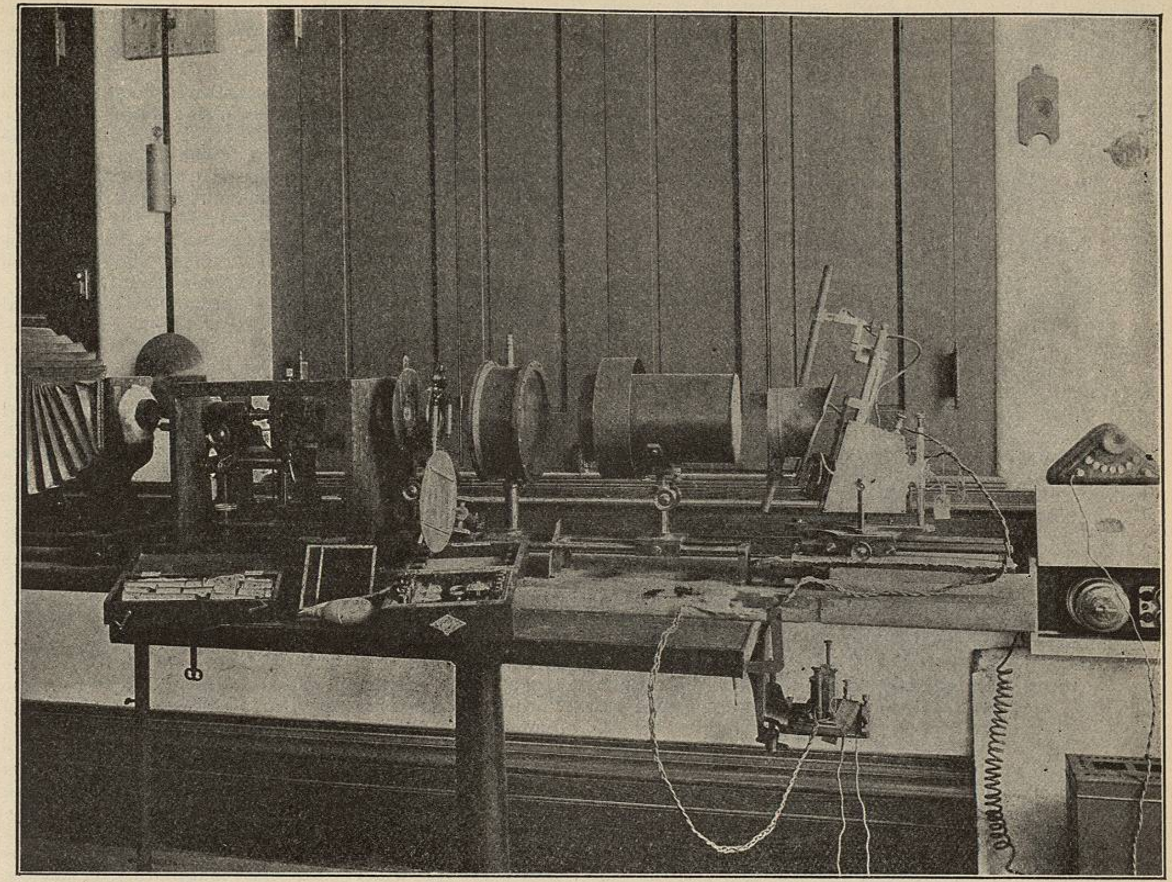

FIG. 3806.—The Optical Bench, Arranged for Photomicrography with the Electric Arc Lamp. The objects are arranged, from left to right, in the following order: end of camera, microscope, screens, shutter, water-bath, condenser system, arc lamp; on the table: battery of oculars and objectives, color screens and bulb of pneumatic release of shutter; under arc lamp—the adjustable shunt coil; at the extreme right, against the wall: switches and rheostat.

In practice a cloth is thrown over the frame which encloses the microscope, for the purpose of shutting out the rays of light from the eyes of the operator, while permitting at the same time all necessary manipulation. The screens, water-bath, condensers, and arc lamp are all enclosed in such a manner as to reduce to a minimum the escape of light into the room.

quis of Northampton, then president of the Royal Society, Mr. Reade exhibited more perfect results, and some of his photomicrographs were on sale at a bazaar in Leeds the same year. It was not until after Daguerre had announced his discovery before the Academy at Paris on the 19th of August, 1839, that attempts to use photography to obtain pictures through the microscope were generally undertaken. In 1840 Mr. Dancer, of England, photographed through a gas microscope upon silvered plates; he also by means of the solar microscope photographed wood sections and fossils on paper and glass plates. Dr. Donné, of Paris, in 1840, presented to the Academy of Sciences photomicrographs on daguerrotype plates; and in collaboration with M. Léon Foucault, in 1845, published an atlas on the study of the fluids of the body, illustrated by cuts from daguerrotypes. One of the first publications in England to use photomicrographs as illustrations was the *Quarterly Journal of the Microscopical Society*, which in 1852 contained prints from negatives by Mr. Joseph Delves. Since these early attempts the practice of photomicrography and its use for illustration have steadily grown. The list of those who have done notable work is a long one, and contains many well-known names.

The Apparatus.—The several parts comprising the apparatus for making photomicrographs are collectively called an installation. In its simplest form it may be a long bellows camera with a photographic lens on the front or on the front of a conical extension, as ordinarily used by photographers for making enlarged copies; such an arrangement is useful when the original object is of comparatively large size and the magnification slight, as the limit of a few diameters is very quickly reached by this method. For most photomicrographic work a microscope is a necessity, as are also the accessory apparatus on the optical bench and, in the present day of rapid dry plates, the camera. Sometimes, in the days when the slow, comparatively non-sensitive wet plates were in use, the room in which the optical bench and microscope were placed formed the camera; the source of illumination was outside the room, and enough diffuse light was admitted through yellow glass to enable the operator to work. Such an arrangement was used by Surgeon-General J. J. Woodward in making his now classical photomicrographs of difficult test diatoms, etc. At the present time, however, the rapid color-sensitive plate demands much greater care in the exclusion of all light not used in taking the picture, and many forms of photomicrographic apparatus have been devised. Some operators, in Europe especially, prefer to work with the vertical apparatus, subsequently enlarging the pictures so obtained; but most of the English and American photomicrographers use the horizontal apparatus, and with the long camera bellows obtain the desired magnification directly. The installation, then, may be described as consisting of the source of light, the optical bench with its accessories, the microscope, and the camera.

The Source of Light.—This may be an oil lamp of one or more burners, illuminating gas, a Welsbach burner, or an acetylene flame. All of these may be classified as illuminants of a low order, as when high powers are used their illumination becomes too feeble to enable satisfactory focussing of the image. The lime light in any of its modifications forms the next higher order of illuminant; magnesium ribbon or flashlight the next; then may be put the arc light; and, most powerful of all, the sun. When the sun is the source of light, it is necessary to use an heliostat to control the rays used for illumination, as after centring the light it should remain centred without appreciable variation; otherwise much time is wasted and many vexatious failures are inevitable. It is desirable that the heliostat be of comparatively simple construction in order that it may not easily get out of order. I have found that what is known as the Prazmowski heliostat is a very efficient form, being very easily adjusted and quite simple in construction. This instrument carries a single mirror on its axis which is caused to follow the sun by clockwork. The rays, being thrown at a convenient angle by adjustment when starting, are maintained in the same direction. A second mirror on an adjustable stand intercepts the rays reflected from the heliostat mirror and, if the installation is rightly placed, directs them through the microscope and camera. If, however, it is not convenient to have the installation so placed, a third mirror on the optical bench directs the rays in the desired direction (see Fig. 3805). All photomicrographers who have worked with sunlight know, however, how few are the perfect unclouded days when the work can be satisfactorily performed, as even the thinnest cloud passing across the sun's disc practically extinguishes the light with resulting delay and difficulty in making correct exposure; but notwithstanding the annoyances and difficulties attending the use of sunlight, until recent years those accustomed to it generally returned to its use after trying other methods of illumination. At the present time, however, with the electric current almost everywhere available, the use of the arc light frees photomicrography from many of the difficulties formerly obtaining. The essentials for illumination by the arc light are, the continuous current, a simple form of focussing lamp, a rheostat, and a shunt coil of simple form used outside the zone of heat radiated by the lamp, and capable of delicate adjustment. Many of the failures to obtain satisfaction from the arc lamp, aside from too delicate construction, have been due to the fact that the controlling coils were within the lamp body. Now, while such a lamp may work perfectly in the open where its heat is radiated away quickly, when we enclose it so that its light may not escape into the room to the annoyance of the operator, it soon begins to focus irregularly or not at all. The reason is simple: the actuating mechanism of the lamp is controlled by an electro-magnet; temperature has a decided influence on electro-magnets; with a given strength of current, the higher the temperature of the iron core the less will be the amount of magnetism developed therein. The remedy is also simple. A shunt coil with its armature balanced over a contact point and capable of close adjustment is inserted in the circuit anywhere between the lamp and its rheostat. It can thus be put where it will be unaffected by heat, and can be relied upon to perform its functions at all times. The normal current goes as usual by the two main wires to the lamp and back, but when the arc has reached such a length, determined by the adjustment at the shunt coil, that the resistance becomes too great, the current goes from the main wire by a small connecting wire through the shunt coil, actuates its electro-magnet, pulls down the armature, and through the contact mentioned above is shunted through a third wire, which enters the lamp by a separate binding screw and actuates the controlling mechanism. The lamp immediately focuses, and so delicately can the shunt coil be adjusted that the lamp will automatically adjust its focus every other second or two, each time moving the carbons together only a fraction of an inch, and keeping the crater of the positive carbon practically in the optical axis without flickering or change in the steadiness or intensity of the beam of light, the prime requisite of any illumination for photomicrography (see Fig. 3806).

The Optical Bench.—This consists of two parallel rails or V's or a slotted board fixed between the microscope and the radiant (the mirror reflecting the sunbeam, the crater of the positive carbon, or the flame of gas or lamp), and holding the condensers, water-bath to absorb the heat rays, diaphragm stands and screens for various purposes, and sometimes the shutter for the exposures. These are all arranged on stands so that they may be moved to and from the radiant. They should also be adjustable as to height as should the radiant itself.

The Microscope.—The microscope may be of the usual pattern; but for those using as low a power as a three-inch or four-inch lens, a microscope with a body tube of larger diameter and shorter length will be found most convenient. The long focus, low-power lenses can then be used inside the body tube, being held by a cone fitted to screw in place of the draw tube; beside the usual substage condenser there should be an achromatic substage condenser of about 1 N. A. adjustable for centring, a ring with screw thread to hold lenses sometimes used as condensers, and a simple low-power condenser for illuminating large objects when slight magnification is desired. There are also accessory pieces of apparatus, such as prisms, black ground stops, devices for oblique illumination, monochromatic illumination by means of the rays of the spectrum, etc., all fitted to the ring of the condenser carrier so as to be interchangeable. These latter are rarely used except for special lines of work. The stage of the microscope should be large and of the type known as mechanical, moving in any direction in its own plane. The aperture of the stage should be of such size that the high-power condenser may be brought close to the object. The front of the stage may be fitted with a sliding carrier for roughly centring the object and a tilting carrier for special occasions. The battery of objectives may consist of any number desired; it will be found, however, that a large number is by no means necessary for widely differing magnifications, as by lengthening or shortening the distance between the microscope and the sensitive plate, various magnifications may be had with the same objective. An amplifier may be used for the same purpose, as also oculars of differing powers.

The Camera.—This may be of any usual make, the size adapted to the wants of the operator, or it may be a specially made long bellows camera. It may be firmly fixed to the same bench or plank that carries the microscope, optical bench, and radiant; or it may have a separate stand of its own and be capable of movement to and from the microscope. It is quite necessary that the connection between the microscope and camera, while excluding all light not used for illuminating the object, should be of such a nature that no vibrations may be transmitted to the microscope when adjusting the plate holder or withdrawing the dark slide. A cone front with cylindrical end is usually placed on the camera, and this may be connected with the microscope by a light-tight sleeve of fabric, or it may fit in, without touching, a double metal cylinder on the eye tube. When using a long bellows camera, some means of focussing both the coarse and the fine adjustments of the microscope from back of the camera must be added to the installation. Various methods of accomplishing this have been described by photomicrographers, each having its advantages. The essential points are that whatever method is used, it must not convey any jar or vibration to the microscope, or bring a strain upon the screws of either adjustment. It must of necessity work smoothly.

Procedure.—It is necessary when first setting up and adjusting the various parts of the apparatus to consider some one part as fixed and adjust all the other parts to it. Generally it will be found best to consider the microscope as the fixed part, and that imaginary line passing through the centres of objective and ocular and indefi-

nitely prolonged, called the optical axis, as that line with which the centres of all the other parts from radiant to ground glass of camera must coincide. Suppose we have a long bellows camera, an arc lamp, an optical bench (with a large condenser, a water-bath, and supports for diaphragms or screens), and a microscope, and that we wish permanently to mount them upon a long narrow table or bench, two or three feet wide by about twelve feet long. At one end of our table we would place the lamp, next the optical bench, then the microscope turned to the horizontal position, and finally the camera. Upon the size of the ground-glass screen of the camera would depend the height above the table of the tube of the microscope. This having been determined, the base of the microscope is clamped firmly to the table in its proper position, so that the optical axis passes over a line drawn through the centre of the table in the direction of its length. The camera may now be placed behind the microscope and adjusted roughly as to the centring of ground glass with the optical axis. The same may be done with the optical bench in front of the microscope, and then with the lamp. A quick method of rough centring, which I have found practical, is to cross threads diagonally from corner to corner of the camera back, the ground-glass screen having been removed. This will give the centre of the ground glass screen. From this centre stretch a thread through the camera-tube of the microscope, through a pinhole diaphragm in the stage, and on through like diaphragms on the optical bench, fastening the thread at last to one of the carbons of the lamp. The various parts are now adjusted until the thread, being stretched taut, passes through the diaphragms without touching. The final centring is by the light. Removing the thread, putting a low-power objective in the microscope and starting the lamp, we focus the condensers so that the image of the crater, taken up by the objective, is thrown upon the centre of the ground-glass screen of the camera. After the centring is accomplished we are in readiness to take a picture. The object is fastened to the microscope stage and the low- or high-power substage condenser adjusted. The image may now be thrown upon white cardboard for adjustment, centring, etc., or by interposing ground glass and a color filter between the radiant and the substage condenser to render the light bearable to the eyes, the operator may view the image directly through the microscope in the ordinary way. The camera is then connected as above to the microscope and the final focussing done from back of the ground-glass screen, or, as some prefer, by means of a magnifying glass adjusted to the surface of a plate glass screen, which occupies the same position as the sensitive plate when the picture is taken.

We must now wait a few moments and then re-examine our image. If it is as sharp as we left it, we may proceed to photograph it; if, however, it is not so sharp as when we had finished focussing it, it will be necessary to find the cause and the remedy. The change of adjustment may be caused by jarring, by a worn thread on the micrometer screw, by too strong a spring in the micrometer movement, or by a change in the temperature of the room or parts of the apparatus. The microscope should be so mounted that no jar can be transmitted to it; worn parts should be replaced; and the temperature of the room should always be warm so that the starting of the lamp will not cause a noticeable increase in that temperature. It is always well to start the lamp a few minutes before one is ready to take the picture, and allow the different parts to adjust themselves to any changed conditions. The adjustment of focus, etc., being satisfactory, the exposing shutter is closed. The plate-holder containing the sensitive plate is placed in position and the exposure made. The subsequent operations of developing and printing are purely photographic, and are the same as in ordinary photography.

Special Forms of Apparatus.—Of special forms of apparatus and adaptations to special purposes there are many. Perhaps among the most useful to the laboratory worker in bacteriology, where a limited range of magnification (*i.e.*, from two hundred to one thousand diameters) is desired, is that of the Misses Foot and Strobell. Any of the small vertical cameras may be used, and the microscope may be the same one used in ordinary research. The novelty consists in obtaining the focus directly by the eye, observing the image through the microscope with any one of a series of negative lenses placed on top of the eyepiece. The negative lenses used are those test sets furnished by opticians, and number from one to ten dioptries and their fractions. The use of this lens will of course cause the image to vanish and refocussing will be necessary. If the right minus lens has been chosen, upon its removal from over the eyepiece the image will be found thrown upon the ground glass of the camera above as a sharp picture. In each case the minus lens, best adapted to the end in view, must be found by trial. The method is faulty in that no provision is made for removing the negative lens from the eyepiece without some risk of disturbing the focus obtained. It has, however, the great advantage that any light can be used that one would ordinarily view objects through the microscope by, as ordinary diffused daylight. The exposure will of course run into the minutes with its attendant risk of change of focus or displacement. The preliminary wait, after obtaining the focus by this method to allow for change in focus, etc., is more important than with the horizontal apparatus; for the microscope being in the vertical we have the influence of gravity acting directly upon the focussing mechanism.

Photomicrography of Colored Objects.—In former years, when the wet collodion process was in general use, and when later the gelatin dry plates were introduced, the photomicrographer was limited in the selection of subjects to those that were nearly colorless, and was unable correctly to render those objects that contained mixtures of red, or yellow and blue. The chloride of silver of the wet plate and bromide of silver of the dry plate were alike sensitive to the light rays of short wave length (*i.e.*, the blue and violet) and comparatively insensitive to the rays of longer wave length (*i.e.*, the green, yellow, and red). The blue portions of an object would be fully impressed on the plate long before the green, yellow, or red portions made any impression at all; and if an attempt was made by prolonging the exposure to render the latter, the blue portion through over-exposure would be lost. It was not until Vogel announced his discovery that an ordinary gelatin dry plate, when bathed in a solution of an aniline dye, became more sensitive to the rays of longer wave length, that it became possible to represent by the light and shade of the photograph the brilliancy of the various colors as they affected the eye. It was not enough simply to dye the plate. The dye, while rendering the plate more sensitive than before to the yellow end of the spectrum, did not diminish its sensitiveness to the blue which was still in excess. The problem was solved by diminishing, or in some cases entirely cutting out the blue and violet rays by the use of fluids that absorbed them. Such fluids, termed color filters, had previously been in use for just the opposite purpose, *i.e.*, to allow only the rays of highest refrangibility to pass through the object, for the purpose of increasing the resolving power of the objective. It was afterward found that films stained with the proper dyes could be used in place of the fluids, a gain in convenience. Since then the color or colors of the object do not present much difficulty, provided, however, the object is not too thick nor too deeply stained in parts; nor, on the other hand, so lightly stained as not to afford sufficient contrast, as in certain thin pathological specimens where the diseased tissue will not take a good stain. It may be almost impossible to obtain a satisfactory photomicrograph of such objects. It is possible at the present time to go beyond the mere representation of colored objects in monochrome, as by the use of the proper color screens, as first demonstrated by the writer in 1895–96, three separate photomicrographs may be taken of a section stained in three or more stains; and by means of the commercial three-color printing processes now in use, it can be quite faithfully reproduced in its original colors.

Preparation of Specimens.—The special preparation of specimens for photomicrography is not at present so necessary as before the introduction of the color-sensitive plate and the color filter. There are, however, certain requirements that have to be complied with if the best results are to be obtained, as, for instance, sections of tissue must be thin, evenly cut, and, above all, they should be flat. Many an otherwise good specimen cannot be used for photomicrography because sufficient care was not taken to get it perfectly flat upon its slide, and with its cover-glass down upon it. Now it must be remembered that the objective has no depths of focus: that is, only those objects or portions of the object in one plane at right angles to the optical axis can be in focus at one time. Any other plane of the object requires a separate focussing of the objective to render its image sharp; and therefore a section only slightly irregular, and which to the eye, (owing to its power of accommodation, which is involuntarily used) seems quite flat, upon being photographed will give a negative for the most part sharply defined, but containing spots or areas of various shapes which are quite blurred. The photomicrographer cannot by any means short of flattening such a specimen obtain from it a good result: for if he should, by stopping down the substage condenser or when possible the objective, seek to render more than one plane of the specimen sharp, he would inevitably introduce errors of refraction which in themselves would spoil the result. Ridges or knife marks, due to the chattering of the knife blade of the microtome when cutting the section, will always show in the photograph. Special staining, as mentioned above, is not necessary, though it is always difficult to secure a good result from a section too deeply or too lightly stained; but in general any section stained so as to show well to the eye in the microscope will make a good photograph.

Limitations.—To photomicrography, as to all other things, there are limitations. These are more especially evident when we seek very high magnifications. As we go beyond one thousand diameters, it becomes more difficult to obtain satisfactory images; and while it is possible to obtain sharp images of certain selected objects, such as a portion of the frustule of a diatom, up to five thousand diameters, it will be found that only such objects as lend themselves to the work can be so taken, and that, except as a *tour de force*, the results are all out of proportion to the labor and time expended. When much higher magnifications than one thousand are desired, the only practical way is first to photograph the object with as high a power as will give a good, sharply defined image (say up to three thousand diameters), and then to enlarge the negative. In this way it is possible to attain magnification of ten or twelve thousand diameters. But again we are limited in this method, as when we attempt to enlarge a gelatin negative more than three or four diameters, the grain of the gelatin begins to become disagreeably apparent and to interfere with the sharpness of outline of the image. It should always be remembered that the magnification of the objective is the only magnification that resolves the details of the object. What further enlargement we may get by oculars of high power, by increased length of camera bellows, or by enlarging the negative, does not add any detail to that resolved by the objective originally; it simply spreads the image as given by the objective over a larger surface. It follows then that to magnify any object further than to make its details clear to the unaided eye is useless and to be condemned. *Edward Leaming.*

BIBLIOGRAPHY.

Journal of the Royal Institution, 1802.
John Towler: The Silver Sunbeam.
Captain Abney: A Treatise on Photography.
Medico-Chirurgical Review, July, 1864.
Moitessier: La Photographie appliquée aux recherches micrographiques.
Beale: How to Work with the Microscope.
Neuhass: Mikrophotographie.
Sternberg: Photomicrographs and How to Make Them.
Foot and Strobell: Zeitschr. für wissenschf. Mikroskopie, etc., Bd. xviii., 1901, pp. 421, 426.
Leaming: Studies from the Department of Pathology, College of Physicians and Surgeons, Columbia University, vol. v., Part i., 1896-97.

PHOTOTHERAPY. See *Roentgen Ray, etc.*

PHOTOXYLIN.—A nitro-cellulose, similar to pyroxylin, but prepared from wood pulp instead of cotton.

A three- to five-per-cent. solution in equal parts of alcohol and ether is recommended to replace collodion in plastic surgery and other conditions in which such an application is suggested. The solution forms a thick liquid, which upon evaporation leaves a firm, dense film, which is stronger than that of collodion. *Beaumont Small.*

PHRENIC NERVE.—ANATOMY.—The phrenic nerve, or the internal respiratory nerve of Bell, is the principal motor nerve of the diaphragm. The spinal origin in dogs and rabbits is located in the anterior horn of the spinal cord at the level of the fifth and sixth cervical vertebræ, and in man in the centre of the anterior horn, extending from the middle of the third to the sixth cervical segment. The superficial origin of the nerve is from the third, fourth, and fifth cervical nerves in the following proportions:

	Number of cases.	Fourth only.	Fourth and fifth.	Third, fourth, and fifth.	Third and fourth.
Luschka	32	12	7	7	6
Brook	16	4	9	3	0
Green	52	9	21	13	9
Total	100	25-25%	37-37%	23-23%	15-15%

When there is a single root, it is always from the fourth nerve.

COURSE.—The course of the nerve is as described in the standard text-books, there being but few variations. Passing over the anterior surface of the scalenus anticus, diagonally downward and outward, it passes in front of the first part of the subclavian artery and behind the subclavian vein. In about four per cent. of cases, however, the nerve passes in front of the vein, and so lies immediately behind the clavicle. Two cases are on record in which the nerve passed through the vein. Passing into the thorax it lies, on the right side, external to and slightly behind the right innominate vein and the superior vena cava; on the left side, in front of the arch of the aorta. On both sides it passes between the pleura and the pericardium, anteriorly to the roots of the lungs; on the right side being in close contact with the root, and on the left side passing out and to the left, in order to pass around the heart. The right nerve has an almost vertical direction, and passes to the upper surface of the diaphragm, where it divides into from three to six branches, which pierce the diaphragm externally to and in front of the opening for the inferior vena cava. The left nerve has a more circuitous route, and generally divides in the substance of the diaphragm.

Branches.—1. Communicating: (1) From the upper ganglion of the cervical sympathetic gangliated cord. (2) Occasionally, from the loop formed by the descendens and communicans hypoglossi. (3) From the nerve to the subclavius. (4) The right nerve, at its termination, sends branches to the right semilunar ganglion of the solar plexus. (5) The left communicates with the sympathetic plexus to the œsophagus above the diaphragm.

2. Distribution: (1) On the right side, to the superior vena cava. (2) Pleural branches, from one to three in number. (3) Branches to the pericardium, usually three. (4) Luschka has described twigs to the right auricle. (5) Terminal branches to the diaphragm. This is the main distribution of the nerve. It supplies the entire diaphragm except an area along the costal margin, about 3 cm. in width, which is supplied by the lower six intercostal nerves, and an indeterminate area on the crura, probably supplied by the vagus. The exact area, supplied by the fibres from the various roots of origin, is as yet undetermined. A single case of a dog, in which Schroeder divided the upper roots of origin, and on post-mortem found degeneration of the anterior and middle portions of the muscular portion of the diaphragm, with the lateral and posterior portion intact, is the only case of the kind on record.

RELATIONS.—In the neck the nerve lies on the anterior surface of the scalenus anticus muscle, behind the great vessels and the sterno-cleido-mastoid muscle, the omohyoid muscle and the transversalis colli vein. In crossing the subclavian artery the nerve generally lies external to the origin of the internal mammary, but internal to the course of the artery in its course in the thorax. The other relations have been noted.

The physiological function of the nerve is that of the principal motor nerve supply to the diaphragm.

PATHOLOGY.—1. Paralysis of half of the diaphragm, as a result of inflammation or degeneration of the phrenic nerve, on the corresponding side, as a result of exposure, lead poisoning, or compression, may occasionally occur. The condition generally comes on slowly and is characterized by inversion of the type of respiration, which reduces intra-abdominal pressure, causing difficulty in defecation, etc. Respiration is usually affected only during exertion, when dyspnœa results.

2. Neuralgia. Some authorities describe a form of neuralgia characterized by pain in the lower and anterior part of the thorax, along the line of diaphragmatic attachment, extending up into the neck and along the inside of the arm, with painful areas at the points where the nerve becomes superficial. This condition is said to complicate angina pectoris, Graves' disease, and some forms of cardiac disease.

3. Surgical Pathology. Injury to or division of the nerve may occur in gunshot wounds or stab wounds, or in the course of surgical operations. This complication has generally been regarded as fatal, and the statement has been generally made in the surgical literature that it was necessarily so. A careful review of the literature, however, shows only six cases on record in which the nerve was injured. In all other cases, usually reported as injuries of the phrenic nerve, an examination of the original article shows that some other adjacent structure had been injured instead of the phrenic. Of the six cases of actual injury to the nerve, in the first four (those reported by Schurmayer, Beck, Bardeleben, and Erichsen) there was also injury to some other important structure, which was alone sufficient to cause death. Of the two cases of injury to the nerve alone, the first (reported by Mackenzie) was instantly fatal. The second (reported by Schroeder in 1902) ended in recovery, with paralysis of the corresponding half of the diaphragm. Mackenzie's case was that of an Indian coolie, who suddenly fell dead, and on post-mortem examination the reporter was unable to find any sufficient cause of death, except a rupture of the right phrenic nerve. It hardly follows, however, that the rupture of the nerve was the cause of death.

Schroeder's case, then, is the only one on record in which the phrenic was injured without injury to surrounding structures, and in which the exact extent of the injury was known. In removing a fibroma, which was attached to the borders of the foramen formed by the third and fourth cervical vertebræ, the upper root of the phrenic, coming from the third cervical, was found traversing the upper and outer part of the tumor, while the lower root came from below. As the tumor was thought to be malignant, an attempt was made to dissect the nerve from the tumor; but in doing so, the roots of the nerve were torn off. There was no material change in the patient except an increase of respirations to 32. The nerve was united by sutures, and on being pinched below the suture, the diaphragm responded. There was no cough or hiccough nor any other symptom, either during the operation or afterward, except that the respirations remained at 24 to 32 for four or five days, and then came down to 20. Examination after recovery showed the left half of the diaphragm stationary and two and one-half inches above its normal position. The patient left the hospital completely recovered, and resumed his former occupation.

Experimental Researches.—1. On the Human Being. In eighteen cases of tuberculous glands of the neck, the nerve was pinched during operation with the following results: Contraction of the corresponding half of the diaphragm, with sudden rising of the anterior abdominal surface below the costal arch. In ten cases the right nerve was pinched and the left in eight. In one case on each side there was some pain in the region of the diaphragm, but it subsided in forty-eight hours. The symptoms usually attributed to irritation of the diaphragm (*i.e.*, sneezing, coughing, and hiccoughing) were not observed in a single instance.

2. Experimental Researches on Dogs. In the course of an extended series of experiments on dogs, the following results were obtained: After resecting as much as possible of the cervical portion of the nerve, it was found that after resection of one nerve only, there was an increased thoracic expansion and a slight abdominal retraction, changes which were more evident on the divided side than on the normal side. In case of a double resection there occurred an inverted type of respiration, *i.e.*, decided retraction on inspiration and increased thoracic expansion, due to the action of the accessory respiratory muscles. In unilateral resection kymographic tracings showed that the normal half of the diaphragm rose half an inch on inspiration and fell the same distance on expiration, while the half of the diaphragm on the side on which the nerve had been resected moved only an eighth of an inch, as it was moved passively by the movements of the normal side. After division of the nerve, the diaphragm becomes relaxed and the muscle arches up into the thorax. The type of respiration becomes increasingly costal when one nerve is divided, and inverted when both nerves are cut. The accessory respiratory muscles become very active. There is no sneezing or coughing. In one case of double division the respiration became labored, but remained so for only a few days.

Post-mortem Findings.—In cases in which the dogs were killed in from seven to fourteen days after resection of the nerve, the atrophy of the diaphragm was not great and the color was reddish-yellow. When a longer time had elapsed, the atrophy was marked, the paralyzed part being thin and flabby, the color pale yellow, and in older cases translucent. In all cases there remained a margin from one-quarter to three-eighths of an inch in width at the costal border, which retained its normal color and thickness. This margin is supplied by the intercostal nerves.

Summary.—1. From clinical, experimental, and anatomical data it would seem that the diaphragm is not an essential muscle of respiration, and that the importance of injury to its principal nerve, the phrenic, has been exaggerated. Injury to the phrenic or division of one nerve is not necessarily fatal. It may, however, predispose to lung infection or be followed by diaphragmatic hernia.

2. While the diaphragm is supplied with branches from the lower six intercostal nerves, they are inferior to the phrenic in importance and unable to take the place of the phrenic after division of the latter.

[A full bibliographical list will be found in the February number, 1902, of the *American Journal of the Medical Sciences.*] *William E. Schroeder.* *Frederick R. Green.*

PHTHISIS PULMONALIS. See *Lungs, Tuberculosis of.*

PHYSICAL MEASUREMENTS. See *Naval Hygiene,* and *Recruits, Examination of.*

PICHI.—FABIANA. The dried leafy twigs of *Fabiana imbricata* R. et P. (fam. *Solanaceæ*).

This large evergreen, heather-like shrub is common upon high dry hills in Chile. It is rather closely related to the tobacco plant. Only the small twigs should be col-

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