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PRACTICAL HINTS

ON

THE SELECTION AND USE

OF THE

MICROSCOPE.

INTENDED FOR BEGINNERS.

By JOHN PHIN,

Editor of "The American Journal of Microscopy."

SECOND EDITION.

Fully Illustrated and Greatly Enlarged.

NEW YORK:
THE INDUSTRIAL PUBLICATION COMPANY.
1877.

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PREFACE TO SECOND EDITION.

The fact that an unusually large edition of this work has been sold in a comparatively short period, is, to the author, evidence that such a work was needed, and that the present volume has, to a certain extent, supplied the want. In the present edition, therefore, he has endeavored to introduce several important improvements, while at the same time the elementary character of the work remains unaltered. With a few very slight and unimportant exceptions, the entire matter of the former edition has been incorporated in the present, and in addition several important subjects, particularly the chapter on objectives, have been greatly enlarged.

Many important points still remain untouched, but it is believed that in its present form most beginners will find in it all the information that they may require upon general topics.

As the want of all illustrations of the stands of different makers, and of many accessories, has been urged as an objection to the first edition, and as we have not deemed it advisable to fully supply this omission in the present issue, a word of explanation may not be out of place. One great object in view in the preparation of this book was the furnishing of a *cheap* manual for those who cannot afford the more expensive books of Carpenter, Beale, Frey, etc. To have given anything like a fair representation of the products of the different makers of this country and of Europe, would have nearly doubled the size and price of the volume. But if the reader will examine the illustrations of this class in the books just mentioned, he will find that, even in the best of them, the engravings are mere reproductions of the figures found in the descriptive lists of the various dealers. As new editions of these lists are being constantly issued, and as they may in most cases be obtained without cost from those that issue them, we have thought it best to refer our readers to these catalogues for information in regard to the construction of the instruments of different makers, and to facilitate their doing so, we have given at the end of the book a list of the prominent makers with their addresses.

In this, as in the previous edition, we have omitted all descriptions of objects, believing that the proper aim of a book on the microscope should not be to teach the general principles of botany, zoology or histology, but simply the best methods of using the microscope in the pursuit of these studies. The proper books in which to find a description of objects, are those which treat of that department of science which takes cognizance of the special subject under consideration. The present volume is intended merely as a guide to the best general methods of using the microscope.

It has been a source of great satisfaction to the author to be assured by those whom he deems good authority, that this little book has done much to foster the use of the microscope in this country, and he hopes that the present improved edition will tend to still further increase the deep interest which is already felt in an instrument which has done more than any other to extend our knowledge of organic nature.

New York, August, 1877.

PREFACE.

The Microscope and its applications in the Arts, and in general science, having deservedly occupied a prominent place in the pages of THE TECHNOLOGIST, OR INDUSTRIAL MONTHLY, a very large number of enquiries in regard to the best methods of using and applying this useful instrument have been directed to us. It would have been easy to answer these enquiries by a reference to some one of the many treatises that have been published on this subject, but as most of these works are expensive, and as many of our correspondents desire an answer in a more concise and simple shape, we have endeavored to give, in cheap and compact form, the information that is most usually demanded.

It is an unfortunate fact that while the microscope is daily growing in favor with those who know anything of its achievements, the operations of certain parties, too well known to the public, have brought a certain degree of suspicion upon all attempts to popularize this most valuable instrument. Microscopes, varying in price from twenty-five cents to two dollars and a half have been offered for sale, and the claim made for them that they are capable of showing clearly the structure of the more minute tissues, and that they may be used to advantage by physicians and naturalists. To the young student whose means are limited, and to the country practitioner, whose ability to supply himself with needed books and instruments often falls far short of his desires, the offer of a serviceable microscope for a couple of dollars is a great temptation, and when the instrument in question is endorsed by a long list of clergymen, lawyers, and even editors, this temptation becomes irresistible. And if the purchaser should happen to be unfamiliar with really good microscopes, and unable to discriminate between a clear and accurately defined view of any object and one that is distorted and incorrect, he may be led to use it, and so fall into the most serious mistakes. That this, unfortunately, does happen too often must be well known to all who are familiar with the subject, and it is within our own knowledge that the most worthless caricature of a microscope has been purchased and used under such circumstances.

We indulge a faint hope that the information conveyed in the following pages will enable the inexperienced reader to avoid these mistakes, and to assign a proper value to the certificates of clergymen and editors who vouch for the excellence of articles concerning whose properties and uses they are profoundly ignorant. These two classes we single out for reprobation, because—in this respect, at least—they seem to be sinners above all other men.

As stated in the title page, it is intended for beginners, and not for beginners in the use of the microscope only, but for those who have had little or no experience in the use of instruments of any kind. Hence the directions that are given are of the very simplest kind, and all theoretical explanations have been avoided, for the reason that any person that is desirous of studying the optical principles upon which the microscope is constructed will find in the ordinary text books on natural philosophy all the information he may want. Our object has been solely to impart such information as will enable the reader to make a beginning in the practice of microscopy, hoping that the start thus given will lead him to proceed with his studies, and ultimately acquire that knowledge, skill and dexterity which will enable him to avail himself of the extraordinary powers and advantages which the use of this instrument confers, both in scientific pursuits and in everyday life. Above all things, therefore, we have endeavored to be accurate in our statements and judicious in our directions, and the reader is assured that no processes or methods are given which we ourselves have not frequently and successfully put in practice.

JOHN PHIN.

New York, January, 1875.

INTRODUCTION.

Thousands of microscopes throughout the country are at the present day lying idle, simply because their owners do not know how to use them. If properly employed they might be made to afford an incalculable amount of instruction and amusement; but, as it is, they are a drag upon the popularization of science, because they convey the idea that the microscope is a difficult instrument to use, and that it is not of much account after we have learned to use it. The owners of these microscopes have examined all the mounted objects at their command, the entire number of which probably does not exceed two or three dozen, and they have no information as to the best methods of preparing common objects for examination or preservation. Even the objects that they possess have never been explained to them, and are merely pretty toys. The fly's eye is interesting because it looks like a piece of netting, and the butterfly's wing is attractive because it is probably a little more brilliant than the most brilliant silk dress, but neither of these objects interests of itself and because of its beautiful structure.

Moreover it often happens that an instrument which, when first purchased, was of very fair quality, has, through ignorance and carelessness, become so soiled and dimmed that it no longer serves the purpose intended. On more than one occasion have we seen a fine microscope leave the dealer's hands in excellent order, and return in a week entirely unfit for use. Microscopes in this condition, instead of being a source of instruction and pleasure, are an eyesore and an occasion of annoyance. They continually serve as reminders of awkwardness and failure, of wasted time and ill-spent money. And yet with proper instruction and a due amount of care all this might have been avoided.

It is also a fact to be regretted that heretofore the microscope has not been extensively employed in the arts, and in everyday life, simply because practical men have not been taught how to use it, and consequently have been unable to avail themselves of the advantages which it offers; but if carefully and judiciously selected, and properly handled, it is capable of affording an amount and kind of assistance which cannot be safely neglected. It may be made to aid in the examination of raw materials, and of the finer kinds of work; it will enable us to measure spaces which would otherwise be inappreciable, and this, in an age when even in ordinary machine shops the thousandth part of an inch is frequently an important quantity, renders it indispensable to the careful and skillful mechanic; on the farm it will enable the agriculturist to examine closely and minutely the various noxious insects and forms of fungi and blight, and thus aid him in identifying them and applying the proper remedy; and in the examination of minute seeds, such as timothy, clover, etc., it will prove a very valuable assistant, enabling him to detect any inferiority in the quality, or any impurity or adulteration. Frequently the agricultural seeds offered in market contain minute seeds of offensive weeds, many of which are so small that they are not easily discovered by the naked eye.

Every farmer and mechanic knows the value of a good pair of eyes, and he also knows that an agent which doubles or trebles our power in any given direction at once confers upon us in that respect a superiority over our fellows. Very few men are twice as strong as their comrades; still fewer have three times the strength of ordinary men, and it may be safely affirmed that no man possesses the power of ten ordinary men. But a microscope of very ordinary capacity at once multiplies our powers of sight by ten, twenty, or even a hundred times, while those of the better class enable us to see things with a keenness and clearness which, when compared with that afforded by the naked eye, is as more than a thousand to one.

There are four distinct and important directions in which a microscope may be made to serve us: 1. It is capable of affording the most refined and elevating kind of pleasure by the exhibition of objects of extreme beauty and interest. There are few more splendid sights than the gorgeous colors displayed by some objects when viewed by polarized light, and even the tints of certain minerals, and the brilliant scales of certain insects, when viewed as opaque objects, by means of a good condenser, surpass anything that is familiar to us in our ordinary experience. On the other hand the exquisite beauty of form which is characteristic of most of the objects with which the microscopist concerns himself can be fully appreciated only by those who have seen them. As a source of innocent amusement and pleasure, therefore, the microscope has few or no equals; for it may be safely affirmed that a five-dollar instrument is capable of affording gratification of greater variety and intensity, and of longer continuance, than that yielded by anything else of the same cost. This arises chiefly from the fact that most other instruments, when once exhibited, with their slides or fixtures, lose their freshness and interest, and become old. While for the microscope, a few fibres of wool from the carpet, a few grains of sand from the sea-shore, or a handful of wild flowers from the field, yield objects of surpassing beauty. Everything in nature and in art may be subjected to inspection by it, and will then disclose new beauties and fresh sources of knowledge. Under it the point of the finest cambric needle looks like a crow-bar, grooved and seamed with scratches; the eye of the fly is seen to consist of thousands of eyes; and the dust on the butterfly's wing appears to be what it really is, scales laid on with all the regularity of shingles or slates on a house; while to prepare and examine these simple objects requires no great skill and no elaborate apparatus.

2. As a means of imparting instruction to the young, the microscope has now become indispensable. The changes which of late years have taken place in the views held by our ablest men in regard to the best education are too well known to need even mention. No education that does not include a knowledge of natural science is now regarded as complete, and there is a very wide range of the most essential and practical knowledge that can be reached only through the microscope. Thus, when we look at a leaf with the naked eye, we see but a green mass of matter, possessing a certain beautiful form, it is true, but disclosing none of those organs which render it more complicated and wonderful than anything ever produced by our most skilful mechanics. Looked at by the microscope, however, this same leaf is found to be made up of innumerable parts, each one of which is highly complex and beautiful; it is furnished with mouths for breathing, with cells for storing, digesting and assimilating nutriment, and with ribs for strengthening its structure; and all this, which is perfectly invisible to the unassisted vision, becomes distinct and obvious when we call to our aid a microscope of even moderate power. It is true that much of this may be taught by means of books, engravings and verbal descriptions, but every one knows that for distinctness and impressiveness the very best engravings fall far short of a view of the real object.

3. As an instrument of research, the microscope now occupies a position which is second to none. There is hardly any department of science in which a student can hope to reach eminence without a familiarity with the microscope. Botany and Zoology have been developed almost wholly by its aid, and so necessary is it in the study of these sciences, that Schleiden, one of the most successful of investigators says of it: "He who expects to become a botanist or a zoologist without using the microscope, is, to say the least of him, as great a fool as he who wishes to study the heavens without a telescope." In chemistry its services have been very important, and in geology and mineralogy it has opened up new fields of research which almost promise to revolutionize these sciences. Medicine has

long acknowledged the microscope as one of its most efficient assistants, and in the practice of the best physicians it is regarded as an indispensable means of diagnosis in some diseases.

4. As an assistant in the arts. Its importance in this department is but just beginning to be recognized, and in a former paragraph we have endeavored to point out a few of the subjects to which it may be applied with good hopes of success.

These important and obvious advantages are not difficult to secure, provided we avoid two mistakes which are very commonly made by beginners. One of these consists in supposing that it is only by means of very expensive and complicated instruments that anything of value can be accomplished in microscopy. Now while it is certain that, in some departments of study, none but the very best microscopes are of any value at all, it is equally certain that a very wide range of study and of practical work can be thoroughly cultivated by means of apparatus of very moderate cost, and of great simplicity of construction. The great discoveries of Ehrenberg, which opened up entire new fields of research and of thought, were made with a microscope which at the present day would not command $25. Indeed some of the French instruments that are sold for $15 will show a very large proportion of the objects that are figured in his earlier works. Most of the great anatomical and botanical discoveries were made with simple microscopes of no great power, and it is not many years since one of the most successful workers in the field of botany gave it as his opinion that a power of 300 diameters is capable of showing everything that is of importance in this science.

The other error is of precisely the opposite kind. It is not at all unusual to meet persons who seem to think that all that is necessary in order to become a microscopist is to buy a microscope and place objects under it! Such people always entertain an exaggerated idea of the power of the microscope as an instrument of research. For example, they think that in order to detect adulteration all that is necessary is to place a sample under the microscope, when all impurities will at once stand out conspicuously! To their imagination every blood corpuscle is clearly marked with the name of the animal from which it was obtained!

Truth lies between these extremes. No progress can be made without steady application and persistent labor, but any person of fair average ability and a moderate degree of perseverance can soon learn to follow the beaten track at least, if not to branch out into original research.

THE SELECTION AND USE

OF

THE MICROSCOPE.

What is a Microscope?—The microscope is an instrument which enables us to see either very minute objects or very minute parts of large objects. It is a very popular idea that the name *microscope* is applicable only to complex instruments of considerable power; but this is clearly wrong. A ten cent magnifying glass has as good a right to the name *microscope* as has a complicated binocular instrument with all the latest improvements. By common consent, however, the small hand instruments, without stands, are generally called *magnifiers*. An attempt has been made to introduce the foreign word *loupe* as an equivalent of magnifier. The word *loupe* is, however, superfluous, and is used only by ostentatious pedants, and by foreigners who are ignorant of English.

What the Microscope Does.—It is well known that the further off any object is, the less it appears. A house at a distance appears less than a man who is close by, and the distinctness with which an object is seen depends largely upon its apparent size. Thus, at a distance, a house not only appears very small, but the windows cannot be distinguished from the rest of the building. As we draw nearer it becomes apparently larger, and the different parts become more distinct. First the windows are seen clearly, then the individual panes of glass, then the bricks, and finally the grains of the material of which the bricks are made. When, however, we approach too closely we again find it impossible to see distinctly, as may easily be proved by a very simple experiment. Place some fine print, such, for example, as the present page, at a distance of six feet from the eye, and gradually move closer to it. At six feet the letters will be indistinguishable; at two feet they will be quite distinct; at one foot still more distinct; at three inches they will be quite blurred. There is, therefore, a limit to the degree of closeness with which we can approach any object for the purpose of examining it, and the object of a microscope is to enable us to get close to it, as it were, without blurring our view. If, without changing the distance of the eye from the paper (three inches) we introduce between the two a lens of one inch focus, and bring it into proper position, we will find that the indistinctness formerly complained of disappears, and the object is now not only seen clearly, but appears very much magnified. That objects appear large in proportion to their nearness to the eye may be thus shown: Take two slips of paper printed with type of the same size (two clippings from a newspaper answer well) and place one at a distance of ten inches from the eye and the other at a distance of five inches—the edge of the upper slip being placed so as to lie about the middle of the lower one. In this way we can readily compare the apparent sizes of the type on the two slips, and one will be found to appear just twice as large as the other, though, of course, we have the evidence of our senses to prove that they are precisely of the same size. Moreover, as the usual distance for distinct vision is about ten inches, in persons of middle age, it will be found that a lens which enables us to view any object clearly and distinctly from a distance of one inch, will enable us to see it just ten times larger and ten times more distinctly than we could do when looking at it from a distance of ten inches. A consideration of these facts led the late Dr. Goring to propose the name *engiscope* as a substitute for the word *microscope*—the word *engiscope* signifying to see things at a very short distance.

The facts which we have just detailed must, however, be regarded as illustrations, rather than explanations of the action of the microscope. It is evident that the power of a lens to increase the distinctness with which any object is seen, depends not only upon the action of the lens upon the rays of light, but upon the influence which such modified light exerts upon the organs of vision. Now, the eye, considered merely as an optical instrument, is in reality a small *camera obscura* in which the cornea, crystalline lens, and other transparent portions, combine to throw upon the retina an image of external objects. That the transparent portions of the eye do in fact act as a lens, and throw a real image upon the retina or posterior portion of the eye, is easily shown by taking the fresh eye of an ox and gradually shaving off the coating at the back until it becomes transparent. If the eye, so prepared, be then held towards a window or any very bright object, a distinct but inverted image of the window or other object will be see on the coat of the eye.

The action of the eye in this case is the same as that of a lens, and the general mode of action of lenses under such circumstances may be easily illustrated by means of a common hand magnifier or even a spectacle glass. If the reader will hold before a window, at a distance of, say, six feet, a sheet of white paper, and will place a magnifier in front of the paper, then by properly adjusting the distance between the magnifier and the paper, a picture of the window will be thrown on the latter. If the magnifier and paper be now removed to a distance of twelve feet from the window, the picture of the latter will be only half as large as it was in the first place, and it will also be found that the distance of the lens from the paper will have to be readjusted and made less.

That the eye possesses this power of adjustment we are all conscious, for we feel that if, when the eye is adjusted for the distinct vision of distant objects, we suddenly look at those which are near, the condition of the eye requires to be changed before a distinct view can be had, and to make this change requires an effort of which we are perfectly conscious.

When a lens is held in front of a sheet of paper, so as to throw on the latter a distinct image of the objects in front of it, the distance between the paper and the lens is called the *focal distance* or *focal length* of the latter. This, as we have just seen, varies with the distance of the object which gives the image. In order, therefore, to secure a standard in this respect the object selected is always one whose distance is so great that it may be practically regarded as infinite.

When we examine an object, first at a distance, and then close at hand, we see it through the medium of two different sets of rays, those in the latter case entering the eye in such a direction that the image thrown on the retina is larger than the image produced when the object is more distant. The lens acts, however, by bending the rays so that the same set, which, if allowed to pursue their natural direction would not produce a distinct image, are caused to enter the eye in such a direction that the image is large and clear. The manner in which the lens acts to produce these effects is not difficult to understand. It is true that the *ultimate causes* which produce these phenomena are beyond our knowledge, but in this respect the ablest philosopher has very little advantage over the veriest tyro. It may be difficult also for the general reader to follow the mathematical demonstrations of the action of lenses. There are, however, a few simple facts which are easily understood, or at least demonstrated and accepted *as facts*, and which, when clearly and firmly grasped by the mind, render the construction of the microscope comparatively easy of comprehension.

There are two ways in which the subject may be studied. We may examine the facts experimentally, by using lenses and actual eyes in the way we have described, or we may follow the course of the rays as laid down in any good book on optics. A combination of both methods will of course give the clearest views on the subject, and we would therefore advise the reader to provide himself with a few lenses of various degrees of curvature, and consequently of various magnifying powers, and test all the statements made in the text. He will thus acquire such a practical knowledge of the action of lenses as can be obtained in no other way. For this purpose the cheapest lenses are good enough. One or two cheap magnifiers and a few glasses from old spectacles will serve every purpose. The simplest methods of arranging such lenses will be found in a note on a subsequent page, and although very accurately made tools are required for the construction of serviceable optical instruments, it will be found that a very large number of simple but valuable experiments may be worked out with the aid of a few wooden rollers and a little paper and paste.

While the magnifying power of lenses depends upon their focal length, this in turn depends upon the material of which the lens is made, and also upon the curvature given to its surfaces. Lenses of precisely the same form, and made respectively of diamond, flint glass, crown glass and Canada balsam would possess different magnifying powers; the diamond magnifying most, the flint glass next, crown glass next, and Canada balsam least of all. On the other hand, of two lenses composed of the same material, that which has the sharpest curvature to its surfaces will magnify most. Now, on reflection, it will be evident to even the least mathematical mind that lenses which have very sharp or *quick* curves must of necessity be small. Suppose the curve which bounds the figure of a lens has a radius of half an inch, it is evident that the largest lens which could be made with this curve would be one inch in diameter, and then it would be a perfect sphere. Most lenses, however, resemble thin slices off the spheres, or in some cases two such slices joined together, so that the diameter of the lens is in general greatly less than the radius of the curves which form its surface. Therefore, we see that all lenses of high power are of necessity small, and when lenses are required of very high power they become so minute as to be handled only with great difficulty. Indeed, before the modern improvements in the microscope, many of the lenses used by scientific men were nothing more than little globules of glass, brought to a round form by fusion.

We have made this lengthened explanation of a very simple matter because we have found amongst beginners in microscopy a very general idea that large lenses are the most powerful. "Send me one of your largest and most powerful magnifiers," is an order with which every optician is familiar, and yet such an order contains a contradiction in terms. A lens cannot possibly be large and magnify greatly at the same time.

The Different Kinds of Microscopes.—Microscopes are divided into two classes—simple and compound—the difference between them being purely optical, and not mechanical; for a simple microscope may be very complex and expensive, while, on the other hand, a microscope may be *compound* and yet contain very few parts. Thus the little vertical French microscopes, which cost only $2,50, are *compound*, although very simple in construction, while a *simple* microscope, if binocular, and provided with all desirable adjustments, might be a very complicated affair. The difference between simple and compound microscopes is this: in the simple microscope we look at the object directly, while in the compound microscope we look at a magnified image of the object. In the simple microscope, objects are always seen in their natural position, while in the compound microscope they are inverted, and right becomes left, and left becomes right. This makes it very difficult for beginners to work upon objects under the compound microscope; and hence simple microscopes are almost always used for dissecting and botanizing.

It is true that by adding more lenses, and making the instrument still more compound, we can again invert the image, and thus bring it back to its original and natural position, and almost all the very expensive microscopes are furnished with these extra lenses arranged in a piece of accessory apparatus technically known as an *erector*. The distinguishing feature of the compound microscope remains, however, the same. Certain forms of the microscope, in which *concave* lenses are substituted for the usual convex form, also give erect images, but this does not affect the general truth of the statement just made.

Simple microscopes frequently consist of more than one lens. Thus, in using the ordinary pocket magnifiers with two or three lenses, it is usual to employ all the lenses at once, looking at the object through two or three lenses at the same time when a high power is required. In this case, however, the two or three lenses are placed close together and act in the same way as a single lens, with surfaces more sharply curved than those of any of the lenses forming the combination. Under such circumstances the image is not inverted, but if we now separate the lenses sufficiently, we will find that on again bringing the object into focus, the image is inverted and greatly enlarged. Moreover, it will be found that the magnifying power may be greatly increased by increasing the distance between the two lenses, and it will also be found that as the distance of the two lenses from each other is increased, the distance at which the combination is placed from the object must be made less and *vice versa.**

The early forms of the compound microscope consisted of little more than the two lenses we have just described, but the modern instrument, even in its simplest form, is a vastly more complicated arrangement. In the best forms, for the lens next the eye there is substituted an eye-piece consisting of two lenses with a diaphragm between them, while the objective, or lens next the object, is composed of from four to ten different pieces of glass, forming two or more lenses, which are so arranged that each shall correct the defects of the others, and this optical combination is mounted on a stand which is sometimes a marvel of mechanical ingenuity.

*The student who possesses a little mechanical genius and a desire to become *experimentally* acquainted with the properties of lenses and the construction of the microscope, would do well to procure a couple of cheap lenses, say one of half inch focus, and one of about two inches focus, and test by actual trial the statements made in the text. Such lenses may be conveniently arranged in a tube formed of writing paper and gummed on the edges. All the most important properties and defects of lenses may be thus illustrated and studied. By means of a little extra care, two such lenses, arranged as we have described, in tubes blackened on the inside, and mounted on a little wooden stand, the focus being adjusted by sliding the tube holding the lenses within another tube, also of paper, will give not only a very fair view of such objects as the wing of a fly, the scales on a butterfly's wing, and even the barbs on the sting of a bee, but it will show the globules of blood quite distinctly, and we have even given a very interesting exhibition of the circulation of the blood in the foot of a frog by means of a temporary arrangement of this kind, which we put together for the purpose of explaining to a little girl the construction of the microscope. We would not recommend any one to use such a microscope for purposes of work or study, because the fallacies to which it may give rise are too numerous and too serious. But any boy, or even girl, who will undertake the construction of such an instrument, cannot fail to obtain thereby an amount of information which the perusal of volumes would not give. As hints towards aiding our young friends, we may remark that our tubes were made of the best stiff paper, rolled up tight and pasted only along the outer edge. The lenses were secured in their places by being attached to the bottoms of pill-boxes, holes being punched through to admit the light. Pill-boxes with holes were also used for diaphragms to reduce the effects of aberration. A piece of mirror reflected the light, and the sides etc., of an old cigar box furnished material for the stand. Fifty cents covered all expenses.

Essential Parts of the Microscope.—When a good lens is held steadily at a certain distance from an object which is properly illuminated, this distance depending upon the form and material of the lens, we are enabled to see the object clearly and distinctly. When, however, this distance is either increased or diminished, the object becomes blurred and indistinct. The point at which vision is most distinct is called the *focus** of the lens, and when we are able to see it clearly the object is said to be *in focus;* when the distance is either increased or diminished, it is said to be *out of focus*. An object is said to be *within* the focus when the lens is too near it, and *beyond* the focus when the lens is too far away.

The performance of any lens depends greatly upon the accuracy with which it is adjusted to the correct focal distance, and the steadiness with which it is held there. For all ordinary purposes, lenses which do not magnify more than ten diameters may be very conveniently held in the hand without any special means of support; but when the power is much greater than this, or where, as in the compound instrument, the microscope is bulky and heavy, it becomes necessary to use some mechanical contrivance which will hold the microscope steadily in its position in relation to the object, otherwise the view becomes indistinct. Thus a good lens, magnifying from thirty to forty diameters, will very readily show the individual corpuscles or globules in the blood of the frog, provided it is arranged on a steady support and accurately adjusted for focus. If merely held in the hand the corpuscles will probably be invisible. Hence the importance of providing efficient means for adjusting the focus and holding and illuminating the object, and the object of the stand is to furnish these means in a compact and convenient form. Every microscope, therefore,

*It is scarcely necessary to inform the reader that the focus described in the text is not precisely the focus of the lens itself, but the focus of a compound lens of which the eye forms one element. Hence the focal distance varies with different eyes, and so does the apparent size of objects. To short sighted people objects appear of larger size than they do to persons of ordinary eye-sight. In working with the compound microscope, we frequently find that different people require a different focal adjustment.

whether simple or compound must possess: 1. Certain means for supporting the object and placing and maintaining it in proper position; 2. Means for illuminating the object, whether it be opaque or transparent; 3. Means for transmitting to the eye an enlarged image of the object.

NAMES OF THE DIFFERENT PARTS.

The different parts which are employed for securing these several ends, have been constructed of an almost endless variety of forms, according to the fancies of the different makers and the requirments of different microscopists. The following are the names of the essential parts of a compound microscope of ordinary construction. The names of the different parts of the simple microscope are the same as those of the compound microscope, but the latter has several parts which do not exist in the former.

The *Stand* is the term properly applied to the entire frame used for supporting and illuminating the object and carrying the optical part, the latter consisting of the eye-piece and the objectives. Stands are frequently sold separately, or furnished with eye-pieces only—the purchaser making such a selection of objectives as may best suit his special needs.

The *Base* or *Foot* is that part which supports the rest of the stand.

The *Body* is the tube to which the eye-piece and objectives are attached.

The *Arm* is tnat part which carries the body.

The *Collar* is the tube in which the body moves. This is found only in microscopes of the Continental form (Plate I) and similar models.

The *Stage* is the plate upon which the object is placed for examination.

The *Eye-piece* is the short brass tube, with its lenses, which is next the eye. The eye-piece contains an *Eye-Glass*, which is that next the eye; a *Field-Glass*, placed next the objective, and a *Diaphragm*, consisting of a brass plate with a hole through it, and so arranged as to cut off the outer rays of light. The tube in which these lenses are secured is in general movable, and the best microscopes are furnished with several eye-pieces of different powers. We may here remark that where a microscope is furnished with several eye-pieces, the *shortest* eye-piece gives the greatest magnifying power.

The *Object-Glass* or *Objective* is the lens or lenses which is placed next the object. The term is frequently applied to the glass plate or slide upon which the object is placed, but this use of the word is entirely wrong, and tends to produce confusion.

A *Draw-tube* is a secondary body which receives the eye-piece, and slides within the main body like the draw of a telescope. It enables us to increase the distance between the eye-piece and the objective, and thus to change the magnifying power, as explained in a previous paragraph.

The objective is moved to or from the object by two methods, which are called respectively the *coarse and fine adjustments.*

The *Coarse Adjustment* is used for bringing the objective approximately but rapidly into focus. To effect this the body either slides through a tubular collar or is attached by means of dovetail slides to the arm, and in either case it is moved up and down either by a rack and pinion (or some substitute therefor) or directly by hand.

The *Fine Adjustment* is employed for bringing the object exactly into focus. It usually consists of a fine screw, which moves either the entire body or the lower part of it. In some cheap stands, the fine adjustment is effected by moving the stage towards the objective.

The *Mirror* reflects the light, and causes it to pass through the object and the body of the instrument.

A *Sub-stage* is furnished with some instruments. It is used for holding and centering various means of illumination.

Clips are springs attached to the stage for the purpose of holding in place the glass slide or plate carrying the object.

The *Object* is that which is subjected to examination. It is usually mounted upon

A *Slide*, or plate of glass, which is laid upon the stage.

DIFFERENT FORMS OF THE SIMPLE MICROSCOPE.

To describe the different forms in market, either of simple or of compound microscopes, would require a large volume. We shall therefore content ourselves with a description of certain typical models which afford variety enough for all practical purposes.

Hand Magnifiers.—These are so generally useful and applicable that no person who attempts to work much with the microscope can possibly do without one. They are found in market in a great variety of forms, styles of mounting, and price, and are too well known to need minute description. Large lenses, magnifying two or three times, are mounted singly, and used chiefly for the examination of pictures, and as reading glasses; the smaller sizes of the same style serve for the examination of fine engravings. Very small lenses of considerable power, and simply mounted in a frame, are also sold by most opticians. They are known as "watch-charms," and magnify about fifteen diameters. We have also seen a very powerful magnifier mounted in a little ring attached to a pair of eye-glasses.

For the purpose of the student and naturalist, a very excellent form is that which is shown as attached to the Excelsior microscope. It consists of three lenses, mounted in frames, and enclosed in a case so as to be perfectly protected. Each lens has a different focal length, and the three, when combined, give a magnifying power of twenty-five to thirty diameters. Being very portable, and possessing a variety of powers, it is a favorite form of pocket microscope.

Magnifiers composed of two or more lenses, are to be had of two very distinct kinds. The lenses may either be simply united in one frame, without any special adaptation to each other, or the instrument may consist of two or more achromatic lenses combined together in a fixed and accurately determined relation. Examples of the former are found in the ordinary two and three lens magnifiers we have just described; the latter are not so common, since they are somewhat expensive when well made. They are known as doublets and triplets, and one maker in this country, Mr. Tolles, of Boston, has become famous for the excellence of the simple achromatic microscopes of this class, made by him. These doublets and triplets are altogether the most satisfactory simple microscopes in use, and several firms make a specialty of their manufacture. In addition to Mr. Tolles, the Bausch & Lomb Optical Company, under the direction of Mr. Gundlach, make a very excellent lens of this kind, and in England, Mr. Browning makes a very excellent achromatic magnifier under the name of the *Platyscopic Lens.*

Where two or more simple lenses are used together (without being combined so as to form a compound microscope) the power of the combination is always equal to the *sum* of the powers of the separate lenses. Thus if we have a lens of half an inch focus and one of one inch focus, one magnifying ten and the other twenty diameters, the resulting power is thirty and and not two hundred times. In the compound microscope, on the other hand, the combination of an objective magnifying twenty diameters with an eyepiece magnifying ten diameters, gives a magnifying power of two hundred diameters.

Two or more lenses, properly adapted to each other and used together, give results greatly superior to anything that can be obtained from a single lens, at least so far as clearness and accuracy of definition is concerned. But when used as a working or dissecting microscope, they are open to the objection that the distance at which they must be placed from the object is very small, and hence it is frequently inconvenient to use them for working upon objects. Thus if we have a plano-convex lens of a quarter of an inch focus, and one of three quarters of an inch focus, and place them at a distance of a sixteenth of an inch from each other, we will have a very good magnifier which will enlarge objects about thirty-five to forty times, but we must place it at but a very short distance from the object. If we separate the lenses a little, the definition will be improved, but the working distance, as it is called, will be diminished. Those who have studied optics are quite familiar with these facts, but the ordinary reader does not always think of them, and yet they are very important when we come to choose a microscope for working or dissecting purposes.

Watch-Makers' Eye-Glasses.—These are well known, and may be obtained of almost any power within the useful range of a single lens. The eye-glass ordinarily used by watch-makers magnifies about eight times, but glasses magnifying twenty diameters are not uncommon. Glasses of the latter power are usually *doublets*, that is, they consist of two lenses, arranged together, one being of much longer focus than the other. If well-made they give excellent definition and a large field, and, when mounted on a stand, are very serviceable as *dissecting microscopes**, especially in working upon coarse objects, and picking out shells, the larger foraminifera, etc. Their form enables us to support them by means of a small wire ring, arranged as in a retort stand, and the large bell-mouth of the frame prevents any light from entering the eye, except that which has passed through the lens. They are very cheap, and any intelligent boy can make a tolerable stand for one. The same stand will answer for several glasses of different powers.

Engravers' Glasses.—These are mounted in frames, in the same manner as the watch-maker's eye-glass, but as they are larger, and are therefore not so readily held in the eye, after the fashion of the latter, they are always used with a stand of some kind. Those of the best quality are, in general, doublets, which give a large field of view, with very good definition, and they are altogether the best microscopes for examining bank bills, fine engravings and similar objects.

*The term *dissecting microscope* is applied to all microscopes used for working upon objects under moderate magnifying powers. They are used not only for dissecting, properly so called, but for the study of botany, mineralogy, etc., as well as for numerous investigations in the arts. A good microscope of this kind is absolutely indispensable to those who hope to do more than merely look at objects prepared by others. In subsequent paragraphs we describe some of the best instruments of this kind. A complete dissecting microscope should be furnished with stand, mirror, etc., and if the student can afford it, there should be some good mechanical means of adjusting the focus.

The Coddington Lens.—Whenever a power greater than twenty diameters is required for *examining* objects, a Coddington, if well made, will be found to be the best lens in use, always, of course, excepting the carefully corrected doublets and triplets previously mentioned. The price of the latter, however, is in general four to eight times that of a good Coddington. It has this defect, however, that the working focus is very short, and therefore for a dissecting microscope a doublet is to be preferred. In using a Coddington lens, great care must be taken to secure good illumination of the object, and the shortness of the focus makes this difficult to those who have had no experience.

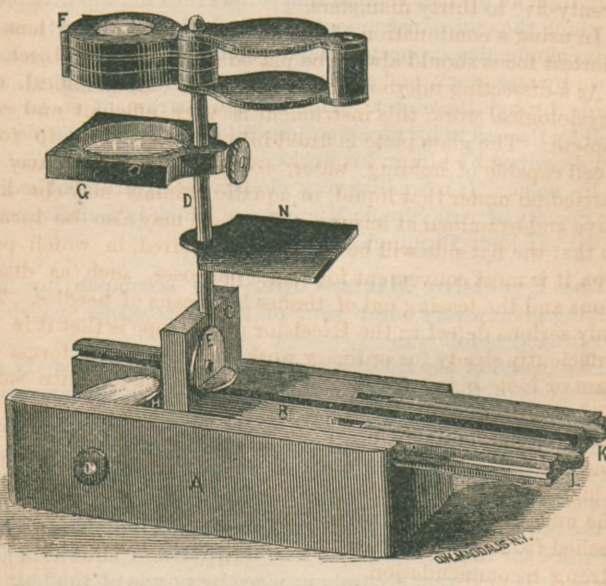
The Stanhope Lens is similar in form to the Coddington, but is very different in construction. It consists of a cylinder or rod of glass, one end of which is rounded so as to form a lens, while the other end is either flat or slightly curved. The distance between the lens and the flat surface is exactly equal to the focal distance of the lens. Transparent objects, such as the scales of insects, animalculæ in water, etc., are simply placed on the flat surface of the glass cylinder, and when looked at through it, they appear greatly magnified. It is easily used, but can not well be employed as a working microscope. It is this kind of lens that is used in the construction of those watch charms in which a large picture is seen on looking through a very small hole. The picture is a photograph attached to the flat end of a small glass rod, the other end of the rod being formed into a lens of exactly the right focal length required to show the picture clearly and considerably magnified. Lenses and photographs of this kind are usually mounted as miniature opera-glasses.

Stands for Simple Microscopes.—For ordinary purposes of examination, the magnifiers we have just described serve very well when merely held in the hand, but their performance is greatly improved when they are mounted on appropriate stands, which not only enable us to adjust the focus with great accuracy, but which hold the lens steadily in relation to the object, and thus prevent any necessity for that constant adjustment of the eye itself, which always occurs when a lens trembles. Of the simple microscopes in use there are but two that require attention—Raspail's and the Excelsior. For a description of the elaborate dissecting microscopes of the London microscope makers, as well as those of Nachet, and others, we must refer to the large works of Carpenter, Beale, Frey, etc.

Raspail's Microscope.—In this instrument the magnifying glasses are supported by an arm which projects horizontally from an upright column that screws into the top of a box, in which the entire instrument is packed when it is not in use. This column also supports a stage which may be moved up and down by rack work, and a mirror for reflecting the light upwards through the object. This was the instrument so largely used by Raspail in his investigations into the structure of plants, and described by him in his works, and hence it has been called by his name. It resembles very closely the instrument called the Society of Arts Simple Microscope, which is manufactured by Mr. Field of Birmingham.

The Excelsior Microscope.—The accompanying engraving gives a very clear view of this microscope, which is constructed as follows:

To one end of the lid of a small wooden case or box, is attached one of the ends of the box; and when the lid is reversed and turned upside down, it may be slid into the groove which usually receives it, and then forms a stand for the lenses and glass stage, as is shown in engraving. The lenses and stage are supported by a steel rod, D, the lower end of which is hinged to the lid, so that it may be turned down and lie in a groove provided for it. When raised into the position shown in the figure, it is held very securely in place by means of the button, E; and this button also serves to retain it in the groove when it is turned down. The glass stage, G, which is fitted into a frame of hard rubber, slides easily on the stem, D, so as to be readily adjustable for focus, while at the same time it may be firmly fixed, by means of a set-screw, at any desired height, and will then serve as a stage for dissecting purposes. The frame which holds the lenses fits on to the top of the stem. A mirror, H, is fitted into the case, and is readily adjustable by means of the button shown on the outside, so that light may be reflected up through the stage when the objects to be examined are transparent; and when they are to be viewed by reflected light there is a dark ground of hard rubber (not shown in the engraving) which is also carried by the stem, D, and may be turned under the stage, so as to cut off all transmitted light. Dissecting needles (K and L), with neat handles, fit into appropriate grooves. When the lenses and stage are removed from the stem they are readily packed in the case; the



THE EXCELSIOR MICROSCOPE.

stem is then turned down and held in its groove by the button, E; the lid is drawn out of the groove, turned over, and replaced so that the vertical piece (C) closes the open end of the box, and the whole thing is packed into a compass which readily admits of its being carried in the vest pocket.

The lenses are well made, and being provided with a proper diaphragm, great clearness of definition is secured. Two styles of frame are sold, one containing two, and the other three lenses, the latter being altogether the cheapest, in proportion to the power furnished. The magnifying powers are about as follows: With the lens of longest focus, five diameters; with the lens of medium focus, eight diameters; with the lens of shortest focus, ten diameters. When the lenses of shortest and medium foci are combined the magnifying power is about eighteen diameters; all three lenses together give a power of twenty-five to thirty diameters.

In using a combination of two or more lenses, the lens of shortest focus should always be placed nearest to the object.

As a dissecting microscope for botanical, entomological, and physiological work, this instrument is very efficient and convenient. The glass plate is fitted into the stage so as to form a cell capable of holding water, so that dissections may be carried on under that liquid, or aquatic animals may be kept alive and examined at leisure. The stage may also be turned, so that the flat side will be up when so desired, in which position it is most convenient for some purposes, such as dissections and the teasing out of tissues by means of needles. The only serious defect in the Excelsior microscope is that it is not sufficiently steady for ordinary work, the case which forms the base or foot being, for portability's sake, made quite small. This difficulty is, however, easily remedied by screwing the case to a piece of pine board six inches long, four inches wide, and three-quarters of an inch thick. A single small screw, which does not deface the instrument, is sufficient, and when the microscope is to be carried in the pocket it is easily detached from its temporary stand. Its low price, $2.75, is a strong recommendation.

A very serviceable stand for a simple microscope is easily extemporized as follows: Procure a good sound wine cork and bore two holes through it, the holes being at right angles to each other, and to the axis of the cork. The holes should be of the right size to slide easily, but firmly, on a wire about the sixteenth of an inch in diameter. One piece of such wire is stuck perpendicularly in a wooden foot, and serves as a stand upon which the cork slides up and down; another piece of wire has a ring at one end for holding the magnifier, while the other end is thrust through the second hole in the cork and is supported by it.

Whenever a piece of apparatus is to be supported steadily, while at the same time it is necessary that it should be easily moved and adjusted, nothing serves so well as a fine cork sliding on a smooth wire.

Twenty-five cent Microscopes.—Before leaving this subject it may be well to say a few words about those very cheap microscopes which have been so extensively advertised. We frequently see in the papers an advertisement in which some person offers to send for twenty-five cents a microscope which will show animalcules in water, globules of blood etc., etc., and the question naturally arises, Are these microscopes good for anything, or is the advertisement a swindle—the advertiser taking the money and sending nothing in return?

As a general rule, those who send to such advertisers, receive in return, a plate of brass or lead, with a glass bead fastened in a hole in the centre. The glass bead is formed by fusion and is frequently ground flat and polished on the side by which it was attached to the thread or rod of glass from which it was made, forming in such cases a hemispherical lens. Such lenses are very easily made by any one. Take a strip of flint glass, such as a piece of flint glass tubing, or a piece of glass rod, draw it out to a thread in the flame of a spirit lamp, fuse the end and allow it to gather into a drop. Give plenty of time and a good strong heat, so that the surface of the little globe may become well-fused and truly round. The best results are always obtained by holding the thread perpendicularly, as when held horizontally the globule is apt to become distorted. Make one or two dozen of these, and in separating them from the glass rod leave about an eighth of an inch of the latter attached to each globule, to serve as a handle, in the next step of the process, which consists in inserting them to about half their depth in a plate of cement, consisting of shellac thickened with very dry and finely powdered pumice-stone. To form such a wax plate, melt some shellac in a ladle or large iron spoon, mix it carefully with as much powdered pumice-stone as can be conveniently stirred in, remove it from the fire, stir well until it begins to stiffen, and then pour it out on a flat metal plate—the surface of a smoothing iron answering very well. The plate of cement should be from one-half to three-quarters of an inch thick, and the little globules are easily fastened into it by seizing them by the small handles left on them, holding them by a pair of forceps in a lamp flame until they are hot enough to melt the cement, and then pressing them in to about half their depth or a little more. When quite cold they will be very securely held. The little handles, or tails, are now nipped off with a pair of cutting pliers, and the globules ground all at once on a fine grindstone, or still better on a metal plate charged with emery. When they have been reduced nearly to the surface of the plate of cement, they should be ground with emery of the finest kind, and as soon as all coarse scratches have been removed they should be polished on a buff leather with crocus martis or putty powder. When finely polished they may be removed from the cement by means of a small chisel, and any cement that adheres may be dissolved off by means of alcohol. They are then mounted in thin plates of lead, brass, or, what is better still, vulcanite. Out of two dozen such globules, carefully made and well polished, three or four may be obtained that will give satisfactory definition, and it was with such lenses that the early microscopists made many of their discoveries. These men, however, took great pains in making and polishing them, and rejected hundreds as unfit for use. The objections to the microscopes of this kind, that are ordinarily sold, are that they are badly made, and that good and bad are sold together without any selection being exercised. But, even if well made, they are very difficult to use, and very unsatisfactory in their results, even in the hands of persons of great skill. The polish of a fused surface never equals that of a surface finely cut and polished, as every housekeeper that is familiar with common, and with cut glass, very well knows. The fused surface of these little globes is, therefore, always more or less, covered with striæ or very minute ridges which interfere with their defining powers, and we have described thus minutely the process of their manufacture, rather for the purpose of giving our readers such information as will enable them to understand how they can be sold so cheaply, than in the hope that they will endeavor to make them for themselves.

Penny Microscopes.—A few years ago a man in London made a living by selling through the streets a microscope which would show the eels in paste and vinegar, and of which the price was only one penny, (equal to two cents.) These microscopes were thus made: In the bottom of a pill-box he punched a small hole and then blackened the inside of the box. In this hole was placed a drop of Canada balsam or damar varnish, which was allowed to dry. When hard, the balsam formed a very tolerable lens.

A drop of water, balsam, or varnish, laid on the under side of a slip of clear glass will often enable us to extemporize a microscope capable of doing good service in the hands of a skillful observer. The outline of the drop should be perfectly round, and the glass plate should be held as level as possible. We have derived great assistance from such a lens, when better could not be had.

The Craig Microscope.—This microscope at one time attained an unprecedented degree of popularity, not on account of its merits, but because of the extensive puffing and advertising which it received. It consists of a vertical frame, somewhat like that of the cheap French microscopes, having a mirror, but no sliding tube, as there is no occasion for any. The slide which holds the object is slipped through a horizontal slit cut in the stand, and the lens with its frame is laid on it.

The lens is a fused bead of glass set in a little frame, to the under side of which is attached a thin plate of glass, whose lower surface is exactly in the focus of the bead, so that when a drop of water or vinegar is placed on the glass plate, or such objects as insects' scales, wings, etc., are laid on it, they are exactly in focus. Hence, this microscope is said to require no adjustment for focus. This is true when the objects to be examined are actually in contact with the glass plate, but when we wish to examine objects that are covered with thin glass (as all valuable preparations should be) or objects having a perceptible thickness, it is *impossible* to adjust it for focus, and hence it is impossible to examine such objects satisfactorily. Besides this, nine-tenths of the microscopes of this pattern in market, are very badly made, and distort objects to such an extent that one who has been accustomed to employ a good microscope cannot recognize them. It has unquestionably done a great great deal to impede the progress of microscopy in this country, and we have been led to give this extended description of it, chiefly because so many editors and clergymen have praised it in the highest terms. It has even been patented, although the principle upon which it is constructed is very old; but then we must remember that under our present administration the patent office seems to be conducted rather for the *dis*couragement than the *en*couragement of progress and invention. We daily see patents issued for old and worthless devices, while it is well-known that the author of a really meritorious invention will have the hardest work to obtain protection.

Of the Novelty, Globe, and other similar microscopes, it is unnecessary to speak. In all the microscopes of this kind that we have seen, the optical part is utterly worthless. The lenses are mere fused globules of glass, and they distort beyond recognition the image of any object.

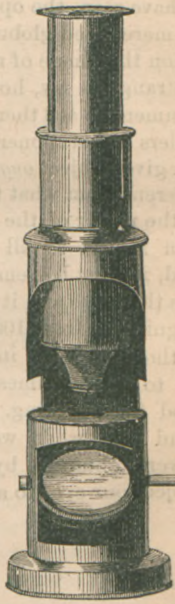
Strange to say, however, even this fact has been used as an argument to sell them. They have been sold chiefly by news-dealers and stationers, and as the purchasers did not know how any given object *ought* to appear, the fact that it looked so very different from what they expected was considered an evidence of the power of the microscope ! !

In regard to all microscopes in which fused globules are used, it must be remembered that the lower the power of the lens the more apt it is to be imperfect. No lens of this kind, magnifying from 100 to 150 times, (according to the estimates of those who deal in them, which, however, is in fact only from ten to twelve times, as measured by proper methods), can be good for anything. On the other hand, it must be borne in mind that when we attempt to examine objects under high powers, obtained by the use of very small single lenses, we subject our eyes to an almost destructive strain.

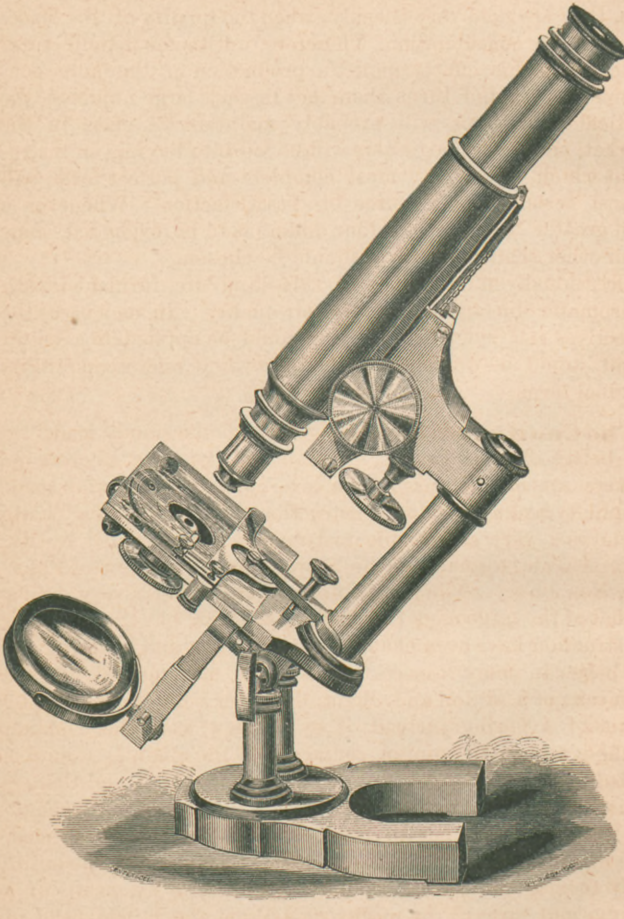
DIFFERENT FORMS OF THE COMPOUND MICROSCOPE.

The variety of styles or patterns which have been devised for the stands and for the general arrangement of compound microscopes, is almost infinite, and as they are continually changing, it would be a hopeless task to attempt to give such a description as would be of real value to the reader, and since, from motives of self-interest, the manufacturers of these instruments promptly publish full descriptions and engravings of new styles as soon as they bring them out, the best plan for those who desire to make a judicious selection is to procure the catalogues of as many manufacturers as possible, and carefully compare the several advantages of the different forms. To facilitate this, we give, at the end of the volume, the addresses of most of the prominent makers.

There are, however, a few typical styles or models to which it may be well to call attention, and of these we give engravings and such descriptions as will enable the reader to form some idea of the stand best suited to his special wants. In selecting illustrations of the different types, we have taken the cheaper forms in preference to the more perfect, but more expensive models.


VERTICAL MICROSCOPE.

French Vertical Microscopes.—This form, although modern when compared with the microscopes of Adams, Baker, etc., is one of the oldest forms in use. It was, we believe, devised by Wollaston, as a stand for his doublet, and it is now too well known to need elaborate description, and as no microscopes of any value are ever constructed upon this plan, it is unnecessary to point out its defects. The smaller sizes are still sold extensively; and being manufactured in large quanti-



CONTINENTAL MODEL.

As made by Geo Wale, Paterson. N. J.

Plate I.

[To face page 35.

ties, they are sold very cheaply, when the quality of the lenses is taken into consideration. Therefore, until some manufacturer concentrates his efforts upon the production of the more convenient forms, and turns them out in very large numbers, the vertical microscope will probably maintain its place in the market, and many beginners will be led into buying an instrument which, even in its most complete and perfect form, will almost certainly be a source of dissatisfaction. Whenever a sum greater than three or four dollars is to be expended, some form other than the vertical should be chosen.

Occasionally microscopes of this kind are furnished with achromatic objectives of pretty fair quality. In such cases the objectives and eye-pieces, if they could be applied to a better stand, would be worth more than the whole microscope in its original form.

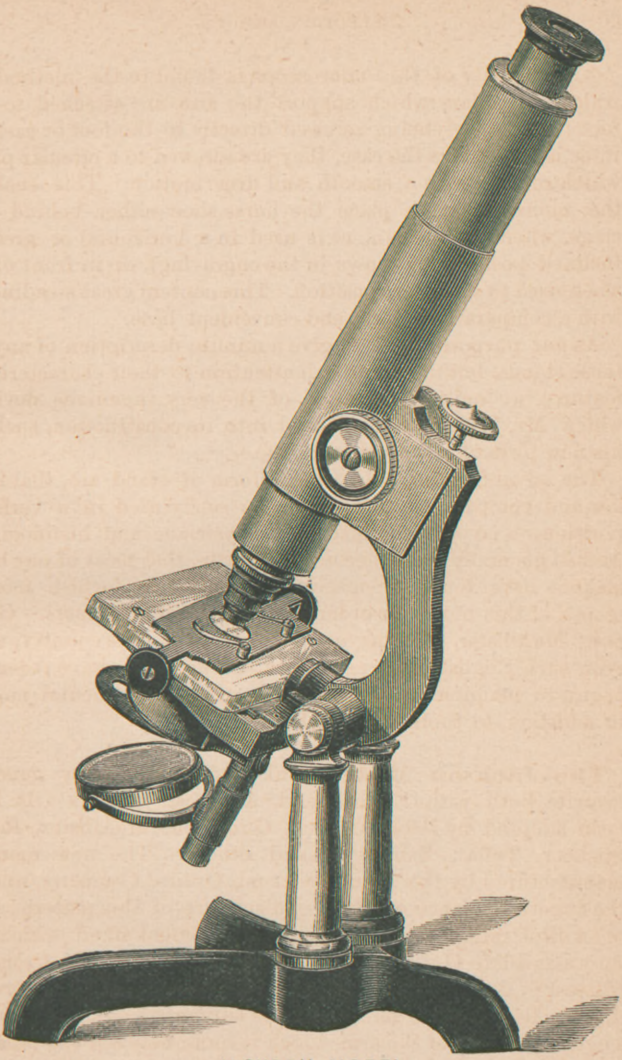
The Continental Form.—Most of the stands made by the better class of French, German and Austrian microscope makers are characterized by a low, compact form, and great simplicity and solidity of construction. Our engraving, Plate I, shows a very serviceable instrument, manufactured by Mr. George Wale, formerly of the Stevens' Institute, now of Paterson, New Jersey. The general form of this stand is very similar to that of the large model of Nachet, of Paris, but the details of construction have been changed considerably, and we think for the better in many respects. The coarse movement is effected by means of a pinion and chain, the latter being kept tight by means of a spring instead of by a screw, as is the common method, and as the pinion round which the chain is wound is milled so that the links fit into it, all slip is avoided, and there is positively no "lost motion" whatever—the movement responding promptly in either direction even when suddenly reversed. The fine movement consists of a lever which carries the entire body (coarse movement included) downward by means of a spring, and upward by means of a screw, the milled head of which is placed below the arm which carries the body. This brings both movements so close together that the hand may be kept on both at the same time—the thumb and fore finger operating the coarse movement, while the third and fourth fingers make the fine adjustment.

A peculiarity of this microscope is found in the method by which the pillars which support the arm are attached to the foot. Instead of being screwed directly to the foot or cast on it, as is sometimes the case, they are screwed to a circular plate which rotates with a smooth and firm motion. This enables the microscopist to place the horse-shoe either behind the stage, when the instrument is used in a horizontal or greatly inclined position (as shown in the engraving), or in front of it when used in a vertical position. This confers great steadiness, with a comparatively light and convenient base.

As our purpose is not to give a minute description of any of these stands, but merely to call attention to their characteristic features, we omit all mention of the very ingenious devices which Mr. Wale has introduced into its construction, such as his new form of iris diaphragm, etc.

The advantages of this general form of stand are, that it is low and compact, so that it can be easily used in a vertical position—a favorite method with physicians and histologists. And so generally has it become a favorite, that most of our best makers have found themselves compelled to furnish microscopes of this model in order to retain their customers. Grunow, McAllister, Zentmayer, and others in this country, and even such English makers as Beck, Crouch, etc., have recently begun to manufacture microscopes of the Continental model in addition to their other styles.

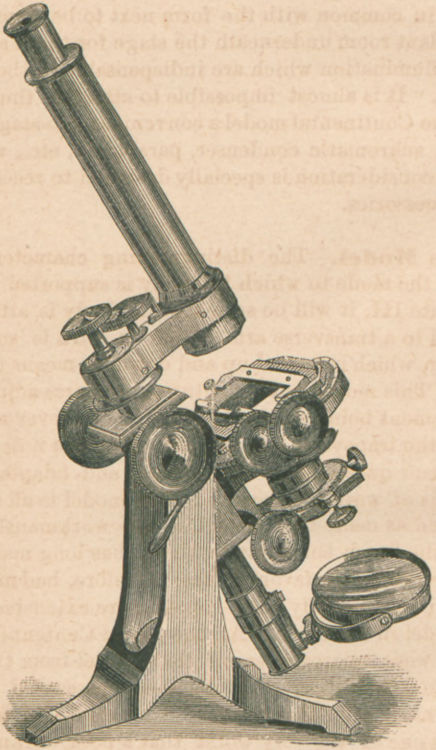
The Jackson Model.—This model is a very general favorite both with English and American makers. It has been adopted by Beck, Crouch, Gundlach, McAllister, Ross, Spencer, Tolles, Zentmayer and others. The new models manufactured by the Bausch & Lomb Optical Company, under the superintendence of Mr. Gundlach, are of this pattern, and as an illustration we have taken their Student stand, which is shown in Plate II. The binocular microscope of Mr. Crouch, (Plate IV), is also constructed on this model. It will be observed that the body of the microscope is supported along its whole length by means of the arm, which is hung between two pillars, so as to give great steadiness. To add to this steadiness, all sharp angles are avoided, and the arm is gracefully curved in-



JACKSON MODEL.

As made by Bausch & Lomb Optical Company.

Plate II. [To face page 36.



ROSS MODEL.

Latest Pattern as made by Ross & Co, of London.

Plate III. [To face page 37.

stead of joining the body at a right angle, as in the Ross model, and many of those made after the so-called Continental pattern.

The special advantages of this model are great steadiness and the fact that in common with the form next to be described, it affords abundant room underneath the stage for those accessory methods of illumination which are indispensable in the highest class of work. It is almost impossible to attach to the smaller patterns of the Continental model a convenient sub-stage, carrying polarizer, achromatic condenser, paraboloid, etc., while the model under consideration is specially designed to receive these important accessories.

The Ross Model.—The distinguishing characteristic of this model is the mode in which the body is supported. By referring to Plate III, it will be seen that the body is attached at its lower end to a transverse arm, which in turn is supported by a stout bar, which is moved up and down by means of a rack and pinion. This movement constitutes the coarse adjustment, the fine movement being effected by means of a lever which is concealed in the transverse bar, and acts upon the nose-piece.

So far as mere questions of convenience and adaptability to different kinds of work is concerned, this model is all that can be desired, and as made by Ross & Co., the workmanship is so perfect, and the finish so exquisite, that it has long maintained a high position in public favor. It has, therefore, had numerous imitators, and has probably been copied more extensively than any other model in existence. At the recent Centennial Exhibition there were microscopes on this model from the most widely scattered localities. Canada was represented by two microscopes made after this design. Unfortunately, however, this model is one of the very worst that a poor workman can attempt to imitate, for unless the workmanship is far above the average, the results are execrable. The reason for this is very obvious. The body, being supported only at the lower end, every vibration causes the upper end to swing through a comparatively large arc, and hence any motion arising from looseness in the joints is multiplied a hundred fold. And even when the joints are firm and without shake, any vibration communicated to the table on which the instrument stands, is greatly increased in its effects when it reaches the upper end of the body. In addition to this, the unsupported part of the body acquires, by each movement, a momentum which reacts powerfully on the lower part, and consequently on the objective.

These defects have induced Messrs. Ross & Co. to bring out a new pattern designed after the Jackson model. This design has been carefully worked out by Mr. Wenham, and is certainly very beautiful in appearance, and very efficient and convenient in use. Our readers will therefore bear in mind, that all microscopes made by Ross & Co., are not made on the "Ross model."

It is not our purpose to enter here into the details of the construction of the stage, and the various means of illumination which accompany this microscope. For these we refer to the extensive illustrated catalogues, which may be obtained from the manufacturers.

Browning's New Model.—The importance of being able to rotate the object in relation to the illumination is generally recognized, and in almost all the better class of stands, full provision is made for this. It has always been difficult, however, to secure perfect coincidence of the centre of rotation with the optic axis. In the better class of microscopes, made a few years ago, the makers depended upon perfect workmanship to secure this end, and consequently a satisfactory rotating stage was to be found only in the very best instruments. After all, however, *perfection* is not to be found, and even the best stages of this kind were very liable to get out of order. To obviate this, Mr. Browning has constructed his stand with the stage in two pieces, the lower part being connected with the foot, and the means of illumination, while the upper part, which rotates on the lower, is rigidly attached to the arm which carries the body. In this way the body, arm, and stage may all be rotated in relation to the illumination, and for ordinary purposes this answers very well. When polarized light is used, however, it is obvious that it is impossible to rotate the object in relation to the polarized ray, without also rotating the analyzer, and, as every one that has worked much in this direction knows, it is often of great importance that both polarizer and analyzer should be kept stationary, while the object itself rotates between them.

The Inverted Microscope.—Some years ago, Professor J. Lawrence Smith devised a microscope specially adapted to chemical investigation. In this instrument the stage is placed *over* the objective, which is inverted, and the body connected with it at an angle. A prism reflects the image of the object, and causes it to pass up the body to the eye of the observer. For some purposes it is a very useful instrument. Nachet seems to be the only maker that keeps this form in stock.

The Binocular Microscope.—More than two hundred years ago, attempts were made to construct binocular microscopes, and yet a good and efficient binocular is a thing of yesterday. Professor Riddel of this country, M. Nachet of Paris, and Mr. Wenham of London, seem to have been most prominent in the efforts that have been made of late years to perfect this instrument, and to Mr. Wenham is due the credit of having produced a method which is at once efficient and easily made. Indeed, so little does the binocular feature now add to the expense of even good microscopes, that a London made stand, which in its monocular form costs $90, can be had as a binocular of the most excellent quality for $100. Mr. Wenham has, therefore, laid all microscopists under deep obligations, not only by devising such simple and efficient means of accomplishing a most desirable result, but by giving the use of his invention freely to the world.

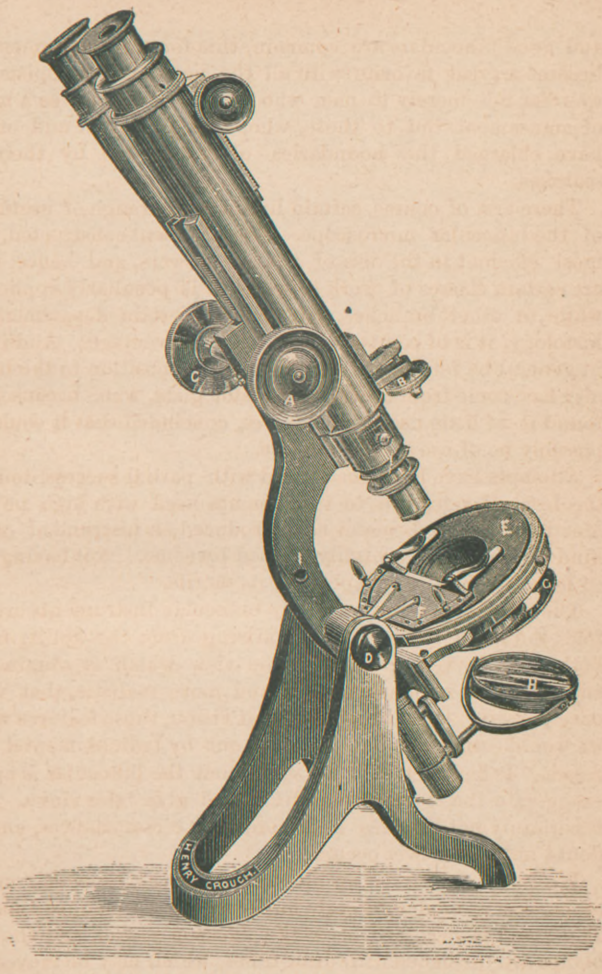
Of the value of the binocular, there is a wide difference of opinion, some regarding it as a mere toy, and altogether beneath notice as an instrument of scientific research, while others consider it a most important addition to our means of investigation. Since, however, it will almost always be found that those who place a high value on the binocular are those who have used it most, while those who decry it know absolutely nothing of its merits, and are even ignorant of the manner of using it, the reader will have but little difficulty in deciding on which side the truth lies. In England, where cheap and good binoculars are common, this form of instrument has become a great favorite with all the noted microscopists, and we refer not merely to men who own microscopes as a means of amusement, but to those, who, like Carpenter and others, have enlarged the boundaries of knowledge by their researches.

There are, of course, certain limits to the range of usefulness of the binocular microscope. As at present constructed, it is most efficient in the use of the low powers, and hence, there are certain classes of work to which it is peculiarly applicable, while in other branches, particularly certain departments of histology, it is of comparatively slight advantage. And it will in general be found that the principal opposition to the binocular has come from continental histologists, who, because they found it of little use to themselves, concluded that it could not possibly be of use to any one else.

Attempts have been made, and with partial success, to apply the binocular feature to instruments used with high powers. Messrs. Powell & Lealand have produced an instrument of this kind which has been highly praised by some. Not having seen it, however, we cannot speak of its merits.

The advantages presented by binocular instruments are two fold; the relief to the observer arising from the ability to use both eyes is very great, and the view which is obtained of any object is so much clearer and more realistic, that we at once perceive, by our mere sense of vision, those features which we would otherwise have to work out by tedious mental processes. It has been said by some, that the binocular is apt to exaggerate the stereoscopic effects, and give false views. This is certainly not the case under ordinary circumstances, and we doubt much if it ever occurs.

We have chosen as an illustration of the binocular microscope, one of moderate cost, made by Mr. Crouch, of London. The stand is designed after the Jackson model, and the two bodies are furnished with draw-tubes, which may be moved out or in simultaneously by racks and pinions, the milled heads of which are seen at the upper part of the instrument. The fitting of the Wenham prism which produces the binocular effect, is seen just above the nose-piece; by withdrawing it slightly, the



STUDENTS' BINOCULAR MICROSCOPE.

As made by Crouch, of London.

Plate IV. [To face page 40.

instrument is at once converted into a monocular, equal in every respect to any that are made specially in that way. The fine motion is by a lever, which moves the nose-piece, to which the objective is attached. The instrument is furnished with a well-made mechanical stage, and we would call the special attention of the reader to a point, which we have already noted, viz., the abundant room which is found below the stage for the application of accessory illuminating apparatus. The sub-stage, which has very delicate means of adjustment for focussing and centering, has considerable range, and affords facilities which cannot possibly be combined with what may be called the "dumpy" models.

Binocular Eye-Piece.—A very valuable and efficient means of converting an ordinary monocular microscope into a binocular, has been devised by Mr. Tolles, of Boston. But its price, $80, places it beyond the reach of "beginners," for whom this work is specially intended.

OBJECTIVES.

The modern compound microscope owes almost all its value to the high degree of perfection which has been attained in the construction of the objectives used with it. Some of the old microscope stands were quite as elaborate, and quite as costly, as anything that can be found in the workshops of our modern opticians, but from the fact that the objectives were little else than simple lenses, their value as instruments of research was of a very low degree. This being the case, it is of some importance to the microscopist that he should have at least a fair understanding of the causes to which the superiority of modern objectives is due.

When we use a simple glass lens as an objective for a compound microscope, we find on attempting to examine objects under powers of more than one hundred diameters, the following defects and difficulties: The field of view is so dimly illuminated that objects are seen with difficulty; the outlines of the different parts, instead of being sharp and clear, are thick and hazy; several of the lines are fringed with brilliant colors, but colors which do not belong to the objects, and finally, if the outlines of the object should happen to be straight lines, and be known to be such, it will be found that they will appear to be curved and distorted. It is evident, therefore, that a simple lens cannot be used as an objective in any important work; its indications are unreliable, and the imagination is allowed full scope, so that the eye is enabled to see whatever the mind desires to see.

The defects which we have just detailed, and which are found in every simple glass lens, whose surfaces are bounded with curves that are parts of circles, are largely due to what is called *spherical* and *chromatic aberration*. As these terms are probably not familiar to many of our readers, we will give as full and simple an explanation of the subject as can be done without the formal aid of mathematics.

Spherical Aberration.—The enlarged image formed at the focus of any lens, and rendered visible on a screen or sheet, is produced in this way: The rays proceeding from the object, and passing through the lens, are, by the action of the glass, bent from the path they would otherwise pursue. The object may of course be supposed to consist of an infinite number of points, and from these points rays proceed in every direction, and consequently through every part of the lens. If the lens were perfect, all the rays from any one point would be brought together at a second point corresponding with the first. Unfortunately, however, the ordinary lens does not do this; the central portions of the lens and the outer portions act differently; the one brings the rays to a focus at a point a little nearer to the lens than the other, and, consequently, although we move the screen to a slightly greater or less distance, we still get an image of about the same degree of distinctness. It is obvious, therefore, that when placed at any distance within certain limits, the screen will receive not one image, but a series of *layers* of images as it were, and this consequently gives an indistinctness to the resulting image.

Our readers will find no difficulty in thinking out this matter for themselves, and when they have arrived at clear ideas upon the subject, they will see that spherical aberration is caused by the difference between the extent of the refraction produced at different parts of the lens, and this applies not only to all the rays proceeding from each individual point, but to the several pencils which proceed from different points.

It is evident that if some parts of the lens bring the rays to a focus at a shorter distance than others, these parts must magnify more, and such is in reality found to be the case. But if one part of an object is magnified more than another, the image will be distorted, and hence we have what is sometimes known as *aberration of form.* This distortion is easily seen by examining a piece of muslin with a magnifier of high power and large diameter. The threads in the centre of the field of view* will appear to be straight, while those at the outside will appear to be curved.†

Chromatic Aberration.—This is a defect of ordinary or uncorrected lenses, whereby they not only act as magnifiers, but as prisms, decomposing the light, and causing objects seen through them to appear with a fringe of color. Common hand magnifying glasses, used in the ordinary way, do not exhibit this defect to a very marked degree, but when the images formed by lenses of this kind are again magnified, as is done in the compound microscope or telescope, the color becomes very disagreeably perceptible.

* By field of view is meant that portion of the object which is visible through the magnifier.

†In ordinary lenses and microscopes, in which this defect is not corrected by the structure of the glasses themselves, the effects of spherical aberration are lessened by contracting the field of view, so that only those parts of the object which are seen through the centre of the lens or objective are looked at. This contraction is usually effected by means of diaphragms, or round plates of metal pierced with a central hole, which are so placed as to cut off the rays which pass through the edge of the lens, and leave only those that are central. This plan, however, is only the substitution of one defect for another, for by lessening the field of view of the lens, we are prevented from seeing more than a very small portion of the object, and in addition to this the light is so much reduced that the object is seen only with very great difficulty, and not at all clearly.

Corrected Objectives.—The defects which we have just described have been the chief difficulties in the way of perfecting both the microscope and the telescope. In the case of the latter, however, it was long ago found that very excellent results could be obtained by forming the lenses of two or more pieces of glass of different kinds, and numerous attempts were made to apply the same principles to the construction of the microscope, but without marked success. The small lenses used for the microscope seemed to defy the skill of the practical opticians of those days, and resort was had to such devices as lenses made of precious stones, and the use of light which could not be decomposed—*mono-chromatic* light as it was called, or light of one color. Such light is readily procured by the combustion of alcohol mixed with common salt, and when illuminated solely by such a light, a brilliantly colored painting looks exactly like a plain black and white engraving. But although the use of such a light lessens the evils caused by chromatic aberration, they introduce another which is quite serious—objects which are really colored, appear in black and white only. Moreover, such a light cannot easily be obtained of a brilliancy sufficient to afford good illumination, and in addition to this all the defects due to spherical aberration still remain in full force.

The first attempts made to perfect the object-glasses of microscopes, consisted in the use of doublets and triplets, it having been found that the spherical aberration is greatly lessened, when the total refraction is divided up amongst several surfaces of moderate curvature, instead of one surface in which the curvature is excessive, and this plan is still pursued in the construction of what are known as French triplets, which will be described hereafter. About the year 1829, however, Mr. J. J. Lister, of London, England, published an elaborate paper upon the subject, and it was from the principles laid down in this paper, that all the important improvements in the modern objective took their rise. These principles were embodied in the practical construction of objectives by Andrew Ross, who suggested the important improvement known as the adjustment for thickness of cover. To Lister and Ross, therefore, it may be justly said that we owe that optical wonder, the modern objective, for although great improvements have been made within the past few years, it is upon the results of their labors that these improvements have been based. And yet, notwithstanding this well-known fact, the names of these distinguished microscopists are not so much as mentioned in this connection in the recent work of Dr. Frey, which has been lately translated into English, and extensively circulated in this country!

In estimating the quality of an objective, there are certain features to which especial attention must be given. Aside from magnifying power, which, of course, cannot be regarded as affecting the *quality* of an objective, these points are: 1. Defining power; 2. Achromatism; 3. Freedom from aberration of form; 4. Flatness of field; 5. Angular aperture; 6. Penetration; 7. Working distance.*

Defining Power.—This is undoubtedly the most important quality to be sought for in objectives. A glass that is deficient in this point is absolutely worthless. Want of defining power is shown by a general haziness and thickening of the outlines, together with a want of clearness in the details. It arises from the presence of either spherical or chromatic

*The authors of the Micrographic Dictionary enumerate the following points as those in which object-glasses differ from each other: 1. Magnifying power. 2. Defining power. 3. Penetrating power. 4. Their corrective adaptations. The functions attributed to "defining power" are the same as those given by other writers; "penetrating power" seems to be equivalent to what is generally called "resolving power;" "corrective adaptation" is merely the presence of a means of adjusting for thickness of glass cover. Frey distinguishes two attributes of object-glasses, viz., defining power, and penetrating or resolving power—penetrating power and resolving power being considered by him to be the same thing. Carpenter enumerates four distinct attributes of object-glasses, viz., "(1) *Defining power*, or the power of giving a clear and distinct image of all well marked features of an object, especially of its boundaries; (2) its *penetrating power* or *focal depth*, by which the observer is enabled to look into the structure of objects; (3) its *resolving power*, by which it enables closely approximated markings to be distinguished; and (4) the *flatness of the field* which it gives." We cannot regard any of these classifications, as strictly logical. Beale makes no formal statement, but gives some very excellent practical directions in regard to the selection of objectives.

aberration, or both. It might be caused by a want of finish on the surfaces of the lenses, but this is seldom the case in practice, except where the objective has been exposed to some corroding fumes or liquids. Old objectives that have been very excellent in their day, sometimes fail in defining power, from the fact that the surface becomes covered with a greasy deposit, very slight, it is true, but just enough to destroy the efficiency of the glass. Objectives in this condition should be returned to the makers to be cleaned. In one case we found that in a lens which failed to show anything clearly, the difficulty arose from the fact that the cement used for uniting the glasses of the combination had become affected. The objective was by a well-known maker, but was over twenty years old

Achromatism.—When an objective shows much color, it fails to define well except by monochromatic light, such as that obtained by passing sunlight through a cell filled with the blue solution of copper in ammonia. A very slight degree of color is not regarded as objectionable, and indeed it has been found almost impossible to secure the requisite angular aperture and absence of spherical aberration without leaving a little color. Some of the best objectives, therefore, show such objects as the *P. angulatum* with decided colors, and yet well resolved.

Aberration of Form.—An objective may appear to define an object perfectly, and yet give a very distorted figure of it, just as a cylindrical mirror gives a perfectly definite, though very distorted, image of objects seen reflected in it. Aberration of form may arise either from over or under correction of the spherical aberration, or from want of homogeniety in the glass used for making the lenses, or from a want of perfection in the workmanship—the surfaces of the lenses not being perfectly spherical. Sometimes this defect is shown very clearly on one side of an objective, while the other side is not affected, and this fact may give rise to very curious results when the objective is tried on different stands, and with oblique light. Owing to a variation in the point at which the screw threads begin in the different stands, the objective, when fairly screwed up, may have a different position in each, as regards the direction from which the illumination comes. The consequence is, that an objective which may give excellent results on one stand, may fail on another. An easy way of testing this fact, is by means of a rotating adapter. Of course the best test for aberration of form is the artificial star, though in the hands of the beginner, a micrometer, ruled into squares, is probably the most available test. Any trace of the defect under consideration will be shown by the lines being curved.

When the lines appear curved, from the fact that the spherical aberration has not been properly corrected, the nature of the error may be determined as follows: When the micrometer lines are widest apart at the centre (like the lines on a map of a hemisphere) the spherical aberration has been over-corrected. It is under-corrected when the reverse is the case.

Aberration of form is one of the worst faults with which a lens can be affected, and experience has shown us that it is the one which is least apt to be detected by a beginner. An objective may give a "beautiful" image, and yet be worthless because affected with this defect.

Flatness of Field.—If, when we examine a perfectly flat object, every part included in the field of view is clearly in focus, the objective is said to have a *flat field*. Want of flatness of field is shown by some parts of a flat object being clear and well-defined, while other parts are out of focus. In general it happens that where this defect exists, the centre and circumference of the objective do not act together.

Angular Aperture.—This subject has given rise to some of the most vexatious questions connected with microscopy, for a discussion of which we must refer our readers to the pages of the microscopical journals published during the past few years. The views which have been promulgated by the two schools into which microscopists have been divided on the questions affecting angular aperture, have been of an extremely opposite nature. Thus, the Boston school claim to have produced objectives whose angle of aperture is 180°, while the English microscopists ridicule any such claims. Moreover, while what may be called the English school lay it down as a law that the angular aperture and penetration must of necessity be in inverse ratio to each other, the Boston school claim to have produced objectives of very high angles, which at the same time possess great penetration. Even the *definition* of angular aperture seems to be unsettled, all of which is, of course, very puzzling to a beginner. In the present work we propose to accept the old definition, and to confine ourselves to generally acknowledged facts in regard to the other points.

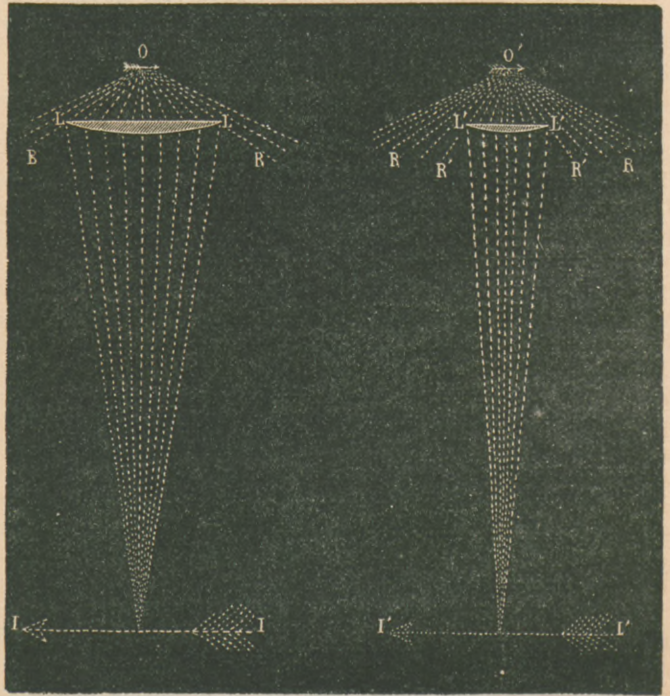


Fig. 3.

It was Dr. Goring, we believe, that first pointed out the special advantages of high angles, and suggested the use of test objects, and the figures on the preceding page were used by him to define and explain what he meant by angular aperture.

In these figures L L and L′ L′ are two lenses of the same magnifying power, but different angular apertures. It will be seen that the cone of rays proceeding from O, is substantially the same as that from O′, but that the lens L L takes in a larger part of the cone from O, than the lens L′ L′ does of the cone from O′. The angles L O L and L′ O′ L′ are the respective measures of the angular apertures of the two lenses.

The definition of angular aperture given by Goring, has been followed by all subsequent writers, the accompanying figure being that used by Dr. Carpenter for the purpose of explaining and defining the same thing. In this figure *a b c* is the angle of aperture. Therefore, while it is not to be denied that other angles may be of great importance in considering the qualities of an objective, it is altogether wrong to apply the term angular aperture to any other angle than the one that has been described.

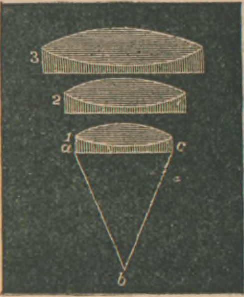


Fig. 4.

Dr. Goring devised several practical methods of measuring the angular aperture of different objectives, and he gives a very full and clear description of an arrangement adapted to his own instrument, in which the foot was made to rotate on a carefully centered and graduated base—a very excellent plan, modifications of which have since been adopted by Mr. Zentmayer, of Philadelphia, and by Mr. Bulloch, of Chicago.

It is not difficult to demonstrate the importance of a comparatively wide angle of aperture, since object-glasses possessing this feature are capable of giving important results which lenses of lower angle cannot give. Thus, when we examine, by means of a superior French triplet of one-sixth of an inch focus, the silicious remains of certain very minute plants of the species *Pleurosigma Balticum,* we are able to see certain lines or markings which exist upon their surfaces. That we may be able to see these lines, it is necessary that the stand be a good one, and that the light be very carefully managed, but, even with the most perfect arrangements ordinarily used, we cannot, with such an objective, discover similar markings upon the *Pleurosigma Angulatum,* although they exist there in great perfection. But if for the French sixth we substitute a first-class objective of less than half its magnifying power, but of wider angular aperture, we shall be able to see the lines quite distinctly. We have now before us an objective of four-tenths of an inch focus, which does not correct for thickness of cover, but which, with any ordinary thickness of covering glass, is capable of resolving the lines on the *Angulatum* perfectly, and we have seen objectives of even lower magnifying power which would accomplish the same thing.

That the effect depends here chiefly upon angular aperture, was shown very clearly by Dr. Goring, from whose work we take the following figures, engraved from seven drawings showing the appearances presented by the scale of a butterfly's wing, viewed with the same magnifying powers, but different angular apertures. A well corrected lens of wide aperture showed the scale as in G; reducing the aperture, while all else remained the same, the appearance was as shown in F, and by successive reductions the stages shown in E, D, C, B, and A, were reached. The slightest examination shows that features which were quite distinct under a high angle, became invisible when the angle was reduced.

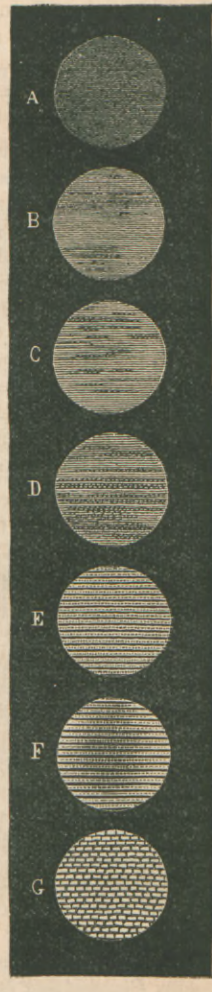


Fig. 5.

This quality of objectives of large angles, whereby they are capable of showing distinctly delicate lines or dots placed very closely together, is known as *resolving power*. In the early days of microscopy, it was called *penetrating power*, the term *penetrating* having been applied to that quality of the telescope by which it is enabled to show separately the individual stars of which the nebulæ are composed. In the telescope this was supposed to depend upon *space-penetrating power* as distinguished from mere magnifying power, and this space-penetrating power was found to depend very largely upon angular aperture. In the case of the microscope, however, it is now generally agreed that what was called penetrating power in the telescope, shall be called resolving power, while to the term penetrating power an entirely different meaning has been given.

Mere resolving power, however, or the power of showing separately lines placed very closely together, is not the only valuable feature of well-corrected object-glasses of high angles. They show delicate lines and fibres, and enable us to make out differences of structure which are entirely invisible to lenses of low angles. Thus, for example, it has been found during recent researches, that the delicate flagella of certain monads can be seen perfectly with high angle lenses, while with very excellent glasses of low angular aperture they are quite invisible. The same fact, probably, holds true in regard to the ultimate fibres of nerves and similar objects.

The researches of Lister and Ross formed, as we have just stated, the first great step in the direction of better correction and increased angular aperture. Whereas, 40° to 65° had previously been regarded as very high angles, even in objectives of the shortest focal distance, Ross, in his objectives, soon attained an aperture of 132° to 135° and, working with the glass at that time available, this was pronounced the highest attainable angle. Attempts had previously been made to obtain a higher angle by the use of the glass which Faraday devised for optical purposes, and which is in fact a borate of lead. But this compound is so easily tarnished and disintegrated, that it was found impracticable to use it. It happened, however, that a young American backwoodsman, Charles A. Spencer, of Canastota, N. Y., a graduate of Hamilton College, had his attention called to this subject, and after careful study he concluded that if he could only procure a durable glass of greater refracting power than that ordinarily attainable, the angular aperture might be greatly increased. He at once went to work, and after many experiments, he succeeded in producing a glass which enabled him to attain immediately an angular aperture of 146°. As early as 1857 he had produced a 1-12th with an angular aperture of 178°. His objectives had corresponding excellence in other directions, and from that time forward this country has been noted for the excellence of its objectives, and especially for their great resolving power. We may note in passing that glass of great refractive power, combined with sufficient hardness and durability, is now produced as a regular article of commerce.

Penetrating Power.—As previously stated, penetrating power, in the early days of microscopy, meant precisely what is now understood by resolving power. Now, however, penetrating power means the extent to which an object-glass shows the depth or thickness of an object. This is a very important feature for some purposes, particularly in histological work, as by it we are enabled to discover the relations between the different parts.

Until within a few years it has been accepted, as a thoroughly demonstrated fact, that penetrating and resolving power always, of necessity, exist in inverse ratio to each other, for it is always found that, other things being equal, resolving power increases with the angle of aperture, while penetrating power decreases. Of late, however, it has been claimed that certain lenses of great resolving power and high angle possess great penetrating power.

In attempting to reach a sound conclusion on this point, it must be borne in mind that resolving power does not depend *wholly* upon angular aperture. Two objectives of the same angle may have very different powers of resolution, on account of the degree of perfection to which the corrections have been carried, and it is quite possible that a lens of great resolving power may have a lower angle than another objective which it excels in this respect. In this case the lens of greatest resolving power might also have the greatest penetration. We confess, however, that we cannot see how great penetration can be combined with very high angular aperture, and in this view we believe that we are in accord with the majority of our best microscopists.

Working Distance.—This is a very important feature in all lenses, and good working distance is specially valuable to beginners. There are many objectives in market that have to be brought so close to the object that ordinary covering glass cannot be used, and even with the thinnest glass, the distance between the objective and the object is such that great skill and care are required to avoid accidents. Such objectives do excellent work in the hands of experienced microscopists, but beginners should by all means avoid them. Objectives of very high angular aperture have in general very short working distances, but there are great differences in this respect amongst the products of different makers. Working distance does not depend upon angular aperture alone.

Immersion Lenses.—Objectives which require a drop of liquid between the front lens and the covering-glass of the object, are now familiar to most microscopists, and have come into very general favor. The liquid employed serves two important purposes. In the first place, it partially extinguishes two of the glass surfaces (the front surface of the objective and the upper surface of the covering-glass) and thus it prevents, to a considerable extent, the loss of light which always occurs at these surfaces. In the second place, it decreases very slightly the magnifying power, and lowers the angular aperture, but increases the penetration and working distance; hence immersion objectives do not require the same precision of adjustment for thickness of cover that dry lenses need, and consequently it is possible to produce non-adjusting lenses on the immersion principle which are easily used and very effective. They are, therefore, great favorites with most histologists. Some makers have carried this principle so far, that the objectives constructed by them can be used only with liquids much more dense than water—pure glycerine for example.

For ordinary work we prefer a dry lens, from the fact that it is some trouble to apply the liquid and clean the lens, and also the cover, and where a large number of observations are to be made, even trifling delays must be considered. Some makers have endeavored to avoid this difficulty by supplying double fronts (a wet and a dry) to their objectives, while Mr. Wenham has elaborated a formula for a series of objectives which work either wet or dry, according as the arrangement used for the ordinary cover-adjustment is set to the one or the other. Not having had an opportunity to examine objectives constructed according to this plan, we cannot speak in regard to its success.

The origin of the immersion objective seems to be disputed. So far as we can learn, the principle was first suggested by Sir David Brewster, but the first really useful lenses of this kind were brought out by Hartnack.

Lens Systems.—Formerly the term "system" was applied only to the entire combination forming the objective, and we had "immersion systems," "correction systems," etc. At present the word is used also to denote the individual combinations of two or more pieces of glass, which, when arranged together, form the whole objective, as will be understood from Fig. 4, where 1, 2 and 3 form the separate systems, each composed of two pieces of glass. Such a combination (the figure of which is, of course, only diagramatic,) is said to form a three-system lens. Very low powers, formed of two achromatic lenses, are said to be two-system; four combinations, four-system, etc.

French Triplets.—A few years ago these objectives were used quite extensively. They are so called because they originated in the country after which they are named, while to further distinguish between them and objectives constructed according to the principles laid down by Lister, the latter were known as the *English* form. Good makers of the English form are now found in the United States, France, Germany, Austria and Italy; and the French pattern is made in many of the cities of Europe outside of France, although as yet neither the English nor the American opticians have been able to manufacture them at prices which can compete with those of continental Europe. The best of the so-called French objectives consist simply of lenses in which the chromatic aberration is corrected by the usual plan of making each lens of two different kinds of glass, while the spherical aberration is corrected partly by the form of the lens, but chiefly by reducing the aperture, and by properly combining a series of single lenses, which, hovever, are never especially adjusted to each other, as in the English forms. Each objective, in its most perfect condition, consists of three lenses screwed together, and in the lower powers these lenses may be separated and used either singly or in combinations of two or three. As the magnifying power obtained with two lenses is less than that obtained by three, the defects of the double combination are not as obvious as they would be if the magnifying power were equal to that of the triple combination. As, however, the spherical aberration in the case of a single lens, whether it be a plain lens or an achromatic combination, is always greater than that of a doublet, and the aberration in the doublet greater than that in the triplet, it is never a good plan to attempt to obtain a low or moderate power by separating the lenses of a high power objective, and using them singly or in twos. Any person having a few French objectives at hand who will try this and attempt to secure the same magnifying power by the use of two lenses, and also by the use of three, the latter being a regularly adjusted combination, will find that the results obtained by the use of the latter are far superior to those afforded by the former.*

Considering their quality, these French objectives are remarkably cheap. Thus a French No. 1, which is nearly equivalent to the half-inch objective of the English and American opticians, can be bought for $5, while the cheapest student's objective of this power would cost at least double that sum. In addition to this, the French objective may be divided so as to afford two other objectives of about three-quarters and one inch each, and although the performance of these is far inferior to English or American objectives of the same power, they are

*In making such a trial, it is, of course, necessary to use lenses of equal quality in both cases, since the quality of the professedly achromatic French objectives in market varies very much. We have seen objectives of this class of the same magnifying power, one of which would not resolve the markings on the scales of the clothes-moth's wing, while the other would resolve the *Pleurosigma Balticum*.

capable of showing a great deal that is interesting and instructive. Two or three years ago these lenses were the only ones furnished with microscopes costing less than $50, and in the very cheap instruments the different powers were always obtained by the division of one doublet or triplet, which was thus made to yield two or three different objectives. Those, however, who cannot afford American objectives, and who wish to do work that is of some real value, are advised never to separate their objectives, or at least never to separate any but the very lowest—that is the No. 1, and against even this we would protest were it not for the fact that cheap lenses of lower power than the half-inch are seldom found in market; and therefore, no other course except the division of a No. 1 is left to us when we wish to use a lens of lower power. But this system of dividing is often carried too far, and we find microscopes in market which are furnished with No. 2 or No. 3 objectives which are divided when lower powers are needed. This is decidedly wrong. If a power lower than No. 1 be needed, it may be admissible to divide this number, because this is in general the only course left to us, but a No. 2 should never be divided for the purpose of obtaining an objective equivalent to a No. 1.

The value of the numbers assigned to the different French objectives varies according to the fancy of the maker, but those of the better class usually found in market are about as follows:

Number.	1	2	3	4	5	6
Corresponding focus in parts of an inch....	1-2	1-4	1-6	1-8	1-10	1-12

Frey, in his recent work on the microscope, regards the English system, whereby the focus is expressed in inches, as "peculiar." It certainly is "peculiarly" definite and positive, instead of being indefinite and arbitrary, as is the system adopted by the French and German opticians. According to the English and American systems, an objective of an inch focus ought to be the same, no matter by what maker it has been constructed, but when designated after the plan which Frey seems to prefer, it is impossible to tell what the focus of the lens may be, and consequently what its power is. Thus—a No. 2 of Nachet has a focus of half an inch, while a No. 2 of Hartnack has a focus of one inch, and a No. 2 of the ordinary French objectives is about a quarter of an inch in focal length. As it is often useful to the microscopist to know the powers of the different objectives made by prominent continental makers, we give the focal lengths of the objectives of Nachet, Hartnack, and Gundlach, premising, however, that by so doing we by no means intend to class these objectives with ordinary French triplets.

Nachet's ordinary objectives are as follows:

Number	0	1	2	3	4	5
Focus in inches	2	1	1-2	1-4	1-5	1-8

The immersion and correction objectives of the same maker are as follows:

Number	6	7	8	9	10	11	12
Focus in inches	1-10	1-14	1-15	1-20	1-30	1-40	1-50

Hartnack's objectives of recent construction are as follows:

Number	1	2	3	4	5	6	7	8	9
Focus in inches	2	1	3-4	1-2	1-4	1-4	1-6	1-9	1-11

Hartnack's new objectives with immersion and correction are as follows:

No.	Focus in inches.	No.	Focus in inches.
9	1-12	14	1-28
10	1-16	15	1-33
11	1-18	16	1-40
12	1-21	17	1-45
13	1-25	18	1-50

The following is Gundlach's scale:

No.	Focus in inches.	No.	Focus in inches.
I	1	VI*a*	1-12
II	1-2	VI*b*	1-12
III	1-3	VII*a*	1-16
IV	1-4	VII*b*	1-16
V	1-8	VIII	1-24
		IX	1-32

VI*a* and VII*a* are not adjustable for thickness of cover, while VI*b* and VII*b* are. VII*a*, VII*b*, VIII and IX are immersion lenses.

Since taking up his residence in this country, Mr. Gundlach has adopted the system of the English and American makers, and designates his objectives by their focal length. The table given above, however, will prove of service to those who either possess or intend to purchase specimens of his earlier work, some of which was very excellent.

Testing Objectives.—At first sight it would seem to be the easiest thing in the world to test an objective, and find out whether or not it is capable of doing certain work, but a little experience soon teaches those who are not too self-conceited, that it is the easiest thing in the world to be deceived. We have seen those who considered themselves the most capable of judges, condemn lenses that had received the approbation of the ablest microscopists in the world—lenses too that had shown their efficiency by doing really good work; showing that even those who consider themselves very expert, may sometimes arrive at wrong conclusions. If this is the case, then, with men of training and experience, how can a beginner, who has had no experience, hope to be able to form a correct judgment in regard to the quality of an objective ?

But while it is difficult, or perhaps impossible, to pronounce a positive opinion in regard to the quality of an objective, especially those made for some of the higher departments of microscopic work, it is in general easy for those who have had experience, to form a judgment in regard to ordinary objectives, or at least those designed for ordinary purposes. The ability to form such a judgment depends rather upon experience and a comparison with the work of other glasses than upon a reference to any special standard; and therefore, as a general rule, we would advise beginners who are about to purchase objectives, to obtain the advice and assistance of some skilful friend. To those who cannot obtain such assistance, we offer the following hints.

The great difficulty in the way of arriving at a decision in regard to the quality of an objective, is the want of a standard with which to judge its performance. When we examine the image which an objective gives of any object, it is very difficult to decide whether or not that image truly represents the object. Take, for example, the podura scale: wide differences of opinion exist as to its structure, and how it *ought* to look; suppose, then, that two objectives show entirely different appearances of this object, who shall decide which one is correct ? And if, even in the case of expert microscopists, this holds true absolutely, which it does, how shall a beginner determine that the images which he sees through an objective are true or false ? In some departments, the most earnest and long-continued discussions have been maintained in regard to the accuracy or inaccuracy of certain images as seen by professional microscopists, and, strange to say, these disputes affect the very tests most commonly used, viz., the Podura scale and the test diatoms.

Makers of objectives, and skilful microscopists, being aware of the fallacies which beset examinations of this kind, resort to certain artificial standards of which the construction is positively known, and which should therefore give appearances conforming to this known structure. Numerous tests of this kind have been suggested, but the only ones generally accepted are the artificial star* and ruled glass plates. Of the latter, ordinary micrometers answer a very good purpose, but the most delicate tests are the famous ruled plates of M. Nobert.

In the examination of objectives, there are a few simple general rules which must be observed by the microscopist if he would secure accurate results.

The first important point, and one to which sufficient attention is not generally given, is the health of the observer at the time of making the trial. The eye is a very delicate organ, and the slightest derangement of the stomach or nerves affects it to an extent that few persons realize. We have an object-glass of comparatively low power, with which, when in good personal health, we find no difficulty in resolving the *P. angulatum*, though a very slight disturbance of the digestive organs, renders the lines perfectly invisible.

It must also be remembered that in the case of such delicate observations, personal peculiarities, irrespective of health or sickness, exert a marked influence, so that it does not follow that what one observer sees, all can see. We have frequently

*The artificial star is a very minute globule of mercury, obtained by crushing a small drop by means of a smart tap with a flat slip of iron or ivory. This globule is made to act as a small convex mirror, reflecting the light of a lamp, candle or window. It is not mentioned by modern writers on the microscope (Carpenter, Hogg, Beale, Frey, etc.), but is used by some of our best opticians. Dr. Royston Piggott, has recently revived its use. Goring devoted considerable space to an account of the best methods of using it.

seen those who could not distinguish lines that were visible to others, and we have also met those to whom an objective, in which the chromatic errors were very obvious, seemed to be perfect. This probably arose from a kind of color blindness. We have also met eyes which distorted objects, and those which saw fringes of color round objects viewed through an objective of generally recognized excellence.

Attempts have been made to get rid of the errors arising from personal peculiarities (or what may perhaps be called the "personal equation") by employing photography, it being assumed that if a lens will give an image which can be photographed, it must give an image that may be seen, and that whatever is photographed must of necessity be a real image. But from the known fact that the foci of the chemical and visual rays do not coincide, and that the corrections required in the one case are not those calculated to give the best results in the other, we have little faith in photography as the best test of the excellence of an objective, except, of course, in those cases where photographic work is the chief purpose in view. Lenses intended to transmit an image to the eye must be tested by the eye, and if certain eyes show peculiarities not possessed by the average eye, then lenses must be corrected specially for them.

It is scarcely necessary to say that when an objective is put upon its trial, the stand and means of illumination ought to be such as will do it justice. The best stand in the world cannot make a good objective out of a poor one, but a poor stand will give poor results even with the best objective. The eye-pieces also should be of good quality, and if an objective, which the microscopist has reason to believe is a good one, fails, it should not be condemned until it has been tried with eye-pieces either by the same maker, or of a known standard of excellence. And we must also remember that it is not sufficient to examine an objective in combination with a shallow eye-piece, or one giving a low magnifying power. An objective may perform very well if used with low eye-pieces, and utterly fail when a higher power is applied. Most makers of objectives test their glasses under eye-pieces of very high power—a quarter and even an eighth of an inch focus, or what would be equivalent to H or K on the usual scale.

The room in which the test is made must also be a subject of careful selection. Very many of our best microscopes are used in our large cities; at least they are very generally examined there with a view to purchase. Now, those who are familiar with the subject, know that during the day time the buildings along the principal thoroughfares in our large cities are in such a state of constant vibration, that good results are rendered impossible, and therefore that an objective and stand which, under such circumstances, fail to resolve difficult tests, or to define clearly, should not on that account be condemned.

The illumination employed must also receive careful attention. An objective which readily resolves the *P. angulatum* by central illumination, when lamp light or good daylight is used, may fail when poor daylight is employed. Special directions on this point are given under the head of light and illumination, and therefore we would merely say here that an objective which has been tested only by the dull blue light of a northern sky, cannot be said to be inferior because it has failed either in resolving or defining power.

On the other hand, we must not place too high an estimate on an objective which, by the aid of monochromatic light, (the blue-cell, for example,) has resolved certain difficult tests. It is not uncommon to find that lenses of a quarter-inch focus will, with blue light, resolve the *Amphipleura pellucida*, but fail completely with ordinary light. Even eighths and tenths by the same makers, and of a grade quite as good as the fourths just mentioned, fail to resolve the *Amphipleura* by ordinary illumination, even when well managed. The aid which is derived from blue light in the resolution of difficult diatoms is unquestionable, but it is not quite so clear that this kind of light gives the same assistance in the matter of definition. Our own experience leads us to believe that the real assistance derived in the latter case is very slight. Therefore, we do not regard it as a very high recommendation for ordinary work that a lens can resolve the *Amphipleura* by blue light. We have, however, seen a fourth which would resolve the *Amphipleura* by the light of an ordinary hand lamp, aided by Wenham's reflex illuminator. The objective was made by Tolles, and manipulated by him.

To determine the quality of an objective it is best to take up in succession the several features which we have just detailed, and examine its efficiency in each of these directions. First of all, the defining power should be carefully tried, this being the most important quality that a glass can possess. No special test can be named for this, and in fact the formation of a correct judgment in regard to it will depend more upon the experience of the observer than upon any particular rules that can be laid down. As Carpenter well says: "An experienced microscopist will judge of the defining power of a lens by the quality of the image which it gives of almost any object with which he may be familiar." To which we may add that the *inexperienced* microscopist will in general fail to detect a want of defining power, no matter what object he may examine.

The chief points seem to be that the outlines should be sharp and clear, the blacks black, and the other natural colors clear and distinct. Frey compares the image given by a good lens to a good copper plate, or a print with sharp letters, and no illustration could be more to the point. He also states that an objective which is deficient in this respect, is best tested with a pretty strong eye-piece. In our own experience we have found no surer test of excellence than this: An objective which is deficient in defining power, is sure to "break down" under a high eye-piece. Deep eye-piecing does not effect the resolving power of a lens to the same extent that the defining power is lessened, and therefore, the fact that a glass shows lines under a high eye-piece, is not an absolute demonstration of its excellence as regards definition. At the same time, it will be found that considerable angular aperture is absolutely necessary to enable *any* glass to bear deep eye-piecing, because without this, the loss of light is so great that nothing can be seen clearly. Hence the truth of the somewhat paradoxical statement, that an objective may be really good under a low eye-piece, and yet fail under a high one.

With the English opticians a favorite test for definition is the *Podura scale.* Unfortunately, however, the structure of this scale and even the identification of the scale itself, seem to be a matter of doubt. Page after page has been written for the purpose of showing how the Podura scale ought to look, and still the question seems to be undecided. Carpenter, in his last edition (page 702) says: "The sharp and distinct bringing-out of the 'exclamation marks' of the Podura scale, constitutes, when it coexists with the greatest practicable freedom from color, and with adequate 'focal depth' or 'penetrating power,' the most valuable proof of the fitness of an Objective of high power for the purpose of scientific work."

Fig. 6.

To give our readers an idea of how the podura scale ought to look, we give a figure copied from the engraving published by the late Richard Beck, in his work on the microscope. The figure shows "the appearance of the Podura scale when the adjustment of the object glass is correct and the markings are in focus." The objective used was a one-eighth, giving a magnifying power of 1,300 diameters.

It is, we believe, generally conceded that in the present state of the art, *perfect* correction for color cannot be obtained, but so long as the residuary chromatic abberration does not interfere with the defining power of the objective, it cannot be regarded as an objection. And yet we have seen a would-be critic reject a very excellent lens because it showed a little color, while he was loud in his praise of another lens which, although more perfect in this respect was almost worthless otherwise. Like specks of dirt on an eye-piece, which do no harm and are never even seen by experienced microscopists, slight color and want of flatness of field are the *bêtes noirs* of beginners. They are the defects which are most easily detected, and the detection gives the critic an air of knowledge which is to him a source of great pride.

The best English and American opticians now slightly under-correct their best objectives, so that the field shows a slightly greenish hue, while any prominent markings on the object, such as the dots on the *Angulatum* stand out clear and well defined and of a very delicate ruby tint. According to Frey the majority of continental makers adopt the opposite plan. Their lenses are over-corrected, and objects show a bluish border.

A want of correction for color is shown when thin objects with many cross lines are examined, especially with slightly oblique light. As a test for achromatism in low powers, Carpenter prefers a section of coniferous wood, showing the glandular dots. He also recommends the tracheæ of insects, but almost any lined object will answer the purpose.

The existence of aberration of form is best proved by the use of a fine micrometer or a Nobert's plate. When this defect is very marked, it is easily seen in the curved and distorted lines of which the image consists, but such a state of things exists only in extreme cases. Where this distortion is not very glaring, it may be necessary to compare the magnified image of the lines in the stage micrometer with straight lines ruled on a thin plate of glass laid on the diaphragm of the eye-piece—in other words with an eye-piece micrometer in which the ruled lines are quite long.

For testing for flatness of field and aberration of form, Frey recommends "a slide thickly smeared with India ink, in which small circles or other figures are scratched with the point of a fine needle. * * * If the instrument is adjusted with transmitted light for such a circle, it should appear sharply cut on the black ground, and not surrounded by a halo of light. If the circle is then brought out of focus, it gradually enlarges, while its sharp borders disappear, without spreading a strong halo of light either inwards or outwards over the black field."

The angular aperture of an objective can be determined accurately only by measurement, and this is something that beginners will hardly attempt. To measure accurately the angular aperture of an objective, is a task requiring considerable skill and knowledge, and most of the appliances furnished by microscope-makers for this purpose, fail to give accurate results. It must be remembered that in measuring the angle of an objective, we must comply with the same rules that govern the accurate measurement of any other angle. Dr. Carpenter, in his work, gives a method which he calls "the simplest and most convenient." We venture to say, that none but an expert can obtain by it results that are anywhere near accurate, especially with high powers. We therefore consider that any directions upon this subject, addressed to beginners, would be worse than useless.

Since, however, the resolving power of an objective depends in a large measure upon its angular aperture, we may feel pretty certain that an objective which fails to resolve tests suited to its magnifying power, is deficient in angular aperture, unless, indeed, its inefficiency should arise from want of defining power, which may be tested by other means. Of ordinary working lenses, the half inch ought easily to resolve the *Pleurosigma Balticum*; the quarter inch should resolve the *P. angulatum* by oblique light, and those of a fifth or sixth inch focus should resolve the latter test by axial or central light. An eighth, tenth, or twelfth, ought to resolve all the diatoms on the *Probe Platte* below the 17th. It is true that objectives of a quarter inch focus have been made to resolve everything on the *Probe Platte*, but such glasses cost too much to render it likely that they will fall into the hands of ordinary students. Twelfths and sixteenths should go through the *Probe Platte* easily. If they cannot do this it would be better to take a lower power of better quality, and use it with a higher eye-piece.

We must also be on our guard against an old source of error—the use of lined tests which vary from the accepted standard.* Great differences exist in the different specimens of the various test objects that are used, some, owing to individual characteristics and the methods employed in mounting, being much more easily resolved or shown than others. Conse-

*"The proof objects [finely lined insect scales] originally discovered by me, are sufficient for that purpose in *honest hands*, and when used with the precautions I have pointed out. But it is well known that they have been shamefully abused, owing to the various facilities of resolution which exist between different specimens of lined objects, the external characters of which closely resemble each other; so that it may be said that *there are proof objects to suit the capacities of all microscopes;* nay, they are actually perverted to the purpose of deceiving the unscientific part of the public in a much more effectual manner, than could possibly have been done without them."—*Goring*. What is true of the scales used by Goring is also true, though perhaps not to the same extent, of diatoms.

quently, because an objective resolves one specimen of the *P. Angulatum*, it does not follow that it will resolve all others. One of the most important steps in the direction of uniformity in this respect, at least so far as testing the resolving power of objectives is concerned, is furnished by the test-plate (Probe Platte) of J. D. Möller. Upon a slide of the usual size, he arranges twenty diatoms, carefully selected as to cleanness, and also as to resolvability. Those that he has chosen for the purpose are named in the accompanying table. They are arranged on the slide in a line which is about a quarter of an inch in length, the beginning and end of the row being marked by a specimen of *Eupodiscus Argus, Ehrbg.* The table on the opposite page gives the closeness of the lines and the direction of the markings in these diatoms according to the best authorities. In this connection it must not be forgotten, however, that mere closeness is not the only feature which makes a series of lines easy or difficult of resolution. Every micrometer maker knows that of two sets of lines, both ruled at 10,000 to the inch, one may be much more difficult to resolve than the other. The strength of the individual lines has as much to do with it as the mere distance at which they are placed apart. Möller's Probe Platte is furnished of two kinds, dry and in balsam, the latter being, of course, by far the most difficult test. It is an unfortunate fact, however, that even with all the care and skill exercised, even the test-plates of Herr Möller do not always conform to a standard; and, therefore, were it not for the facts just stated, it would seem that the most trustworthy tests are the ruled plates of M. Nobert.

It is not difficult to test an objective of moderate power for flatness of field, provided we have on hand a suitable object. For this purpose a thin section of wood, or of an echinus spine, is generally chosen. For low powers a very excellent test is one of those micro-photographs which are so common. One showing a sentence or sentences should be chosen in preference to a picture, since, unless the field of view be flat, the whole of the letters will not be clearly readable at once, while in a picture the effect known as aerial perspective may give rise to an impression of want of flatness of field. In applying tests for flatness of field, it is of course obvious that we must make sure

MÖLLER'S TEST PLATE. (PROBE-PLATTE.)

	Direction of Striæ.	Striæ in 1-1000 of an inch: Smith.	Sollitt.	Morley.	Others.
1. Triceratium Favus, Ehrbg.	....	..	....	3.06 to 3.08	4–5
2. Pinnularia nobilis, Ehrbg.	Transverse.	..	....	10.8 to 12.5	10–20
3. Navicula Lyra, Ehrbg. var.	Transverse.	..	....	16.3 to 18.5	16–17
4. Navicula Lyra, Ehrbg.	Transverse.	..	....	25.0 to 27.1	24–25
5. Pinnularia interrupta, Sm. var.	Transverse.	..	....	26.5 to 26 8	....
6. Stauroneis Phoenicenteron, Ehrbg.	....	..	....	31.1 to 33	....
7. Grammatophora marina, Sm.	Transverse.	..	....	36.3	62
8. Pleurosigma balticum, Sm.	Transverse.	38	40–20	31.5 to 34.3	....
9. Pleurosigma acuminatum (Kg.) Grun.	Transverse.	..	....	42.7	....
10. Nitzschia Amphioxys, Sm.	....	..	....	42.9 to 45.3	....
11. Pleurosigma angulatum, Sm.	Diagonal.	52	51–46	43.8	....
12. Grammatophora oceanica, Ehrbg. (= G. subtilissima.)	Transverse.	..	....	61.2 to 61.7	80
13. Surirella Gemma, Ehrbg.	Transverse.	..	....	51.4 to 54.8	....
14. Nitzschia sigmoida, Sm.	Transverse.	85	....	63.0 to 63.3	75
15. Pleurosigma Faciola, Sm. var.	Transverse.	64	90–50	55.5 to 56.5	....
16. Surirella Gemma, Ehrbg.	Longitudinal.	..	....	63.0 to 70.4	80
17. Cymatopleuro elliptica, Bréb.	....	..	....	63.3	....
18. Navicula crassinervis, Bréb. (= Frustulia Saxonica, Rabh.)	....	..	....	79.4 to 82.2	85
19. Nitzschia curvula, Sm.	....	..	....	84.5 to 84.7	....
20. Amphipleura pellucida. (= Navicula Acus.)	Transverse.	..	130–120	92.7 to 92.9	95

that the test used is itself flat. Common glass slides are not flat, and as they are used for the cheaper kinds of microphotographs, this fact may give rise to errors if we are not careful in our selections. The best slides are cut from glass plate which has been ground and polished so that the sides are perfect planes, and it is this kind only that should be used. Care should also be taken to see that the object lies flat on the slide, and is not distorted by the cover. We have seen an objective condemned because it did not show all the diatoms in the field of view in focus at once, when the fact was that the diatoms were attached to the cover which was slightly wavy as covers often are. When it is suspected that the fault is not in the objective, but in the slide or cover, the object should be carefully passed across the field of view, and the changes in focus noticed. This will in general tell where the defect lies, for if the part that is apparently foggy should move as the object moves, it shows that the object itself is not flat. It has been recommended by high authority to test objectives for flatness of field by strewing some fine powder on a slide and seeing whether all the grains are in focus at once. For obvious reasons this is a very unreliable method.

Penetration in low powers is perhaps most readily determined by the examination of opaque objects of considerable thickness. The round pollen grains of the hollyhock, and the rounded forms of the polycystina are excellent tests for objectives of an inch or inch and a half. Lower powers ought to show coarser objects in all their dimensions, while for those of medium power the coarser cellular tissue of plants answers very well. It is more difficult to indicate a good test for penetration in the higher powers, in which, by the way, we have often seen want of penetration mistaken for want of flatness of field. This arose simply from the fact that scarcely any object is absolutely flat, and hence, as explained under another head, the curvature of the object is sometimes taken as an indication of a defect in the objective. Want of good working distance makes itself obvious during the examination of any object suited to the objective.

ON THE SELECTION OF A MICROSCOPE FOR PRACTICAL PURPOSES.

The object of all the information given in the preceding pages, is to enable the reader not only to understand and use the microscope, but to select one judiciously; and, therefore, in every section we have offered hints bearing in this direction. We now propose to give the reader such special instructions as are necessary in addition to those previously offered.

In selecting a microscope, regard must be had, not only to the excellence of the instrument, but to its adaptability to the purpose for which it is intended, and to the person who is to use it. A complicated and expensive compound microscope, if placed in the hands of a person having little experience or skill, would evidently be worse than wasted, while to attempt to conduct elaborate and delicate investigations by means of a cheap non-achromatic instrument, would simply be to throw away time, and wantonly incur the risk of serious errors. And yet no mistake is more frequently made. A microscope is wanted; the purchaser is liberal with his means, and he is saddled with an expensive instrument entirely unsuited to his requirements. Or, on the other hand, a physican or student of limited means requires an instrument, and being unable to afford the price of a really good one, he is induced to purchase a cheap affair, whose indications, when applied to the subjects for which he requires it, are entirely unreliable; whereas, he ought to be told that if he cannot afford a microscope with *good* objectives, he ought to leave microscopy in its applications to medicine and physiology alone. So, too, we often see compound microscopes sold to students of elementary botany, when a cheap dissecting microscope is really what they need.

It would be impossible to give anything like a list of special cases in which the different styles of microscopes prove most useful : the reader whose attention is called to this point will have little difficulty in deciding the question for himself. We merely give the general rule, that where dissections of plants and animals are to be carried on, a simple microscope should in general be chosen, while the compound microscope furnished with good objectives, is indispensible whenever high powers are required for the *examination* of objects.

Having decided upon the *kind* of microscope that is needed, the next step is to determine the individual quality of the different instruments that may be offered to us. To do this thoroughly, it will in every case be found a good plan to take up, point by point, all those elements that are necessary or desirable in a microscope, and in this way subject the instrument to the most careful scrutiny. Unless a microscope is made specially to order, it will be difficult to find one that will combine all desirable features, but the plan we suggest certainly enables us to decide most readily and accurately as to the presence or absence of those points which are desirable for our purposes. The following are the chief points that demand attention:

Magnifying Power.—We place this first, because usually the first question in regard to a microscope that is asked by beginners is, "What is its magnifying power?" Now magnifying power, although an important element, is after all but a secondary consideration. A microscope magnifying a thousand diameters could easily be made and sold at a profit for five dollars, and a few cents expended in paper and paste will at any time double, or even treble, the magnifying power of an ordinary compound instrument. The proper question is not how much does a microscope magnify, but how much will it show. A magnifying power of one hundred diameters, obtained by the use of first-class objectives, will enable us to see more of the true structure of an object than could be reached by a magnifying power of five hundred, the lenses in the latter case being of inferior quality. But, although not the first consideration, magnifying power is a feature of sufficient importance to deserve careful deliberation, and without a knowledge of the powers required, and the mode in which they are expressed, the beginner will often encounter difficulty. Both these points being essential, therefore, before discussing the magnifying powers best suited to different purposes, it may be well to say a word in regard to the mode in which magnifying power is always expressed by scientific men.

When we look at a small object through a microscope, and see it magnified to twice its length, it is evident that its breadth is also magnified twice, and consequently its surface, no matter what the shape may be, is magnified four times. It might also be said that as we only take cognizance of bodies having a sensible thickness, this thickness must be magnified twice, and therefore the object is magnified twice four, or eight times. The latter, however, is a view which is never insisted upon, and even those who claim the most for their microscopes, never do more than express the magnifying power in surfaces. Scientific men are, however, agreed that to express a magnifying power in surfaces is to convey a wrong impression in regard to the assistance rendered by the instrument to the natural vision, for a careful study of the physiology of vision, teaches us that our power to appreciate and distinguish the featnres of any object depends upon the distances to which the characteristic points of that object are separated, and this can be measured only by linear, and not by superficial units. There are other considerations which lead to the same conclusion, but for the beginner it is sufficient to know that *all* scientific microscopists are agreed that when the magnifying power of a microscope is stated, it shall be stated in diameters, and not in areas. By common consent, then, ten times means ten diameters. And yet it is a very common thing for charlatans, and those who wish to deceive the public, to say that a microscope sold by them magnifies ten thousand times, or one hundred diameters, and as "ten thousand times" is much more readily appreciated by the popular mind than "one hundred diameters," the majority of those who read such statements suppose that they will be enabled to see ten thousand times more than they could see with the naked eye, which assuredly is not the case. In some instances these advertisers do not even state the diameters. We have now before us, clipped from a journal of deservedly good reputation, an advertisment which reads as follows, omitting what printers call the "display" arrangement of the words: "Microscopes constructed on scientific principles magnifying 10,000 times." The microscope in question, as we learned by personal examination, gives a magnifying power of about one hundred diameters. Carpenter speaking upon this point says: "The *superficial* magnifying power is of course estimated by *squaring* the linear; but this mode of statement is never adopted by scientific observers, although often employed to excite popular admiration, or attract customers, by those whose interest is concerned in doing so." We would, therefore, advise our readers to look with suspicion upon any concern advertising in this manner. Of course an advertisement claiming a magnifying power of "10,000 *areas* or 100 *diameters*" is unobjectionable, because both expressions are placed upon an equal footing. It must also be borne in mind that great though unintentional mistakes are often made by dealers in stating the power of the microscopes they offer for sale. Not long ago a friend told us that he had been offered a small microscope having a magnifying power of 500 diameters, for a moderate sum. We called to see it, taking the precaution to put a micrometer and a foot rule in our pocket. By actual measurement the highest magnifying power of this microscope was 45 diameters! Another instance occurs in the catalogue of a well-known and honorable business house, who offer a very neat and well made instrument, whose magnifying power is claimed to be 350 diameters. Careful measurement of several instruments, however, gave an average power of less than 200 diameters! Indeed it will in general be found that the magnifying power stated by dealers who do not devote their chief attention to microscopes, is greatly over estimated.

So much, then, being clearly understood in each case, the question naturally arises, What should be the magnifying powers possessed by microscopes intended for certain specified purposes? That a certain magnifying power is necessary, no matter what the quality of the lenses may be, is true beyond a doubt. Thus, for example, suppose we wish to see the lines on the *Pleurosigma Angulatum*, which lines are about the one fifty-thousandth of an inch apart; what magnifying power would be necessary?

With the best illumination, the average human eye can just clearly distinguish lines which are the two-hundredth of an inch apart. Some eyes, under favorable circumstances, can see lines placed as close together as 250 to the inch, but the average is as we have stated.* To be visible even to the best eyes, therefore, the lines on the *Angulatum*, must be magnified so that they will present the same appearance as lines spaced so as to give at the very most, say, 200 to the inch. This requires a magnifying power of 250 diameters, and with less than this they cannot be seen, no matter how good the objective may be. And when Dr. Frey says that they can be seen with a power of 80 or 100 times, while "weaker objectives, magnifying 40 or 50 times, should show something of the lines," he makes a statement that we cannot accept.

In order, therefore, that an object may be distinctly seen, it must be magnified to a certain extent, but the magnifying power absolutely necessary in any given case, will also depend upon whether the microscope is to be used for general purposes of investigation, or merely for the *recognition* of known forms. For the latter purpose a power of 100 may be sufficient, while for the former, on the same class of objects, a power of 500 would be the least that would be serviceable. The following are a few of the cases in which the power required can be stated approximately:

For medical purposes (except for pocket instruments, intended merely to enable the observer to recognize known forms) a power of 400 is needed, and the objective should be of really excellent quality.

Students of histology require a microscope with a wider range of power. Low powers are more useful to them than to the medical man, and if they push their researches in certain directions, there is no limit to the magnifying power needed.

*To test the statement in the text, place a glass micrometer, ruled 200 lines to the inch, on the stage of a microscope, and by means of the mirror throw a beam of light upon it, just as if for examination by transmitted light in the usual way. If we now look at the lines, not through the tube, but simply from one side, they will appear distinctly as well-defined lines. Try the same with a micrometer ruled 250 to the inch; some eyes will be able to distinguish the lines, but very many will fail to do so.

A good two-third, one-fifth, and one-tenth, giving magnifying powers of from 50 to 1000 diameters, will, in general, answer most requirements. It must be borne in mind, however, that *beginners* can hardly be expected to use a one-tenth inch objective to great advantage, and, therefore, the purchase of this item may safely be deferred.

For the study of botany, and the ordinary facts of vegetable physiology, a power of 300 is sufficient; but the very minute forms of vegetable life require a much higher power, and so do certain of the higher points in the physiology of plants.

For the detection of adulteration, Hassal recommends the inch and the quarter-inch objectives, giving a magnifying power with No. 1 and No. 2 eye-pieces, of from 60 to 350 diameters.

For ordinary purposes of instruction and amusement in the household, a microscope magnifying from 30 to 150 diameters will be found most satisfactory, and for these reasons: Such an instrument is easily managed; if well made it gives a power amply sufficient for all ordinary objects, and it need not be expensive. Moreover, while it is an easy matter to prepare objects so that they may be seen satisfactorily under low and medium powers, it requires great skill and long practice to enable the student to prepare objects so that they may be examined with profit under a high power. And finally, under a high power, but a very small portion of any ordinary object can be seen at once, and consequently many of those things that are best suited for popular examination can only be seen piecemeal—a very unsatisfactory mode of proceeding. Thus, under a power of 750 diameters, a fly's foot could not possibly be seen as a whole; we might examine a single claw or pad at a time, but not the whole foot, and consequently would find great difficulty in acquiring an idea of what the general structure of the foot is. To give the reader clearer ideas upon this point, we have just measured the diameters of the fields seen under French and American objectives, with the following results: With a magnifying power of 25 diameters, the field is about a quarter of an inch; with 50 diameters, it is one-eighth of an inch; with 100 diameters, one-sixteenth of an inch; with 500 diameters, one-eightieth of an inch; and with 1000 diameters, the one-hundred-and-fiftieth of an inch, a space which is ordinarily invisible to the naked eye. Consequently, when these high powers are used, it becomes very difficult for beginners to place the object properly under the microscope, for, as will be readily seen, unless it is adjusted with a variation less than the one-hundred-and-fiftieth of an inch, it cannot be seen at all.

The lowest powers that will show satisfactorily certain well-known objects, are about as follows: The scales, or so-called feathers on the wings of most butterflies can be very well seen with a power of 25 diameters; under the same power, the eye of a fly shows very distinctly the several smaller eyes, or *ocelli*, of which it is composed; the individual corpuscles or globules of the frog's blood can be distinguished with a power of about 35 diameters, human blood requiring 40 to 50; to show distinctly the form, etc., of these same corpuscles requires a power of 200 and upwards. The same may be said of starch granules. Human hair and wool may be seen very satisfactorily under a power of 100 diameters, the former appearing like a cord, a quarter of an inch thick. In order to show the peculiar characteristics of these fibres, however, the lenses must be good. Cotton and flax can be readily distinguished under a power of 80 diameters.

A question very frequently asked in regard to cheap microscopes is, Will they show the animalcules in water? And in almost all the advertisements of cheap microscopes, we are told that they will do this. Now, good well water does not contain animalcules that can be seen with ordinary microscopes. It is only in stagnant water that they are found, and many of them can be seen with the naked eye, without the use of any microscope whatever. Others require the use of microscopes having powers a hundred fold greater than that of the best microscopes in ordinary use. It is evident, therefore, that such statements are worthless as affording any indication of the character of a microscope. A microscope magnifying fifteen to twenty diameters will show objects that are perfectly invisible to the naked eye, and with fifty diameters, provided the definition is good, we can obtain a very interesting view of many of the most beautiful objects described in the books, and sometimes called animalcules, such as the *Volvox Globator*, the larger *Vorticelli*, etc., etc.

The Stand.—This should be firm and substantial, with the centre of gravity very low. Nothing detracts so much from the performance of an objective as tremor and vibration, and a large majority of the microscopes in market are very shaky, from the fact that they are made tall and showy in order to command a higher price. It is well, therefore, to bear in mind that size is no criterion of the value of a microscope. Instrument makers very properly give the size of their instruments, and it generally happens that the largest instruments by the same maker bear the highest prices. Other things being equal, however, small, compact instruments are altogether to be preferred. Some years ago the rage was for large, showy microscopes, which made a fine appearance in the office of the physician, and the study of the naturalist. It was found, however, that in this case efficiency was sacrificed to show, and all our best makers are now cutting down the sizes of their instruments, and making them steady, substantial, durable and easily operated.

There is, of course, a limit to the extent to which stands may be reduced in size without sacrificing their efficiency, and some makers seem to forget this. There are stands in market that are too small every way for anything but special classes of work. The bodies are too small to secure efficiency in the eye-pieces and objectives; the stage is too small to allow of the use of slides of proper size, and there is no room beneath the stage for the attachment of proper illuminating apparatus. All this is as inconvenient as the three-feet-high microscopes of the end of the last century.

The weight of the stand is a subject concerning which many seem to differ in opinion. One writer goes so far as to say that no stand weighing less than fifteen pounds can be steady enough for the performance of good work. It will be found, however, that a judicious distribution of the material, and a proper construction of the different parts, will more effectually resist the usual sources of unsteadiness than any increase of absolute weight. Of course, if it is merely desired to make the microscope steady, in the sense that an inkstand is steady—that is, not liable to be tipped over—weight is everything. But the stands that are most difficult to tip over are not those that resist vibrations most perfectly. For the latter a tripod with a small area of support is best; for the former a stand with a flat base resting over its whole surface on the table should be preferred.

It is obvious that the causes of unsteadiness are either vibrations transmitted from the floor, or movements caused by the hand in performing the necessary manipulations and adjustments. The first can never be stopped by weight, unless, indeed, we make the stand so heavy that its weight will impart rigidity to the table and floor, and this would require a good deal more than fifteen pounds, or even twice that. For the checking of vibrations transmitted from the floor, no device is better than the stand or table described in a subsequent section. So far as movements transmitted by the hand are concerned, if a stand of three or four pounds will not resist them, the observer should set himself about learning delicacy of movement before he proceeds any further.

All microscopes made in this country and in England are now constructed so that the body may be inclined to any angle, thus giving the power of using the microscope in any position —vertical, inclined or horizontal. The importance of this is easily seen when we consider that on the one hand, when liquids are to be examined, it is sometimes necessary, or at least desirable to use the microscope in a vertical position, though this is a very tiresome and inconvenient position, and one that is not calculated to enable the observer to obtain the best possible results; and on the other, it is equally necessary that the body of the microscope should be capable of assuming the horizontal position when the camera lucida is to be employed for making drawings, as will be hereafter explained. And yet Frey actually gives the preference to microscopes that do not incline, and which must always be used in a vertical position! This, of course, necessitates the complicated and expensive arrangement which he describes for adapting the camera lucida to the vertical instrument, a singular instance of prejudice against an obvious and successful improvement.

The Stage.—In every case, a large, roomy stage is of the utmost importance. One great objection to most French instruments is that the stages are too small. It should also be firm and substantial, so that its position in regard to the other parts of the stand cannot be varied by slight pressure.* The most important points connected with the stage are the means provided for holding and moving the object, and the facilities afforded for attaching accessory apparatus.

In the most complete stands, the object is held between *sliding* clips, which form a sort of clamp that is capable of being moved in two directions, at right angles to each other, by mechanical means, which generally consist of a screw for one direction and a rack and pinion for the other. This form, which is known as the *mechanical stage*, enables even a comparatively unskilled person to bring any part of the object into the desired position in the field of view, and this with the utmost precision. These mechanical stages may be said to be characteristic of the higher classes of English microscopes, and as they are expensive, they are not generally used. Neither are they absolutely necessary for ordinary work with low or medium powers, for with any objective lower than one-twelfth of an inch focus, the object can be moved by hand quite as readily as by the screws, and we hold it to be a well established rule in all manipulations connected with scientific work, that whenever any operation can be performed satisfactorily by means of the hands alone, all special contrivances should be dispensed with. For low and moderate powers, therefore, we prefer the plain stage, on which the object is moved by means of the hands alone. But when very high powers are used, and especially when delicate micrometrical or goniometrical measurements are to be made, a well-made mechanical stage becomes a necessity. For while it is easy enough to bring an object very near to a given point by means of the fingers alone, it is almost impossible to secure perfect accuracy. In the effort to attain this the mechanical stage is a great assistance, and therefore when Frey utters a wholesale condemnation of the

*At the same time, however, it must be borne in mind that no stage ever was made so firm that even a *slight* pressure would not affect it. If, therefore, the reader is determined not to rest content with anything short of a *perfectly* rigid stage, he will reject all the best microscopes in market.

English microscopes, and asserts that they are unpleasantly loaded with what he is pleased to call "screws and unessential appurtenances," it seems to us that he commits a great error. These costly and complex instruments are intended for the highest class of work, and the most powerful objectives; perfection of the work to be done, and not simplicity in the means by which it is to be done, is the end sought, and this can be attained only by the complex means employed.

We have never found any of the so-called lever stages that fulfilled the requirements of the highest class of work, and, therefore, if a mechanical stage is to be chosen at all, the best form should be procured.

A microscope fitted with a good mechanical stage leaves nothing to be desired, but when other forms are used, it is evident that the chief points to be attained are these: 1. The object should be held steadily, but at the same time perfect freedom of motion should be allowed. 2. It should be possible to remove instantly from the surface of the stage, everything in the shape of clips and holders, so that a clear field should be left for the adjustment of very large slides, plates, etc., or for the rotation of the object in relation to the light. 3. Even the simplest forms of the stage should be so constructed that it may be possible to pass *every* part of the object under the field of view, and this, without any risk of omitting even the smallest portion. This point is of special importance to physicians and naturalists. Thus, it not unfrequently happens that it is desirable to know whether or not certain forms are present in a given drop of liquid; unless we can subject every part of that drop to microscopical examination, we cannot be sure that the forms we are looking for are absent. There is always a risk of omitting some portion of the slide, and consequently doubt must always hang over the exhaustiveness of all our examinations. The only certain means of avoiding all risk of missing any portion of a given slide is to pass it across the field of view in successive parallel bands, just as a plowman plows a field. The process is clearly shown in the diagrams on the following page, Fig. 7 showing the mode in which the entire surface is *completely* covered with a series of parallel ribbons, the breadth of each of which is the diameter of the field of view, while Fig. 8 shows the hap-hazard way in which examinations are usually made, abundant room being left (as shown by the small crosses) for the escape of important features. Now, with ordinary clips, or even with the glass stage,

Fig. 7.

Fig. 8.

it is impossible to effect this, and therefore we prefer those stages in which a cross-bar moves over the plate in such a way that it is always parallel to the front edge of the stage. Such a contrivance also affords facilities for using the Maltwood finder.

In the simpler forms of the stage, the object is held in place by spring clips, which press it down, and under which it is moved. These clips are frequently screwed to the stage, which is a great mistake, as we are thus prevented from slipping them off, and leaving the stage entirely clear. They should always be held by pins, which merely slip into holes in the stage.

The so-called *glass* stage has recently come into very extensive use, and is very much liked by some. We believe it is now generally conceded that it was invented by Mr. Tilghman, of Philadelphia, who placed it in the hands of Mr. Zentmayer to be manufactured. In this country it is generally known as the Zentmayer stage; in Europe it has been called the Nachet stage. It has assumed a great variety of forms, some of them radically different from the original one. Dr. Carpenter seems to prefer this form of stage to all others.

Revolving Stage.—It is often desirable to rotate an object in the optic axis of the microscope, either for the purpose of measuring angles or changing the direction of the illumination in regard to the object. Means for effecting this with perfect accuracy have been applied both to the mechanical stage and the glass stage, though the latter is very frequently so constructed that rotation is an impossibility. Mr. Browning's device for securing rotation in the optic axis has been already described. Another ingenious device for securing coincidence of the optic axis and the centre of rotation is the centering nose-piece, by means of which the objective is moved so as to bring it exactly over the centre of the stage.

Stages for Special Purposes.—It may be safely asserted that there has never yet been constructed a stage which would suit the requirements of every worker with the microscope. Indeed, each investigator seems to require special modifications of his own. Thus, it will be found that the ordinary stage, with all its appurtenances, is too thick to admit the use of that very oblique illumination which is required by the worker on diatoms, while if the stage be made thin enough it loses the necessary rigidity. Some makers have sought to obviate this by supplying two stages—a stout one for common work, and a thin one for diatoms. A microscope now in our possession is furnished with an extra thin stage, which, by a very simple and ingenious device, can be instantly substituted for the heavy one. The microscope is said to have been made by Spencer or Tolles, and must be over twenty years old. A thin stage on the same principle, and called by the maker a *Diatom Stage*, has been recently brought out by Mr. Zentmayer.

The same object is also attained by means of the secondary stage, invented by Mr. Lewis Rutherfurd. This is simply a skeleton stage, which is placed on the ordinary stage, and is raised so far above it that the illumination may be applied between them. Rays of great obliquity may thus be passed through the object. Rutherfurd's skeleton stage forms also an admirable *safety stage*, since the object, being held against the *under side* of the skeleton stage, yields to the slightest pressure of the objective. Mr. Spencer has also taken advantage of this principle, and so formed the under side of the stage in some of his stands, that the object may be pressed against it by the clips, which for this purpose are pushed through from below upwards. In focussing, the objective is passed *through* the stage if necessary. Great obliquity, and perfect safety against breakage of the object by pressure of the objective, are secured. When the microscopist is using valuable slides, costing from fifty to two hundred dollars, the latter feature is one of great importance.

Sub-Stage.—The sub-stage is a device for holding and adjusting illuminating apparatus beneath the stage. It should be moved by rack work, so that paraboloids, achromatic condensers, etc., may be brought accurately into focus, and it should also have adjustments for accurately centering these various pieces of apparatus. We regard the sub-stage as one of the most important parts of the stand.

The Mirror.—In microscopes of modern construction, the mirror is made of glass, coated with pure silver, (ordinary mirrors are coated with an amalgam of mercury and tin) and the best instruments are provided with two mirrors, one plane and the other concave. In both mirrors the surfaces of the glass should be accurately ground and polished. Blown glass will not answer. The plane mirror reflects the light just as it falls on it, while the concave one causes parallel rays (such as those from the sun) to converge and meet at a point, and renders divergent rays (such as those from a lamp) either less divergent, parallel, or convergent, as the case may be. The concave mirror should be large, but the plane mirror is as efficient when small as when large. Where but one mirror is provided, the concave is the one usually selected.

In English and American microscopes of even the cheapest construction, the mirror is so arranged that it may be made to send a beam of light through the object very obliquely. This is absolutely necessary for some purposes, but not for the examination of ordinary objects. The ability to use *oblique light*, as it is called, is, however, a great advantage. It not only enables us to resolve lined objects, but to secure important changes in the illumination of common objects. A very fair dark ground illumination may also be secured by placing the mirror in such an oblique position that none of the light can enter the object-glass directly.

The Body.—The only point connected with the body of the microscope which requires consideration is its size, and this must of necessity vary so much according to the purposes to which the microscope is to be applied, that no rule can be laid down. Pocket microscopes are of necessity small; microscopes intended to give very great magnifying power must be large. A standard size is seven to eight inches in length. The diameter is not of very great importance in bodies of moderate length, but Beale says that in his long tubes, intended to produce great magnifying power, a diameter of two to two-and-a-half inches was found to be absolutely necessary. An inch and an eighth is a good size for ordinary instruments. Since a very long body is inconvenient when the microscope is used in a vertical position, the best instruments are furnished with a

Draw Tube, whereby, the length of the body may be varied at pleasure. As explained in a former paragraph, (page 15,) when the distance between the eye-piece and the object-glass is increased, the magnifying power is increased also. The draw tube, therefore, gives us the means of varying and adjusting the magnifying power of the microscope, and this is sometimes of great use. Thus, suppose it were required to draw an object to a scale magnified exactly one hundred diameters; it might be impossible to procure an eye-piece and an objective that, with a fixed length of body, would give exactly this amplification, but when we are able to vary the magnifying power by changing the length of the body, it is easy to get at it exactly. This, however, is but one of many advantages afforded by the draw-tube. If the objective be good, and the eye-piece not very high, an easy and very satisfactory way to increase the magnifying power of the microscope is to lengthen the body by means of an additional tube. Dr. Beale, who has been a most successful worker with high magnifying powers, tells us that in practice he has found this plan so much more advantageous than the use of a deep eye-piece, that he never uses the latter. In some cases he has extended the length of the tube to two feet with good results. We have frequently adopted this method, and where brass tubing could not be had we have used smooth writing paper, and a little paste with very good effect.

The inside of all draw-tubes and bodies should be well blackened. When bright or white the glare greatly injures the defining power. When draw-tubes are so arranged that they rub against the inside of the tube forming the body, they invariably make the latter bright by friction. They should, therefore, always slide in a collar. It is always well to have the lower end of the draw-tube furnished with the Society screw, as by this means it is sometimes possible to use objectives of greater working distance than could otherwise be employed.

Adjustments for Focussing.—In the cheaper forms of the microscope the adjustment is made directly by hand, one tube sliding within another. In a better class of instruments the objective is brought nearly into position by sliding the body through an outer tube, and then the final adjustment is made by means of a screw or other mechanical means. But in all the best microscopes, the coarse adjustment, as it is called, is made by means of a rack and pinion, while the fine adjustment is made in the manner just mentioned. Instead of a rack and pinion, a chain is sometimes employed, and the coarse adjustment is also made in some cases by screws of very wide pitch, and similar devices. Nothing, however, can equal a smoothly cut and well-fitted rack and pinion. It is sometimes alleged that the chain is more delicate, but this is not so. We have now in our possession a cheap, but well made microscope, the rack and pinion of which is so delicate, that with it we can focus an objective of an eighth of an inch focal distance with sufficient accuracy for all ordinary purposes.

For ordinary purposes, especially the work of the physician and medical student, the coarse adjustment may be more easily dispensed with than the fine one, but at the same time it must be remembered that any mode of adjustment in which the body is liable to turn round, is incompatible with the use of many important pieces of apparatus. Thus, for example, any turning of the body interferes with the use of the double nose-piece, the polariscope in its higher applications, Prof. Smith's opaque illuminator, etc. A rack and pinion, or its equivalent, should, therefore, always be chosen, especially as it does not add more than five or six dollars to the cost of the instrument.

Of devices for fine movements the name is legion. An old plan is to place the object upon a plate attached to the stage, and move it towards the objective by means of a fine screw. This is a cheap and convenient method. In general, however, it is objectionable to have the object move, as it interferes with many of the finer methods of illumination, etc. A very common plan is to make the nose-piece, which holds the objective, movable. The only objection to this device is that it introduces a change in the length of the body, and, consequently, a slight change in the magnifying power, every time a change is made in the focal adjustment. This change is too slight to be observable, but is sufficient to interfere with delicate micrometric measurements.*

To avoid this difficulty, various devices have been introduced. The most common arrangement is a very old one, in which the entire body, including the arm and coarse movement, is carried by the fine adjustment. In its general features this plan is very old, and has at different times been adapted by Grunow, McAllister, George Wale, Zentmayer and others. One of the best, however, is a recent invention by Mr. Gundlach, in which the body is hung on two parallel springs, and moved by a fine screw. This plan, although theoretically defective, is practically perfect. The other method, just mentioned, although theoretically perfect, is, in practice, rarely as good as the Gundlach device—a curious, but not an unusual state of things in mechanics.

In judging of the goodness of either a fine or coarse adjustment, the points to be observed are the delicacy and accuracy with which the objective may be moved to and from the stage, and the freedom from twist or apparent displacement of the object. In many microscopes, when a high power is used, and the body is moved for the purpose of adjusting the focus, the

*It has been alleged that this increase or decrease of magnifying power is more apparent with the higher powers than with the lower powers. Indeed, it has been said that with high powers the change of magnifying power is quite perceptible. This, of course, is mere imagination, as any one of an arithmetical turn of mind can see. Indeed, the facts would seem to be rather the other way.

object is actually thrown out of the field of view. Such a microscope should be at once condemned.

It is a common fault with instruments in which the coarse adjustment is made by rack and pinion, that the body cannot be raised high enough to admit the use of low power objectives. This defect should be avoided. Avoid, also, all instruments in which the *coarse* adjustment is made by moving the *stage* by means of a rack and pinion.

The Diaphragm.—Nothing tends so much to obscure our view of the finer points of structure in any object as to have them "drowned" in a superabundance of light, consequently in order to regulate the amount of light which passes through the object, a diaphragm is employed. As ordinarily constructed, it is simply a metal plate placed below the stage, and pierced with holes of various sizes, which may be brought exactly under the field of view, the small holes allowing but a small amount of light to pass, while the large ones admit a full stream. Considerable difference of opinion exists amongst microscopisis in regard to the proper position of the diaphragm. Thus Carpenter says (page 133) that unless placed half an inch below the object it is comparatively inoperative. Continental histologists, on the other hand, allege that it is useless unless placed close up under the object. Microscopes constructed according to both these plans are to be found in market. Where the microscope is furnished with a sub-stage, the distance of the diaphragm from the object is variable at will.

It is obvious that when the diaphragm is placed at a considerable distance below the object, the illumination is purified, as it were, from all cross rays. When the diaphragm is placed close to the object-slide, the illuminated field of view is contracted. The action in this case, however, is somewhat complex, owing to the action of the slide in modifying the course of the rays.

Several very ingenious forms of Iris or graduating diaphragms have been devised, by which the size of the hole may be changed without interrupting the observation. They are exceedingly convenient, and present advantages which more than counterbalance the cost.

Objectives.—These are confessedly the most important parts connected with the microscope; they therefore deserve the greatest care in their selection. In a former section, we fully explained the general characteristics of the different kinds of objectives in market, and detailed the best methods of of testing them. A careful study of that chapter will, we hope, enable the beginner to avoid a glass that is absolutely bad, though we must acknowledge that all experienced microscopists are agreed that no amount of mere reading will enable a novice to pronounce a correct judgment upon the quality of an objective, unless its defects should be very glaring indeed. In this place we shall confine ourselves to a few hints in regard to those features which adapt objectives not only to special kinds of work, but to the skill of different classes of workers. For it is an undoubted fact that objectives which in the hands of skillful microscopists, and on certain classes of work, would give extraordinary results, would in other hands, and for other purposes, prove of far less value than lenses of what is commonly considered a greatly inferior grade.

We do not here propose to take part in what is called the "battle of the object-glasses," such a discussion being out of place in an elementary work like the present, but we think few will be hardy enough to deny that one who has a taste for such things, but has neither the money required to purchase a first class glass, nor the time necessary to acquire the requisite skill to use it, had better work with a cheap French triplet than not work at all. Moreover, it is astonishing how far patience, skill and experience will go to make up for a deficient instrument, while at the same time, it is unfortunately true that some who possess the very best glasses, and have done the most to throw ridicule upon all work done with inferior lenses, have never made a single contribution of the slightest importance to any department of microscopical science.

In a former chapter we discussed at length the different qualities of object-glasses, and showed how these various qualities might exist in very different degrees in different objectives. It is, of course, obvious that the extent to which any one quality should be sought in a particular glass, must depend altogether upon the kind of work that is to be done. To those who are addicted to what Holmes calls "fighting objectives," resolution will be the quality to be desired; others will prefer penetration, flatness of field, etc. In our estimation, for the purposes of ordinary scientific work, we would assign to these qualities values in the following order: 1. Defining power; 2. Freedom from aberration of form; 3–4. Resolution or Penetration; 5. Working distance; 6. Achromatism; 7. Flatness of field. The first quality that should be secured in every lens is undoubtedly defining power, and this whether its angular aperture be high or low. Achromatism we place low in the scale, because unless so marked as to interfere with the defining power, it does no harm. Flatness of field we place last, because it will be found that perfect flatness of field is very seldom combined with first rate definition. Indeed, we have heard one of the most celebrated makers of objectives assert that the two qualities are to a certain extent antagonistic.

In giving advice in regard to the selection of an objeetive, one of the points concerning which it is most difficult to arrive at a decision, is that of angular aperture. Fortunately, however, experienced microscopists may safely be left to decide this question for themselves, and since those who have had *no* experience will find it difficult to use objectives of very wide aperture, it will certainly be prudent for them to choose those of moderate angle. Objectives of very high angle are worthless, unless the illumination is well managed, and the adjustment for thickness of cover properly regulated. On the other hand, a good non-adjusting lens will give very fair results, with but a moderate amount of skill on the part of the user. Almost all our best makers now produce objectives of moderate angle, which do not adjust for thickness of cover, but which have considerable resolving power. We have now before us a one-fifth which costs but fifteen dollars, and which will easily resolve the *Pleurosigma Angulatum* by central light. An important point for consideration will, of course, be, whether or not the glass is intended for original work, or merely for the study or examination of well known objects. The work of the physician is chiefly amongst well known objects, and may be very satisfactorily accomplished by means of good non-adjusting objectives, a great point in favor of such glasses being that work may be done with them more rapidly than with glasses that require greater care and skill. The same is true of the elementary studies of the botanist and histologist, carried on under the guidance of a competent teacher. And as in all such cases it is easy to find out the special thickness of glass for which the object-glass has been corrected, and to provide a supply of the proper thickness, the absence of a means of adjustment for cover thickness is not very important. But for all the higher class of studies, good glasses, with well-made adjustments for thickness of cover, are indispensable.*

Objectives of very low angular aperture, are, however, to be equally avoided. There is a want of light, and an indistinctness which renders them worthless. It is generally said that the superiority of large angles is most marked in the objectives of high power, and that for low powers the common objectives do very well. In our judgment, however, the superiority of the low powers is quite as marked as that of the higher ones, and much more available to the beginner. It is true that the superiority of a well made one-sixth of high angle, over any triplet of whatever focal length, is immeasurable, but at the same time it is equally true that the view of an opaque object seen through an inch-and-a-half objective, carefully corrected, is as much superior to the same as seen through a common triplet, as it is possible to imagine. We have now before us a specimen of bone of very open structure, mounted as an opaque object. Seen through a first class inch-and-a-half objective, it presents almost a stereoscopic appearance, and the entire structure is easily made out. The view afforded by a very fair French triplet (No. 0) is so markedly inferior, that any person who should see the two would never again use a cheap objective, if he could afford to get a good one. Moreover, the objection which we have just urged against objectives of high power, and

*It is not long since a professional maker of microscopes, and one who seems to stand high in the favor of the medical profession, tried to persuade the author that the covering-glass exercised no influence on the action of the objective, and that a non-adjusting glass could be made with as great a resolving power, as one constructed so as to adjust for different thicknesses of covering glass! To such men, a famous microscopist used to apply the term "shopticians," and they deserve it.

wide angle, viz., that they are difficult to use by novices, does not hold in the case of low powers. A good inch, of comparatively high angle, is more easily used than a poor triplet.

A question which has considerably occupied the attention of microscopists, is the value of objectives of high power, and their efficiency as compared with those of lower denominations. That in many cases considerable amplification or magnifying power is absolutely necessary, admits of no doubt; but the question to be settled is: suppose that we wish a power of 2,000 diameters, would it be better to get this by means of a tenth of an inch objective, magnifying 100 times, and a half inch eye-piece magfying 20 times, or by a twentieth of an inch objective magnifying 200 times, and an inch eye-piece magnifying ten times ?

It is not very many years ago since one of our ablest American objective makers held that a lens of a quarter of an inch focus might be made to do anything that a lens of any power could be made to do, and the ground of this opinion was that the individual lenses of objectives as low as a fourth, could be made so much more perfect than the smaller lenses of higher powers, that this perfection more than counterbalanced the greater magnifying power of the objective of shorter focus. The reasoning here seems sound and obvious, but it has been found in practice that for everything except resolution, the limit to which the power of objectives may be carried, is far beyond a fourth. For resolution it has, we believe, been found that a well made tenth is capable of doing anything that any lens can do; for other kinds of work sixteenths and twenty-fifths, and even fiftieths and eightieths have been declared to possess advantages that are obvious. This, however, is one of those points upon which authorities differ; Beale, for example, favors high powers; Carpenter and Frey seem inclined to think that very high powers show nothing that cannot be seen by means of objectives of greater focal length.

French objectives of the numbers 1, 2, 3 and 4, if carefully selected, are capable of doing really serviceable work. A few years ago, some of the best known makers of American microscopes used nothing else, even in microscopes costing $150, but this course we can scarcely regard as judicious, for whenever the microscopist is prepared to expend $75 or more for a microscope, a large part of this sum should be laid out in the purchase of objectives of the better class, the one-inch and one-fourth, or the three-fourths and one-fifth being those that are usually selected by beginners.

French triplets are, however, going rapidly out of use, from the fortunate circumstance that objectives of low price and excellent quality are now produced by several makers of repute. It is well, however, for the reader to be on his guard against a fraud which has been but too common of late years. Some so-called opticians go so far as to add a little brass-work and engraving, and sell these French triplets as objectives of American make. We do not here refer to the mere operation of attaching the objective to an adapter, and fitting it in a brass box, for this adds greatly to the convenience with which such minute objectives may be handled and preserved, but to a sort of "making over," by which they are completely disguised and made to resemble the objectives of English and American makers. It is hardly necessary to characterize such a proceeding.

Eye-Pieces.—The eye-piece that is at present almost universally used is the Huyghenian, which, when well made, gives very excellent results. In the use of low powers, where a very flat and large field is desirable, the Huyghenian eye-piece fails, and the same is also true in regard to very high magnifying powers, where the enlargement is obtained in a great measure by means of the eye-piece. The extent to which the definition of really good objectives is deteriorated by the use of eye-pieces of great magnifying power, and the loss of light which they occasion, render them practically useless. For high powers, the solid eye-pieces of Mr. Tolles are vastly superior, while for low powers, where a large flat field is desired, Kelner's orthoscopic eye-piece presents important advantages.

Mr. Gundlach has recently brought out a new eye-piece, which he has named the *periscopic*, and for which a large field and excellent definition are claimed. They are much more expensive than the Huyghenian. We have not had an opportunity of examining them carefully.

In determining the quality of an eye-piece, attention is to be paid not only to its general excellence, but to its adaptability to the objectives that are to be used with it. In the higher departments of microscopy, the latter is a most important point, but one which is too frequently neglected. It does not, however, come within the scope assigned to the present work, and we, therefore, content ourselves with a few general hints.

The lenses composing the eye-piece, should be of homogeneous glass—that is, free from air-bubbles, specks and striæ, and the surfaces should be well polished. These points require attention, because we have in our possession a microscope in which—though it cost enough money to be free from such defects—they are glaringly apparent. On looking through the eye-piece at a strongly and evenly illuminated surface, the entire field of view—that is, the whole of the bright circle that is seen, should have the light evenly diffused over its surface, and the edges or border of this circle should be sharp and black.

Eye-pieces intended for first-class objectives should give a large field of view; but on the other hand, if French objectives be used, the field of view should be small, otherwise the definition will be poor. This is a point that is frequently overlooked, and we have seen very fair object-glasses condemned as worthless when used with a stand and eye-piece intended for objectives of an entirely different class. It is an easy thing to contract the field of view, by means of a round piece of thin sheet metal, having a hole of proper size in the centre. As previously explained, such a piece of metal is called a diaphragm, and should always be well blackened.

The magnifying power of every microscope depends upon three things: The focal length of the objective, the length of the body, and the eye-piece. Most microscopes are, therefore, furnished with several eye-pieces, whereby the magnifying power may be varied. There is, however, a limit to the extent to which this may be done. The image obtained by very *deep* eye-pieces, as they are called, is rarely satisfactory.

The different eye-pieces are generally denoted by letters—A, B, C, D, etc. A being the lowest, and B, C, D, etc., successively higher. Some makers use numbers—1, 2, 3, 4, etc. These letters and number, are, however, entirely arbitary, in this point resembling the numbers assigned to objectives by continental makers. A great improvement upon this arbitrary and uncertain system would be to assign to each eye-piece its proper power expressed in inches. Thus, an eye-piece magnifying the same as a simple lens of two inches focus, should be called the two-inch eye-piece.

And here let us call attention to the terms *deep* and *shallow*, as applied to eye-pieces. By all authors of repute, a deep eye-piece is one of great magnifying power, while a shallow eye-piece is the reverse. See the Micrographic Dictionary, and the works of Carpenter, Beale, Lardner, Frey, etc., etc. It is, therefore, singular that Dr. Lankester, in his popular little work, "Half-Hours with the Microscope," should have committed the mistake of giving definitions exactly the opposite, upon the ground that eye-pieces of great magnifying power are always short, while low eye-pieces are always long. It is evident, however, that the terms are liable to give rise to confusion, and we prefer the words *high* and *low*—the meaning of which is so obvious as to require no explanation, as every body knows what high magnifying power is.

While clearness of definition and resolving power are the most important qualities of every good microscope, magnifying power is also of considerable consequence, as explained in a former section. Therefore, every good microscope should be provided with at least one eye-piece of considerable power. It often happens that with the objectives and eye-pieces at hand, the amplification, as it is called, or, in other words, the extent to which the object is magnified, is not sufficiently great to enable us to make out its structure, while the objective has not by any means reached the limit of its defining power. In this case a high power eye-piece, which costs comparatively little, will greatly extend our power of successful examination.

ACCESSORY APPARATUS.

Every microscope should be accompanied with certain pieces of accessory apparatus, which are necessary for the convenient and thorough examination of objects, but which do not form part of the instrument itself. Some of these are intended for

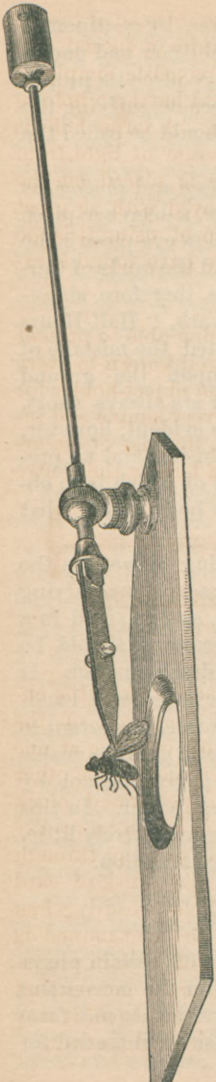


Fig. 4.—FORCEPS AND FORCEPS-CARRIER.

the better illumination of the object, and will be described in the section on "Light;" others are used for the procuring and preparation of objects, and will be described in the section devoted to that subject. The following are employed chiefly for holding and presenting objects that have not been "mounted:"

Stage Forceps.—This little instrument accompanies the oldest microscopes. It consists of a pair of very delicate forceps, such as those attached to the forceps-carrier in Fig. 4, which close by the spring of the jaws, and hold any object that may be placed in their grasp. They are opened by pressing on the pins which are seen at the sides. They are in general fastened to the microscope by being stuck into a hole in the stage, and the object may not only be moved backward and forward, but it can be turned round. The better class of forceps carry a small brass tube (shown in Fig. 4) which is filled with cork, and which serves to receive pins, etc., for holding insects, and other objects.

Foıceps-Carrier.—However well made the forceps may be, it is almost impossible to slide, with sufficient delicacy, the rod through the tube that holds it. Consequently, it is exceedingly difficult to bring into the field of view, the exact part of the object, that we may wish to examine. To avoid this difficulty, the author, instead of inserting the pin of the forceps in the stage, provides a special forceps-carrier like that shown in Fig 4. This consists simply of a metal plate, the size of an ordinary slide, and having a hole in one end to receive the pin of the forceps. A large hole is pierced through the centre, to allow the passage of light from the mirror when that is needed. This plate is placed on the stage like a common slide, and it can be moved with as great delicacy as any ordinary object. The mode of using it is too obvious to require further explanation. We have found it exceedingly convenient.

Object-Holder.—The importance of being able to present an object to the light in all directions is well-known to every microscopist. Many years ago we devised an object-holder for effecting this, the construction of which is very simple and inexpensive. It consists of a slip of metal, the size of an ordinary slide—three inches by one—having a hole in the centre

Fig. 5.—OBJECT-HOLDER.

and a short pillar rising from one end, as shown in the engraving, Fig. 5, which gives a sectional elevation of the instrument. Through this pillar runs a wire, carrying at one end a milled head by which it may be turned, and at the other a ring which holds a perforated block. This perforated block has a milled collar on the lower end, so that it can be readily turned in the ring that carries it. The hole passing through the block is just the size of a stout pin, so that a disk of card or leather, with a pin through it, will be held steadily when the pin is inserted in the hole. The object to be examined is attached to the surface of the card, by means of balsam or mucilage, and it is obvious that by the combined rotations that may be produced by the two milled heads mentioned, it may be exposed to the action of the light in any desired manner.

The changes which are produced in some objects when the light is made to fall on then in different directions are very marked. Thus, for example, the mineral known as *specular iron ore*, when illuminated by light falling on it in one direction, is brilliant in the extreme, while when the light falls in other directions it is dead and lustreless. And as it is not always convenient to change the position of the lamp, it is a great advantage to be able to turn the object round. The simple contrivance just described enables us to do this perfectly.

A more perfect arrangement, intended for the same purpose, has been devised by Mr. Beck, of London. Mr. Beck's is, however, more expensive than ours.

Plain Slides.—The common plain slides serve very well for examining ordinary deposits in liquids. This is particularly the case where inanimate objects, vegetables and minerals are to be examined. Active animals require some contrivance for keeping them still.

The Concave Slide, as it is called, is simply a thick slide with a cup-like hollow ground in the centre. Such slides are cheap, and very convenient. A drop of water placed in one of these concaves, and covered with a thin glass, may be examined easily and thoroughly with moderate power. It is sometimes desirable to employ a cell with a perfectly flat bottom of very thin glass. Such cells may be easily and conveniently made out of a slide of metal, or preferably of vulcanite, through which a hole the size of the proposed cell has been pierced. A piece of thin glass may then be cemented to the under side of the slide, so as to form a water-tight cup. The hole in our slides is round, and has, on the under side, a seat or rebate, a little larger than the hole itself. In this rebate a round glass cover fits, so as to leave the under side of the slide perfectly smooth. Such cells are very convenient, as they are easily cleaned, and are not difficult to repair when the thin glass gets broken. The liquid is also easily covered by means of a thin glass cover, and when full, considerable inclination may be given to the slide before the liquid shows a tendency to run out. Various other devices of a simple kind may be contrived by the microscopist for similar purposes.

Watch-Glasses.—Dr. Beale recommends small flat watch-glasses for holding liquids that are to be examined, and we have found them very excellent. The best kind for this purpose are those known as *lunette glasses*, which are nearly flat on the bottom. They are awkward things to manipulate, however, unless some means is provided for holding them steady, and moving them about on the stage. We use for this purpose a strip of wood, three inches long, and so wide that we can easily bore in it a hole, about one-eighth of an inch less in diameter than the watch-glass, of which the smallest size should be chosen. The thickness of the strip should be such that when laid on any flat surface, the watch-glass will not come in contact with it. Glasses held in this way are very convenient.

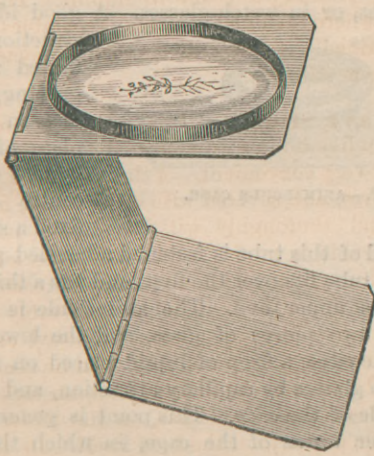


Fig. 11.—WATCH-GLASS HOLDER.

Watch-glasses are very convenient for examining a "dip" from a pond or stream, but for this purpose they require a holder. The little instrument shown in the cut is formed of three pieces of bright tin, which are hinged together. In the upper piece is cut a hole just large enough to receive a watch-glass. A ring of metal of proper height surrounds this hole, and forms a perfect protection to the glass when the instrument is carried in the pocket. The lower slip of tin may be adjusted to any angle, and by turning towards the proper direction, the light of any bright cloud may be reflected up through the liquid. All the joints are made stiff enough to remain in position when once adjusted. A watch-glass arranged in this manner holds a liberal supply of liquid, so that an entire "dip" may be readily examined at once. We have found this little contrivance far superior to more expensive arrangements. It packs into small compass, and is safely carried.

Animalcule Cage.—This forms a very excellent means for holding animalcules that are too active to allow of observation on slides, or in watch-glasses. A good idea of its construction may be obtained from the engraving, where it will be seen to consist of a plate of metal, three by one inches, to the centre of which is fixed a short tube. In the upper end of this tube is fastened a beveled piece of glass, and a second tube fits over the first, and has a thin glass cover secured in its upper end. The animalcule is securely held between the two pieces of glass, and the lower glass being beveled on the edge, a drop of liquid placed on it is held between the two glasses by capillary attraction, and cannot spread over the inside of the cage. This point is generally neglected in the cheaper forms of the cage, in which the lower glass is simply a plain disc burnished into the upper end of the inner tube. The consequence is that when the two glasses are brought together the liquid flows over the entire inside of the cage, and the objects are liable to be floated out and lost. As it is important that the distance of the two glasses from each other should be easily and accurately regulated, the outer tube should be slit, so as to make it springy. In this way it may be made to move with a soft and equable motion.

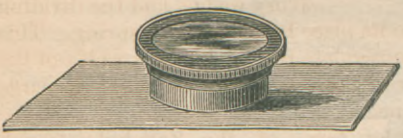


Fig. 12.—ANIMALCULE CAGE.

The Zoophyte Trough.—This little piece of apparatus is almost indispensable to those who desire to watch the growth and development of the larger animalcules and small aquatic plants. Several forms are in common use, the most complete being that shown in Fig. 13. The trough itself is simply a glass tank, to which is fitted a slip of thin plate glass that acts as a division, and enables the observer to keep the objects close up to the front plate. The distance of the dividing plate from the front plate is regulated by an ivory wedge, and the dividing plate is kept firmly up to its place by means of a spring. This contrivance enables us to regulate the thickness or width of the tank, so that the interior of the vessel may be made so large that it can be easily cleaned.

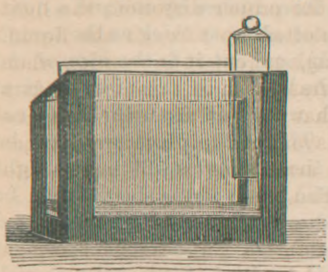


Fig. 13.—ZOOPHYTE TROUGH.

A smaller and simpler form of the Zoophyte trough is shown in Fig. 14. It consists of a simple glass box, open at the top. The back of the box is formed of a stoutish piece of plate glass, to which is cemented three glass strips, forming the bottom and ends. The front is formed of glass as thin as is compatible with durability, and is also cemented to the end pieces. The width of the trough from front to back is generally from an eighth to a quarter of an inch. When the trough is filled with water, and living animals are placed in it, their changes and movements may be very readily watched.

Fig. 14.—ZOOPHYTE TROUGH.

Small troughs, such as that just described, are not difficult to make, though the very low price at which they are sold (60 cents to $1.00) renders it scarcely worth the while of ordinary microscopists to construct them for themselves. Where this is desirable, however, the best method of making them is as follows: Select a piece of plate glass, of the thickness of an ordinary slide, and cut it about three inches by one and a quarter. Then select another piece of glass, as thick as the trough is to be deep (from front to back), and cut it to the size of the outside of the trough. From the bottom of this piece of glass cut a strip a quarter of an inch wide, and from the sides cut also strips of the same width. The centre piece may now be thrown aside, and the ends of the side strips will make a tight joint with the bottom strip. The three strips should then be cemented to the large plate, and over them should be cemented a piece of the thin glass used for covers. The strongest cement is marine glue, but we are told by Prof. Starr, who is well known for his success in keeping and exhibiting living microscopic objects, that marine glue is very apt to destroy animal life. He, therefore, uses old Canada balsam, and we have seen a large variety of minute forms of animal and vegetable life which had been kept for months in a healthy condition in such troughs or cages.

Compressorium.—In the examination of certain objects, it is frequently necessary to flatten, and even to crush them, in order to render their structure visible. This is best accomplished by means of a well-made compressorium, of which there are several different kinds in use. The ordinary compressorium consists of a metal plate, in the centre of which is fixed the disc of glass upon which the object is laid. A second disc, fastened in a ring which is hung at the end of a lever, by means of two pivots, is pressed against the first by means of a screw, which tilts the lever. In this way a very strong pressure may be exerted, while, owing to the free movement of the ring on the pivots, the plates of glass always remain parallel to each other.

A compressorium which may be used to examine either side of an object is constructed by Messrs. Ross & Co. In this form the two plates are brought together by means of a wedge, which is moved by a screw.

Gravity Compressorium.—The animalcule cage above described was invented by Varley, many years ago, and is very excellent, but requires considerable skill in its use. It is difficult to adjust the pressure with sufficient delicacy, and we are apt either to crush the animal or leave it too free in its movements. These difficulties are avoided by the apparatus shown in the engraving. Two plates of metal are provided, each with a hole in the centre, which hole is covered with a piece of thin glass. At one end the upper plate has two pins, which fit into two holes in the lower plate, and serve to prevent all side movements. A screw passes through the other end of the upper plate, and serves to separate the two. A drop of water containing an animalcule having been placed on the thin glass attached to the lower plate, the upper plate, with the screw projecting sufficiently from the under side, is laid on it. Then by turning the screw, we can bring the two plates together to any required degree of nearness, and with the utmost delicacy.

Fig. 15.—THE GRAVITY COMPRESSORIUM.

Any minute animal may thus be firmly grasped, without crushing it, while the compressing power exerted by the mere weight of the metal plate is in almost all cases sufficient, even for the complete flattening out of small worms, etc. Even such creatures as the larva of the common gnat or mosquito may be completely crushed by the weight of a plate less than the eighth of an inch thick; and, where greater force is required, it is of course easy to apply the pressure of the finger. In the latter case, no danger of exerting too great a pressure need be incurred, as the projecting screw prevents all that. The want of parallelism between the plates does not prove a serious objection, as it is so very slight that it is hardly perceptible in the short distances ordinarily under observation. Where, however, it is desirable to avoid this defect, screws may be substituted for the pins, and the points may be made to work in holes bored half through the lower plate.

Where animalcule cages are not accessible, a small animal may be held between a common slide and a thin cover. To prevent crushing it, a hair or even a thread may be placed between the cover and the glass. A German author recommends the use of fine gauze or netting, in the meshes of which an animalcule may be held very conveniently. Acting on this idea, we took a thin metal plate, and bored it full of holes of various sizes. An animalcule placed in one of these holes may be kept in the field of view for any length of time, and exhibited to those who desire to see it, but it cannot be kept quiet for scientific examination. We like a piece of fine wire-gauze, better than cotton or linen netting.

Growing Slides.—Where it is desirable to keep the same living object for a considerable time, so as to watch its changes, it is necessary to use what is called a *growing slide*, by which it may be regularly supplied with air and moisture. A large num-

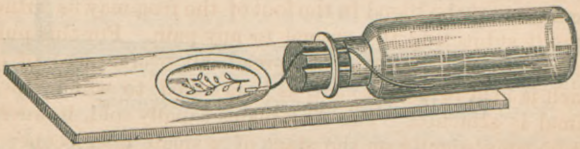


Fig. 16.—GROWING SLIDE.

ber of complicated devices have been described for this purpose, but the following simple contrivance answers the end very well; we have used it for years. To one end of a common slide with a concave centre, cement a small bottle, as shown in the figure. This is easily done by means of a little marine glue. The glue, cut in small pieces, should be laid on the slide at the point where the bottle is to be attached; the slide is then to be gradually heated until the glue is softened, when the bottle is laid on and moved back and forth until it has been thoroughly imbedded in the cement. The bottle is filled with water and corked, the upper side of the cork having two notches cut in it, one for the entrance of air, and the other for the passage of a loose cotton thread. The object is placed in the concavity, covered with a piece of thin glass, and the end of the thread is carried under the cover by means of a small notch cut in the slide with a file. The bottle must be filled with very pure water, otherwise the salts, etc., contained in it, become concentrated under the thin cover, owing to the evaporation, and destroy the object.

Frog Plate.—The circulation of the blood in the capillaries of living animals may be observed in the web of the frog's foot, the tail of a small fish or water-lizard, the larvæ of many insects, the ear of a young mouse and the wing of the bat. The tongue of the frog is also a favorite subject with some, and dissections of the living animal have also been made, and the circulation observed in the parts thus displayed. Except, however, for important investigations, we have no right thus to inflict torture and destroy life, and, moreover, the obvious cruelty of the means employed, will to most minds destroy nearly all the pleasure arising from the beauty of the exhibition. Fortunately the circulation of the blood in the foot of the frog may be witnessed without subjecting the animal to any pain. For this purpose the web of the hind foot is spread out over a piece of glass, which is held in a *frog-plate*, as it is called, to which the little animal is attached. The frog-plates usually sold, however, do not lie conveniently on the stage of a small microscope; they are apt to tip up, and there is no means of attaching them firmly to the stage, so that it is impossible to incline the microscope. The annexed engravings represent a frog-plate, in which these difficulties are avoided. As seen in the figure, it is of the usual form, and has a large opening, into which is burnished a piece of thinnish plate glass upon which the web of the foot is laid. Around this opening is bored a number of small holes, through which threads, tied to the frog's toes, are passed and held firmly by small wooden pins. A series of holes are also bored on each side and cut out at the edge, so that it is unnecessary to pass the twine *through* the holes, as it may be readily slipped *into* them. The frog may be enclosed in a bag, one foot being left out, but a simpler and better plan is to swathe him in a strip of muslin two inches wide and eight to twelve inches long. The muslin is dipped in water, and the

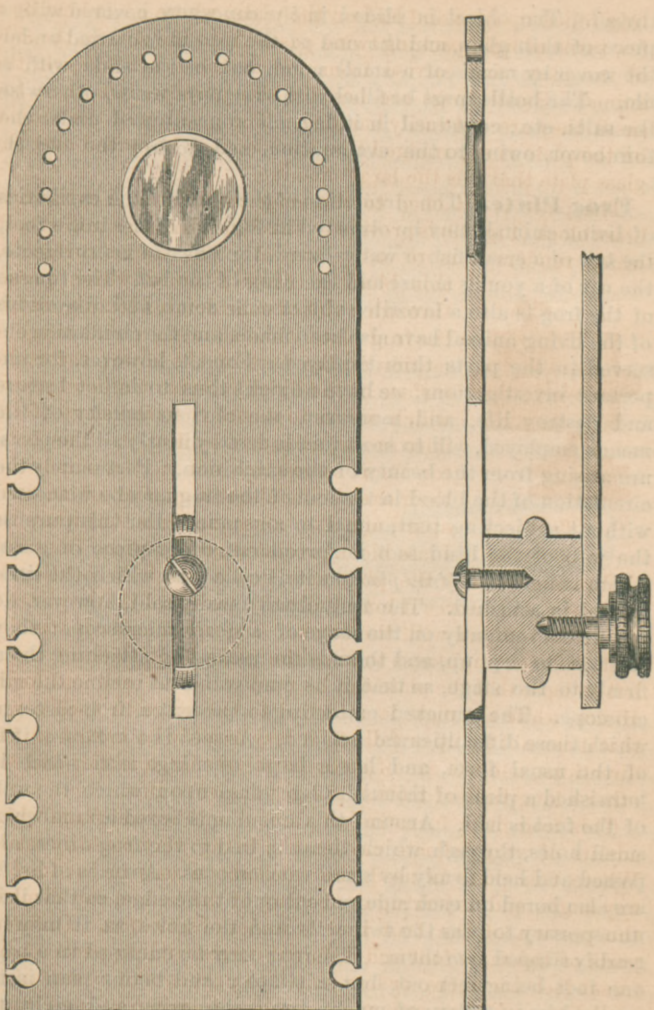


Fig. 17. FROG PLATE, PLAN AND SECTION. Fig. 18.

frog rolled up in it and laid on the plate, where he is held by a few turns of light packing twine passed into the slits in the side of the plate and carried from one to the other and over the animal. Small frogs are best for this purpose, but when too small they are not easily handled. The position of the animal on the plate is so arranged that the foot may be spread over the glass plate that fills the large opening.

The plate is attached to the stage as follows: A cylindrical brass block (Fig. 10) is provided—this block having a milled belt, which renders it more easily turned. The upper surface of this block receives a screw which passes through a slot of considerable length, cut in the frog plate, thus allowing a wide range of motion on the part of the latter; the under surface of the block receives a second screw, which serves to secure it to the stage of the microscope, as shown in Fig. 9. The holes for these screws are not in the same line, their axes being about a quarter of an inch apart, and the consequence is that when the brass block is rotated on the stage, the screw that passes through the plate acts like a crank in relation to the plate, and moves it longitudinally, provided it (the plate) is kept from rotating with the block. The upper screw is inserted with sufficient tightness to keep the plate from shaking, but is left so loose that the plate can be readily moved back and forth. Hence, while the plate is attached to the stage in such a way that it can not tip up or fall off, it may readily be moved in two directions, one the arc of a comparatively large circle, and the other a longitudinal motion at right angles to this.

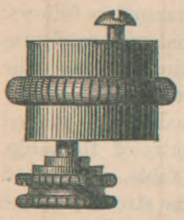


Fig. 19.

This frog plate forms in fact a sort of mechanical stage which admits of very delicate movements being very steadily made. Where this plate is used, the microscope may be inclined to any angle, and no jerking or starting of the animal can displace the portion of the foot that is under observation. Different parts of the same foot and different corresponding parts of different feet are more or less suited to purposes of observation, according as they are more or less transparent and more or less fully supplied with vessels. It is therefore of great advantage to be able to select that part which answers our purpose most perfectly, and this plate affords peculiar facilities for effecting this.

Table.—The table used for supporting the microscope should be firm and substantial, so that all shake and vibration may be avoided. Those who use very high powers, and desire to avoid vibration as much as possible, will find that a barrel or box, filled with sand, and resting on three feet, makes the best support. Some years ago, having some rather delicate investigations to make, we constructed a table in this way, and found the results very gratifying. Our table was arranged as follows: a common barrel, cut down a little, and filled with sand, was supported on three stout blocks nailed to the bottom. The table proper was made of plank, nearly square, and it entirely covered the top of the barrel. It was supported by a + shaped piece of wood, which was fastened to the centre of the table, and descended into the sand. With such a table, walking on the floor, and the passage of heavy teams in the street, produce no vibration, though, on an ordinary table, they render work with high powers almost impossible.

Where several persons wish to look through the same microscope, it is very awkward if each one has to get up and go to the instrument. At the same time it is of course impossible to move the microscope without moving the arrangement for illumination also. This difficulty has been avoided by means of revolving tables, around which the observers sit, each one in turn examining the object, as the microscope is passed round to him. This is a very excellent, but a somewhat expensive arrangement. The same end may be attained by placing the microscope, lamp, etc., on a smooth board of suitable size and shape, and passing this board to each observer in turn. The board, carrying microscope, lamp, etc., may be made to slide quite easily, and if placed on three feet, it is tolerably steady. Such a support, however, is not to be chosen where the microscope is used for scientific investigations.

Double Nose-Piece.—This is one of the most useful accessories that the microscopist can possess. The result to be obtained, and the method of accomplishing it are obvious. The nose-piece screws on to the nose, or lower end of the body of the microscope, and is fitted to receive two objectives of different powers, either one of which may be brought into action by simply turning the nose-piece. In this way a low power may be used for finding objects and examining them as a whole, while the details may, without trouble, be subjected to an object-glass of much higher power. Two forms of the nose-piece are in use. The older form is straight, as in Fig. 20; the later form is bent, as in Fig. 21. The latter form is altogether the most convenient. Nose-pieces capable of receiving three or four objectives have been constructed, and a very old microscope, at one time in our possession, had a nose-piece with eight objectives! The modern nose-piece, so arranged as to be capable of carrying the best objectives, is the invention of Mr. Brookes.

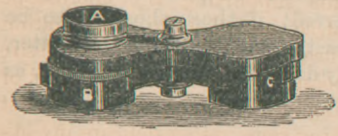


Fig. 20.—STRAIGHT NOSE-PIECE.

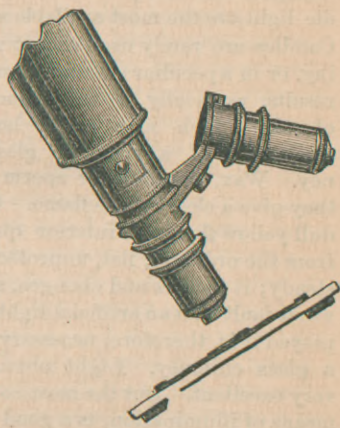


Fig. 21.—BENT NOSE-PIECE.

ILLUMINATION—SOURCES OF LIGHT.

Sun Light.—It is generally acknowledged that the best light for microscopical purposes is that of the sun; not direct sunlight, however, for this is altogether too intense, but sun light reflected from a white wall, or a light fleecy cloud. Sunlight is something which we cannot command at will, and, therefore, the microscopist can do nothing more than select the location of the room which he occupies. In general a room with a northern aspect is to be preferred; if there should also be windows looking towards the east or west, so much the better, provided they can be completely darkened when not in use, as cross lights produce a bad effect.

Artificial Light.—While *good* daylight is the best source of illumination, *poor* daylight is one of the worst, and we have frequently, during the day, obtained by the use of lamps and candles, results which could not possibly be secured by natural daylight. At the present time, gas-light, lamp-light and candle light are the most available means of artificial illumination. Candles are rarely used except when the microscopist is traveling, or in a peculiar situation, but a good candle gives very fair results, especially if the flame be protected from currents of air, which may easily be done by extemporizing a shade out of a piece of glass tube or small lamp chimney. Wax, paraffine or sperm candles should be chosen, as they give a clear, white flame. Common tallow candles give a dull yellow flame of inferior quality. Gas-light, as obtained from the ordinary, flat, unprotected burner, is not sufficiently steady; it flickers and changes, and for microscopy this is the worst fault that an artificial light can have. Where gas is employed it is, therefore, necessary to use an argand burner, with a glass chimney. Light obtained in this way is in general very excellent. But the most convenient, as well as the best means of illumination, is a good lamp, of which the ordinary student's lamp is, on the whole, perhaps the best kind. It gives a pure, steady and intense light; it is easily regulated, both as regards brightness, and also position, and consequently direction, and it may easily be procured almost anywhere. In default of a good student's lamp, any of the ordinary lamps with circular, or flat wicks, may be made to answer. Where a large quantity of light is required, as in the illumination of large opaque objects, the circular, hollow wick, from the superior brightness and whiteness of the light, is always to be preferred. But where a small light of great intensity is needed, the common flat wick, turned edgewise to the mirror, answers very well. It is a curious fact that flame is transparent to light, and, therefore, the greater the depth of flame, the more intense is the light. This is easily tested by looking at the flame of a common hand lamp sidewise and edgewise. In the latter case the eye receives the light from the entire flame concentrated to a mere band.

Several varieties of lamps have been devised specially for the use of microscopists, and some of them are very excellent, the most perfect being that devised by Dr. Drysdale and Rev. W. H. Dallinger, and described in the *Monthly Microscopical Journal* for April, 1876.

It is hardly necessary to say that all kinds of oil have been displaced by the mineral oils ordinarily called kerosene.

Very intense light, such as that from burning magnesium, the calcium light, the Bude light and others, have been tried, but without material advantage. Many years ago, we arranged a common kerosene lamp, so that the air surrounding the flame could be enriched with a supply of pure oxygen when necessary. Dr. Beale describes the same thing in his work, but does not seem to regard it as of any advantage. When used as a source of direct light, however, we found that it more nearly resembled sunlight than any other artificial source of illumination. A large diaphragm or shade, with an aperture of moderate size, was placed close to the light, which was placed at some distance from the microscope, and the rays passed directly through the object, not being reflected from a mirror. The results in some cases were well worth the trouble incurred. It is probable that in some cases very excellent results could be obtained from the electric light if properly arranged. This, however, is a department of microscopy which is certainly not suited to beginners, and we, therefore, dismiss it.

The rays of light, from whatever source obtained, are either *parallel*, *convergent* or *divergent;* and in the illumination of transparent objects the character of the light, as depending upon these features, is of marked importance. This subject, and the action of lenses and mirrors in changing the relative direction of the rays, should be carefully studied by the student, who will find it fully discussed in any work on optics. The general principles may be best explained by a few experimental illustrations.

Take a piece of cardboard about six inches square, and in it punch a hole about half an inch in diameter. If this card be held in front of a wall upon which the sun is shining strongly, we will see the shadow of the card and a round spot of light exactly the size of the hole. If the card be now moved away from the wall, the shadow and the bright spot will still remain of the same size, showing clearly that the rays proceeding from the sun are sensibly parallel. The same holds true of a bright cloud or a white wall placed at a great distance; but when the wall or other reflecting object is very near, the rays no longer possess this character to the same extent.

If in the first experiment the wall be illuminated by a candle instead of by the sun, it will be found that as the card is moved from the wall the shadow and the spot become *larger*, showing that the rays are *divergent* instead of parallel. The same effect is produced by fixing both the lamp and the card on a stand and moving them away from the wall.

Convergent rays, that is rays that tend to meet at a point, can be obtained only by passing parallel or divergent rays through a lens, or reflecting them from a concave mirror. By carefully arranging a large convex lens in the path of rays that are divergent, it is easy to render them parallel. They are known to be parallel when the bright spot which they make on a fixed surface, after passing through a hole, is not varied in size by changing the position of the hole.

The variations which are produced in the appearances of objects when they are viewed by light possessing these different characteristics can only be learned by practice, and the young microscopist should experiment in every conceivable way.

Whatever be the source of light employed, most objects may be viewed by means of any one of several very different methods. Thus, an object, if transparent, may be viewed by *transmitted* light, that is, by light reflected from the mirror, and passing *through* the object. If opaque, it may be viewed by *reflected* light, in which case the light that passes to the eye through the microscope is reflected from the *surface* of the object.

ILLUMINATION OF OPAQUE OBJECTS.

Diffused Light.—This term is applied to ordinary daylight or lamp-light, allowed to fall on the object without the intervention of any special means of concentration. That diffused light may be available for the illumination of objects, it is necessary that the objectives be good. Objects which, with ordinary triplets of low angular aperture, are entirely invisible, become beautifully distinct when a better class of objectives is used. Under favorable circumstances the view obtained in this way of any well marked object is very pleasant.

Bulls-Eye Condenser.—This is a large lens of comparatively short focus, which is made to condense the light on the object in the same way that the common burning-glass acts, but with effects greatly less marked, since the light is so much less intense. In some cases the condensing lens is attached to the microscope, and in some special cases this is very convenient, but where there is only one condenser, it should be mounted on a stand, as shown in Fig. 22, so that it may be placed at any height and turned in any direction. Placed between the object and the lamp, it collects the rays of the latter to a focus which brightly illuminates any object upon which it may fall. Opaque objects, which by diffused light are barely visible under the microscope, become very distinct and clearly defined when thus illuminated, and many of them, such as the wings of insects and certain minerals, appear in the most gorgeous colors, which, however, are perfectly natural, and are not the result of chromatic defects in the lenses.

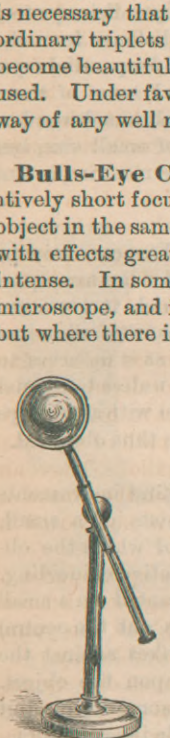


Fig. 22.—BULLS-EYE CONDENSER.

In viewing an opaque object by reflected light, it is evident that we are enabled to judge of the irregularities of the surface largely by means of the shadows cast by the prominences. By raising or lowering the lamp, and also the condenser, the direction and extent of these shadows may be greatly varied. Hence one of the advantages of the students' lamp.

An important use of the condensing lens is to change the direction or character of the rays employed. Thus, when a lamp is in use the rays are divergent, and the easiest way to render them parallel is to pass them through a condensing lens. To effect this the distance of the lens from the lamp must be exactly the same as that at which it brings parallel rays to a focus. In other words, the lens must be at a distance from the lamp which is exactly equal to its focal distance for parallel rays.

Condensing lenses are made of all sizes, and some of them are quite expensive, but we have frequently obtained wonderfully fine results by means of a cheap lens of small size, but good form. A condensing lens is, perhaps, the most important accessory that can accompany a microscope.

Side Reflector.—This is a small silvered concave mirror, which is used to throw the light on the object for the same purpose as the condensing lens. The results which it gives are slightly different, and it is a most valuable means of illumination. It has not been so generally introduced as it deserves to be, and few microscopes are furnished with it unless to special order. It should always be used in combination with a bulls-eye condenser, as light of much greater intensity is thus obtained.

The Lieberkuhn.—This was one of the first instruments used for illuminating opaque objects. It consists of a small, concave, spherical mirror, through the centre of which the objective passes, the focus of the mirror and objective coinciding. The object must be small, and is generally mounted on a small circular disc of leather or card, which stops out the central rays, while the light which passes round it strikes against the concave mirror, and is reflected back again upon the object. The Lieberkuhn gives very brilliant effects with some objects, but it is not very highly prized by modern scientific investigators.

Smith's Illuminator.—This admirable device is due to Prof. H. L. Smith, now of Hobart College, Geneva, N. Y., and is intended for use with objectives of such high power, as prevents the use of the Lieberkuhn, condensing lenses, reflectors, etc. Several different arrangements are used. The first was a small annular silver reflector, placed just above the back lenses of the objective. A hole in the side of the brass mounting admitted the light, which was thus thrown down through the lenses of the objective, on to the object, and back again to the eye. For the silver reflector, some manufacturers' substitute a thin plate of glass, and with excellent results. This illuminator has been used with immersion objectives of high power, and with very good results.

The Parabolic Reflector was first made by Messrs. Beck for Mr. Sorby, who employed it to examine the microscopical structure of iron and steel. As ordinarily constructed, it consists of a parabolic mirror attached to the end of a rod furnished with universal joints, so that it may be placed in any position. It answers admirably for condensing the light on the surface of objects, and by throwing the rays in any particular direction across the surface, the observer is enabled, by means of the shadows, to determine the nature of irregularities upon some objects in a very satisfactory manner. It is in general used in connection with a large bulls-eye condenser, which is thus made to throw parallel rays on it.

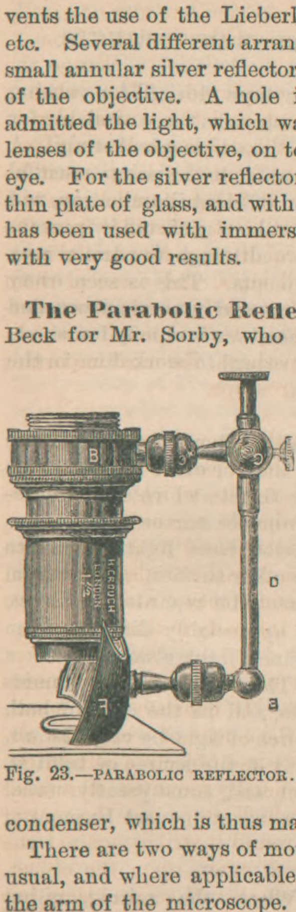


Fig. 23.—PARABOLIC REFLECTOR.

There are two ways of mounting the parabolic reflector. The usual, and where applicable, the best method, is to attach it to the arm of the microscope. Many microscopes, however, have no arrangement for attaching this accessory, and to meet such cases Mr. Crouch has devised the adapter shown in Fig. 23. The jointed arm which carries the reflector is attached to an adapter, which fits between the nose-piece and the objective, and may thus be used on any stand.

ILLUMINATION OF TRANSPARENT OBJECTS.

The different methods which have been devised for viewing transparent objects are quite as numerous as those available for opaque ones, and require quite as much tact and study. A skilful worker, who thoroughly understands the points essential to good, or rather to appropriate and efficient illumination, will attain results wonderfully superior to those achieved by persons ignorant of the subject, and this, too, although the latter may be working with far superior instruments. This is seen every season at our microscopical exhibitions and conversaziones, and although the work done on these occasions is chiefly for show, the same principle holds good in regard to work done in the direction of study and investigation.

Direct and Reflected Light.—When the microscope is so arranged that the light from a lamp or other self-luminous body shall pass directly through the object and into the microscope without being first reflected from the mirror, the illumination is said to be *direct*, in distinction from light which has been first reflected from a mirror or other surface. Light from a cloud or a white wall can scarcely be regarded as direct. Direct light gives results which are appreciably different from those produced by reflected light, since light always suffers a change in character by reflection. These two kinds of illumination may be either axial or oblique, and in the case of both reflected and direct light, if the source of light be very distant, the rays will be sensibly parallel, but if the source of light be very near, the rays will be divergent, and, consequently, under such circumstances, the illumination must in part be more or less oblique.

Axial or Central Light.—When the mirror, either plane or concave, is placed directly in the axis of the microscope, and reflects the light through the tube, the illumination is said to be *axial* or *central*. The same term also applies to direct light, when the direction in which the rays pass through the object coincides with the optical axis of the instrument.

The rays must, of course, be parallel. If either divergent or convergent, some of the rays will be oblique. In the cheaper forms of the microscope, axial illumination is the only kind for which provision is made.

Oblique Light.—Many objects fail to show their peculiarities when illuminated by parallel rays of light passing through them in the direction of the optic axis of the microscope, but are seen very clearly when the light is sent through them obliquely. To secure illumination by oblique light reflected from the mirror, the latter must be so suspended that it can be turned to one side, and thus send a beam of light through the object at an acute angle. Where direct light is employed, the necessary degree of obliquity may be obtained by adjusting the position of the lamp—a device to which we have resorted when compelled to use a stand in which the mirror did not swing to one side. In this way, also, oblique light may be employed to illuminate objects viewed through a pocket lens, and very interesting effects obtained. For the resolution of fine markings upon diatoms, etc., oblique illumination is a necessity. When the angular aperture of the objective is low, and the light is very oblique, the objects appear light on a dark ground—in fact a sort of dark ground illumination is obtained.

The Achromatic Condenser.—The earlier forms of the achromatic condenser consisted simply of an achromatic lens, similar to an object-glass, so arranged that by means of it the light from the mirror could be brought to a focus on the object. With some objects, even this simple contrivance gave very fine results. It was soon found, however, that great advantage was derived from cutting off portions of the pencil of rays transmitted by the condenser, and by means of the proper diaphragms, central, peripheral and one-sided or oblique illumination was obtained. First-class achromatic condensers became, therefore, quite complicated and expensive. Several cheaper but very efficient forms are now made by opticians, a favorite being the Webster condenser, shown in Fig. 24.

Of this accessory Carpenter gives the following very practical description: "In its present form the arrrangement of the lenses strongly resembles that used in the Kellner Eye-piece; the field-glass of the latter serving as a condenser to receive the cone of rays reflected upwards from the mirror, and to make it converge upon a smaller achromatic combination, which consists of a double-convex lens of crown, with a plano-convex lens of flint, the plane side of the latter being next the object. These lenses are of large size and deep curvature; so that when their central part is stopped out, the rays transmitted from their peripheral portion meet at a wide angle of convergence, and have the effect of those transmitted through the peripheral portion of the ordinary achromatic condenser. When, on the other hand, this combination is used with a diaphragm that allows only the central rays to pass, these rays meet at a small angle; and the illumination thus given is very suitable for objects viewed with low powers. Again, by stopping out the central portion of the combination, and removing the condenser to a short distance beneath the object, the effect of a black ground illumination can be very satisfactorily obtained with objectives of moderate angular aperture. Further, by stopping out not only the central, but also a great part of the peripheral rays, so as only to allow the light to enter from a small portion or portions of the margin, oblique illumination can be most effectively obtained."

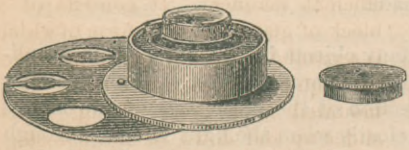


Fig. 24.—WEBSTER CONDENSER.

The Spot Lens.—This is a plano-convex lens of very high curvature, (it is generally hemispherical,) so mounted that its distance from the object may be properly adjusted, and in this way the rays which pass through it may be brought to a focus on the object. The central rays are stopped out by means of a black spot, (hence the name,) so that the object is illuminated wholly by rays which are of too great obliquity to enter the object-glass, except when their direction is changed by the object. The latter, therefore, appears brilliantly illuminated on a dark ground, and in many cases features which could not otherwise be seen are shown very distinctly.

The Parabolic Illuminator.—This is an instrument intended to accomplish the same end as the spot lens, but in a far more efficient manner. It consists of a block of glass, the outer form of which is a parabola with a cup-shaped depression cut in the upper end. It is mounted in a brass fitting, which slides up and down in the sub-stage of the microscope, and thus may be readily adjusted, so as to throw the light properly upon the object. The results obtained by means of the parabolic illuminator are wonderfully beautiful.

Fig. 25.—THE PARABOLIC ILLUMINATOR.

Polarized Light.—The micro polariscope consists of two distinct parts, a *polarizer* and an *analyzer*, each of which is now generally formed of a Nichol prism properly mounted. A

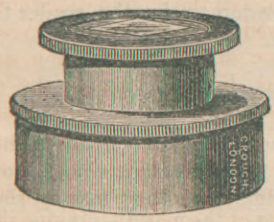


Fig. 26.—POLARIZER.

Fig. 27.—ANALYZER.

common method of mounting the polarizer is shown in Fig. 26. As there shown, the lower ring is intended to slip into the ring of the sub-stage, the rack and pinion of which enables us to place the end of the prism at a proper distance from the object. When the microscope is not provided with a sub-stage, the polarizer is turned upside down, and the brass fitting slipped into a ring, which is attached to the under side of the stage. The milled ring, which is shown uppermost in the figure, enables us to rotate the prism in both cases.

The analyzer may be arranged in either one of two ways. It may be slipped over the eye-piece, or it may be mounted in a brass tube, the upper end of which has an external Society screw that attaches it to the body, while the lower end of the tube has an internal Society screw for receiving the objective. Fig. 27 shows the latter arrangement.

Polarized light, except for the mere beauty of its effects, has not received the attention that it deserves. In some departments of scientific investigation, especially mineralogy and geology, its use has afforded very satisfactory and brilliant results. As regards its applications to medicine and physiology, Dr. Frey says: "The examination of tissues by polarized light has a high scientific value, as, by this means, molecular relations become evident, which by investigation with ordinary light, remain entirely concealed. The interpretation of what is seen, is in many cases difficult, and generally lies within the province of optics, with which the medical observer is usually but little familiar."

To detail the method of using it, and the special features which it discloses, would, however, far transcend the limits of this work, and we must, therefore, refer the reader to some special treatise on the subject.

HOW TO USE THE MICROSCOPE.

The remarks which we are now about to offer, are intended for the merest beginners—for those, in fact, who have never used a microscope at all; and therefore they may, perhaps, to some, appear childishly simple. And yet we have seen not only teachers, but professors in colleges, who might have derived some benefit even from these simple hints. We remember on one occasion seeing a professor of botany attempt to examine a minute plant with a common pocket magnifier with three lenses. In the first place he turned the instrument wrong side up, so that, although he could *see* through it, the results attained were very inferior to what they would have been if the instrument had been properly used; in the second place he wore his hat in such a way as to cut off nearly all the light, and in the third place he did not know how to hold his hands so as to obtain the requisite degree of steadiness. If he had given a few minutes *thought* to the subject, he could no doubt have corrected his bad methods, but then he evidently had never considered it worthy of earnest thought, although it formed the very foundation of his powers of observation.

Simple Hand Magnifiers.—These are perhaps the most important of all optical instruments, and yet we rarely find a person who can use them efficiently. There are but three points that require attention, viz: The proper position of the magnifier itself, the perfection of the illumination, and the steadiness with which the instrument is held at the exact focal distance from the object. Many magnifiers are so constructed that it is impossible to place them in a wrong position; the side which should go next the eye, and the side which should go next the object are so well marked that no mistake can be made. The greatest liability to error exists where two or three lenses of different powers are fixed in the same frame and used together. This forms one of the most common and useful of our magnifiers, and the rule is always to *place the lens of greatest power nearest to the object.* Plano-convex lenses should be placed with the plane or flat side next the object.

Hand magnifiers are, in the majority of cases, used for examining opaque objects, and one of the most important conditions for perfect vision is that the object be well illuminated. First of all, then, see that the light falls full and direct on the object; then place the magnifier as nearly in focus as can be done without actually looking through the lens, and, *after* this, approach the eye to the magnifier. The errors most commonly committed are: Turning the object away from the light; cutting off the light by the projecting brim of a hat or cap; shading the object by the hand or the lens itself; attempting to examine an object in a room that is not sufficiently lighted.

Having secured a proper position for the magnifier and a good illumination, the next step is to devise some means for holding the lens steadily in focus during the examination. This is most readily effected by resting the hand that holds the lens upon the hand that holds the object. Lens and object then move together, and the focussing remains unchanged.

Compound Microscopes.—We presume that the instrument in hand is a very simple one, and that the magnifying power to be used is not very great. No person should attempt to use high powers and complicated instruments until he has served an apprenticeship by using a microscope of simple construction, and objectives of considerable length of focus.

Let the beginner commence by examining some transparent object already mounted. To do this, set the microscope on a firm table, in front of a window by day, or before a lamp at night. Direct sunlight is to be avoided, the light from a white cloud being usually preferred to any other source of illumination. At night use a gaslight that does not flicker, such as an argand burner, or a good kerosene lamp, the German student lamp being very well suited to this purpose. Good results may, however, be obtained from any of the ordinary lamps, especially those with a circular wick, which are now so common. Very fair work may also be done by means of a good candle. This subject has, however, already been discussed at greater length in another section.

If the microscope be a cheap French one, the objectives will be found attached to the body, there seldom being any special provision made for holding them. But with all American and English microscopes, and the better class of instruments from the continent of Europe, special boxes are provided for holding the objectives. These boxes are usually made of brass, and are indispensable to the microscopist that endeavors to take good care of his instrument. Where the objective is kept in a separate box, the body of the microscope must be raised to a sufficient height, and the objective screwed into its place. In doing this be very careful not to let the objective fall and strike against the stage. We have seen more than one good lens spoiled through such an accident.

When the objective has been properly secured in its place, move the body of the microscope up or down until the front lens—that is, the lens which is nearest to the object, is about a quarter of an inch above the stage. Then turn the mirror until the light from the window or lamp is reflected through the microscope, so that when looking through it a bright circle of light is seen.

Place on the stage some mounted object of large size, such as a fly's wing or section of wood. If a low power objective be used, say one magnifying less than 100 diameters, move the body of the microscope up, so as to increase the distance between the objective and the object. At the same time keep your eye at the eye-piece and watch closely. At a certain point the object will be seen with great distinctness; it is then in focus, and is ready for examination. Always begin with low powers. One of the greatest risks that the beginner runs is that of breaking the objective by forcing it down on the object. To avoid this with high powers, bring the objective down almost into contact with the slide; when doing this do not look *through* the microscope, but watch the objective, and stop whenever it is sufficiently near the object. Then apply the eye to the eye-piece, slowly raise the body, and watch for the coming of the object into focus. This is the only safe method with high powers.

Before attempting to place an object on the stage, or to remove one from it, see that the objective is raised at least half an inch above the stage. By attempting to introduce a new slide without raising the objective, when using high powers, you run great risk of injuring both the object and the objective. And in removing objects from the stage, never lift them up; always *slide them off*. In lifting them up, great danger is incurred of bringing them into contact with the objective, and thus doing irreparable injury. Sliding entirely prevents this.

Where the microscope is not provided with mechanical means for adjusting the focus, such as a screw or rack and pinion, a great deal may be accomplished by special methods of manipulation. Thus if, instead of pushing the body directly through the collar, it be moved with a slightly twisting motion, the focus may be adjusted with considerable delicacy, and when the microscope is not provided with a fine movement, a great deal may be done by means of a slight pressure of the fingers on the stage. Few stages are sufficiently rigid to resist even the slightest pressure.

The chief points which the beginner should endeavor to study are the variations which are made in the appearance of the object by means of slight changes in the focussing and the mode of illumination. Experienced microscopists constantly keep their fingers on the fine adjustment of the microscope, and watch the different appearances which are produced by a change in the mode of illumination. Swinging the mirror to one side, so as to send the light through the object in an oblique direction, or, where the mirror cannot be turned to one side, merely turning it on the trunnions which support it, will often produce most important effects.

From what has previously been said in regard to the necessity for clear and brilliant sources of illumination, the young microscopist may, perhaps, be led to suppose that the field of view cannot be too brilliantly illuminated. Such, however, is far from being the case. With ordinary powers (those below 500 diameters) it is almost always necessary to moderate the light, even of a flat-wicked lamp, and still more that of a students' lamp. The finer details of an object cannot possibly be made out if the illumination be too strong; they are "drowned out," and the whole object becomes what artists and engravers call *flat*. The light may be regulated by the diaphragm which has been previously described. Where the microscope is not furnished with a diaphragm, increasing the distance of the lamp from the instrument is the best mode of lessening the intensity of the light.

Very bright light is exceedingly trying to the eyes, and therefore the student will find it advantageous to use lights of moderate intensity, and to increase their efficiency in every possible way. This may be done to a very great extent by judicious management—chiefly by excluding from the eye all *unnecessary* light. In a room very brilliantly lighted with a number of powerful argand burners, it would be impossible to secure the proper illumination of a microscopic object by means of a candle, for the eye, accustomed to the bright light, would fail to be impressed by the weaker one. Extinguish the bright lights, give the eye a short time for rest, and the candle will answer very well. The principle thus illustrated finds a practical application in the use of pasteboard shades surrounding the eye-piece, and excluding from the eye all light except that which passes through the microscope. Such a shade is easily made and adapted to any microscope, and is of great service. We have also in our own practice carried out the same principle by means of extra diaphragms to our eye-pieces, thus cutting off all the light which passes through the microscope, except that which actually serves to illuminate the object.

It will also be found of great importance to secure perfect purity in the special illumination employed. Thus, if we are examining an object by transmitted light, it always detracts from the clearness and beauty of the image if light is reflected from its surface. It is, therefore, of advantage to shade the object by means of a small tin, brass or pasteboard shade, attached to the stage so as to prevent any light from the lamp from falling *on* the object.

A difficulty which frequently occurs to young microscopists consists in the almost impossibility of securing a field of view equally illuminated in all parts. Assuming that the mirror is in proper position, and that there is nothing to shade any part, it will in general be found that the difficulty arises from the fact that the mirror throws images of the lamp, etc., upon the object. Sometimes this is very distinctly seen; the shape of the flame can be clearly distinguished, and the metal portions of the lamp appear as dark shades. The cause is that the lamp is at the exact distance at which the mirror forms an image of it on the upper surface of the slide, just as a lens, held in front of a white wall, will throw an inverted image of a lamp or candle on the wall, provided the relative distances of the wall, lens and candle are properly adjusted. The remedy is very simple; move the lamp either towards the microscope or away from it, as may be most convenient.

As previously stated, the character of the illumination afforded by a mirror, and by a white surface placed at a short distance from the object, are appreciably different. A very pleasant method of illuminating transparent objects consists in the use of a plate of plaster of paris. Its whiteness is probably as pure as that of any other substance, and it is easily procured. The plate we use was cast in the cover of an old tin box, half an inch deep and three inches in diameter. A flat surface was secured by casting it upon a board. If cast on glass or metal, the surface is glazed and shiny, which is bad. Instead of plaster, fine white paper or cardboard may be used. Such surfaces must not be glazed, and they should be kept scrupulously clean.

The light is also sometimes modified by passing it through ground or colored glass—blue being a special favorite. Such light-modifiers, as they are called, produce a pleasant and equable illumination, which is a great relief to the eyes, but, except for the resolution of finely lined objects, we have not found them otherwise of any special advantage. When it is desired to obtain the greatest resolving power that a lens is capable of affording, the *blue cell*, as it is called, is probably the most efficient accessory. This is simply a glass tank, somewhat like a zoophyte trough, filled with a solution of oxide of copper in liquor ammoniæ. The solution is prepared by adding liquor ammoniæ to a saturated solution of sulphate of copper, until the precipitate which is first formed is re-dissolved. The intensity of the blue may be regulated, either by diluting the solution, or by varying the thickness of the layer of liquid.

When it is desired to examine anything by light *reflected from* it, instead of light *transmitted through* it, the object should be placed before a dead-black surface, such as the dark part of the diaphragm, or a blackened card, and at such a distance from it that the surface of the background is not in focus. Then, place the condensing lens in relation to the lamp, so that a bright spot of light will fall on the object, and on bringing it into focus it will be clearly seen. Low powers only can be satisfactorily used for the examination of opaque objects by beginners.

The beginner should commence with the simplest mounted objects, and afterwards, when a little skill in the manipulation of the instrument has been acquired, he should proceed to the examination of such simple unmounted objects as are easily prepared. The latter course will prove altogether the most valuable and instructive, for he who confines himself to the examination of mounted objects only can never hope to become a microscopist. After a time, when a little skill has been acquired in the *preparation* of objects, the student may proceed to preserve and mount them. Most young people try to *mount* before they have learned to *prepare* objects, and the consequence is that they soon find themselves in possession of a large collection of very poor slides.

Care of the Microscope.—A microscope, when not in use, should always be kept well covered, either in its case or under a suitable cover. There is no more convenient mode of keeping a microscope than to stand it upon a cloth mat, and cover it with a glass shade. It is thus kept free from dust and vapors, and is always ready for use; but when it is kept in its case, and especially if it has to be screwed together, interesting, valuable, or even important objects, will often fail to be examined, simply because too much time and labor are necessary to prepare for the operation.

A good microscope should be so carefully protected, that it shall rarely require to be cleaned or dusted, as this wears off the lacquer, and exposes the metal, which, when thus uncovered, soon begins to tarnish. When dusting or cleaning becomes absolutely necessary, chamois leather, or a very fine old linen or silk handkerchief is most suitable. Never use coarse cloths, or those that have been lying about exposed to dust and dirt.

The lenses should be kept in their boxes when not in use, and when they are attached to the microscope, great care should be taken to keep them from coming into contact with liquids. In order to prevent the latter accident as far as possible, never examine liquids unless when they are covered with thin glass. In the pursuit of micro-chemical studies, the microscopist has frequently to deal with liquids that corrode metals, and even glass. In well-appointed laboratories *inverted* microscopes are used in such cases, but with ordinary instruments, special means must be employed. The object should be laid on a large piece of thin plate glass, and the objective should be coated with oil. The rest of the metal work may be protected with oiled silk or thin india-rubber.

When liquids which corrode glass are used, the front of the objective should be protected by means of a very thin leaf of the best mica, which may be attached either by glycerine or balsam.

These, however, are exceptional precautions. In ordinary work it is sufficient to see that the lenses and metal work are kept free from stains and finger marks.

Never touch with the fingers the surface of any lenses, either eye-pieces or objectives, as this will be certain to soil them. Use soft camel-hair brushes to remove particles of dust, etc. Where dirt adheres more strongly, use fine linen *slightly* moistened with alcohol, and wipe dry with very fine chamois leather. Remember, that alcohol, if used profusely, will attack the lacquer of the brass-work, and even dissolve the cement which holds the lenses together. When objectives are smeared with balsam, the best cleansing agent is said to be kerosene oil. The piece of leather used for wiping lenses should be free from dust, and is best kept in a small box by itself, and used for nothing else. It must be remembered that the glass of which objectives are made is easily scratched, being soft when compared with particles of sand and grit; consequently, when frequently wiped it soon loses that exquisite polish upon which its excellence of performance so much depends. What, then, are we to think of the directions given by the author of a popular work on the microscope, in which we are told to use a piece of leather, slightly impregnated with brick dust!! No better method of destroying an objective could possibly be devised. Therefore, see that in wiping, the *slightest* possible pressure is used, lest any particle of grit should make a scratch.

The exposed parts of all microscopes, as well as the objectives and their cases, are lacquered, to protect them from being soiled by handling, but the interior of the boxes which hold the object-glasses are rarely so protected, and the black coating of the interior of bodies, draw-tubes, etc., is frequently not very firmly attached. Therefore, never touch them with the fingers.

After taking an objective out of its box, either screw on the cover of the box, or place the latter with its open end down. Do not stand it mouth up, so that it may catch all the dust.

When exhibiting the microscope to others, great care is necessary to keep meddlesome fingers from soiling the glasses. Some people are never content when merely allowed to look at things: they insist upon handling them, and feeling them. To the young microscopist, we would say that if any of your friends insist upon handling your objectives, eye-pieces, etc., put up the instrument and pack it away. A microscope carefully used is as good after fifty years as when first made, but we have seen an instrument suffer more injury in half an hour at the hands of a thoughtless and dirty person, than it would have sustained in twenty years in the hands of a careful microscopist.

COLLECTING OBJECTS.

Those who are engaged in special studies and researches require no directions for *collecting* objects; but to those who use the microscope for purposes of general instruction or amusement, a few hints may not be out of place. Almost every textbook on botany, physiology, mineralogy and kindred subjects, will not only indicate a long list of objects, but will give directions for procuring them. Plants yield a very large variety of interesting subjects. Thus the cuticles of the leaves and flowers; cellular tissue as shown by dissections, and by cross and longitudinal sections; hairs, pollen, seeds, etc., all deserve careful microscopical examination. Insects furnish an almost unlimited field, and their wings, feet, eyes, mouth, scales, spiracles, hairs, etc., are all worthy of careful preparation and examination.

It is, however, amongst the more minute forms of animal and vegetable life, as found in pools and running streams, that the most interesting objects are to be found, and the number and variety of these is so great that several large volumes would be required to describe them. Even the ponderous works of Ehrenberg and Pritchard do not begin to exhaust the subject, and, therefore, it will be obvious, that even if we were to devote the whole of the present volume to this department, we could but skim the surface. Thus far we have had to depend chiefly upon foreign works for descriptions of these organisms, but it is fortunate that while the higher classes of plants and animals which inhabit Europe, and are described in European works, are entirely different from their congeners on this continent, the same does not hold true in regard to the lower forms. We have found localities which teemed with the *Volvox Globator* and various species of *Closterium*, *Staurastrum*, *Pediastrum*, etc. Hydras are to be found in great abundance, and so nearly like the described European species that the beginner will find it difficult to detect the difference. We have repeatedly found the *Stephanoceras*, *Melicerta* and other beautiful microscopic objects, and as for the more common ones, such as the *Vorticelli*, or wheel animalcules and *Entomostraca*, or water fleas, they are to be found in every pool.

Every young microscopist that is desirous of pursuing his studies in this direction, is met at the outset by two difficulties; the first is to obtain the objects, the second is to find out what they are after he has got them. The first is by no means a difficult task, but the second will often puzzle more experienced students than those whom we expect to be readers of this book. We know of but two ways to accomplish it; one is the laborious plan of searching for them in the "Micrographic Dictionary," or the books of Carpenter or Pritchard; the other is to obtain the desired information from some well-informed friend.

The objects which are of most interest to the microscopist are not difficult to obtain, if we know where to look for them, but they are not to be found everywhere. Many stagnant pools will be found to yield but a scanty supply, while others, which, perhaps, to the uninitiated present a less promising appearance, will yield a rich harvest. Beginners are very apt to entertain the popular notion, that *every* drop of water teems with animalcules, and that when placed under the microscope, it will appear to be literally filled with living things. This idea is fostered by popular writers who describe a drop of water as a globe filled with life, and by lecturers who exhibit pictures and enlarged images of what they call "a drop of water," but which is in reality a considerable quantity of that liquid which has been artificially supplied with inhabitants. Clear well water is almost free from microscopic organisms, and the same is true of the water from clear brooks, which flow swiftly over a pebbly bottom. Ordinary rain water, as found in cisterns having free communication with the air, usually contains large numbers of the larvæ of gnats and mosquitoes, and when exposed to the light it is almost always rich in wheel animalcules, and some of the lower forms of vegetable life. The water supplied to our cities is in general very rich in microscopic vegetables. Thus in the Croton water, which is comparatively pure, we have found a large number of very beautiful species, amongst them the exquisite *Monachinus*. The best way to secure a supply of the animal and vegetable inhabitants of city water, is to pass a considerable quantity of it through a filter, the surface of which will then furnish a large amount of valuable matter.

But it is not in such fields that the microscopist will find his best hunting grounds. Along the edges of quiet pools of clear water is the best place for the finer vegetable forms, such as the *Volvox Globator*, *Closterium*, etc. If the water is much contaminated with dead animal matter or with sewage, nothing will be found but the coarser organisms and animalcules, such as *Paramecium*. The same is true of small pools found in woods, or very much shaded with trees, and filled with dead leaves. Such places are, however, the favorite haunts of the larvæ of insects, and also of frogs and Tritons. The size of the pools is not of much consequence. We remember on one occasion to have found by the roadside in Centre County, Pennsylvania, a little pool which was almost filled with the larvæ of Tritons. The gills, which were beautifully developed, would have formed a splendid object under the microscope, but when we returned next day, for the purpose of securing some, the water had dried up, and the larvæ were all gone.

The little pools formed in boggy ground by the footsteps of cattle will often be found to contain large quantities of one or two species of desmids or diatoms. It will not do to look for these objects in similar pools formed in ordinary soft land, and temporarily filled with rain water. The ground must be naturally and constantly wet, so that the pools are always kept filled by the infiltration of water from the surrounding soil. Such pools, however small, usually contain a large number of specimens, and it is in such places that one is most likely to find a supply of *one* variety unmixed with any others.

While many of the most interesting objects will be found swimming freely about in the water, others of great beauty are always attached to floating weeds, sticks, etc. We have generally been most successful in discovering specimens of this kind when we have placed the gathering in a large glass jar, and allowed it to stand quiet for some time. The water will then settle, and the objects of which the microscopist is in search will have time to expand, when they may be seen in a form resembling light mould, or down, attached to the surfaces of the solid matters.

The surface of the mud at the bottom of ponds of clear water, is frequently very rich in microscopic vegetable organisms. These minute plants seem to seek the light, and to rise through the mud which would otherwise cover them, so that by carefully scraping the surface of the bottom, we are enabled to procure them in large numbers.

It must, of course, be borne in mind, that while some species are found in fresh water, others are *marine*, that is, they live only in sea-water. The best locations for finding marine forms are: 1, the pools of clear water, found in salt marshes; 2, the surface of the mud at the bottoms of harbors and quiet coves; 3, the waters of the ocean itself, as well as that of the bays and coves connected with it.

The apparatus required for capturing these various objects, is neither bulky nor expensive. For larvæ and the larger animalcules, the most useful implement is a small net. Ours consists of a ring of brass wire (iron wire would rust and destroy the net) about six inches in diameter, soldered to a tin tube or ferrule, which fits tightly on the end of a walking cane. To the ring is attached a bag of any light, gauzy material, which possesses the two qualities of letting water out rapidly, and keeping small objects in. With this net it is easy to capture anything from a small fish or a frog to the very smallest larva, and it is very portable, since an ordinary walking cane forms a sort of universal handle for this and other implements. Next to the net, we find the most useful articles to be bottles. They should be of clear glass, so that any object contained in them may be readily examined by means of a pocket lens. For this reason we prefer what are called homœopathic phials of large size (half ounce and quarter ounce), and we generally carry a dozen or two when out on a tramp. A fair sample of the contents of a small pool is easily obtained by gently lowering the phial, mouth downwards, under the water, and bringing it cautiously to the place which is supposed to be richest in specimens. The phial is then turned mouth upward, the air rushes out and the objects are carried into the bottle by the force of the inrushing current of water. For small, shallow pools, the phial is most conveniently held in the hand, but when the water is deep a handle is required, and for this we use the holder shown in

Fig. 28, which is made to fit on the end of the walking stick. It consists of a ferrule having a semi-cylindrical piece soldered at right angles to it. The ferrule fits the cane, and the bottle is fastened to the cross piece by means of a rubber ring—the method of arranging the latter being easily understood from the engraving. A dozen or more bottles of proper size may be taken along, and they are so easily attached to the holder that there is no necessity for transferring a "dip" to another bottle. The contents are most easily carried in the bottle in which they were first obtained.

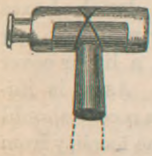


Fig. 28.

When the water is too deep for a walking cane, a fishing rod or any long pole may be used, and where these prove too short, as in harbors, etc., a bottle may be lowered and raised properly by means of strings. For this purpose the bottle must be heavily loaded with lead round the neck, and two strings must be attached to it, one fastened to the neck and the other to the bottom. It is by the latter that the bottle must be lowered, but it must be raised by the other. If properly managed it will descend mouth downwards, but the tension of the string attached to the neck will invert it, and when raised by this string it will bring up its contents very perfectly.

For scraping the surface of the mud at the bottom of shallow pools, we use the spoon shown in Fig. 29. It is simply a ring of tin five inches in diameter and one inch deep. The lower edge is "wired" as the tinsmiths call it, and there is a ferrule soldered to the side so that it may be fixed to the same cane that is used for the net. Over the bottom is stretched a piece of some thin fabric, such as thin muslin, gauze or tarletan, which is held in place by a rubber band that slips over the wire ring on the lower edge It is best to make one side of the ring somewhat flat, so as to adapt it better to the flat surface of the mud. When the pieces of cloth get soiled, they are easily replaced, and, indeed, in some cases it is not a bad plan to carry the mud home in the wet cloths, a dozen or more of which, with their contents, may

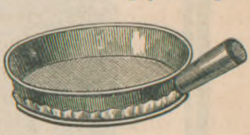


Fig. 29.

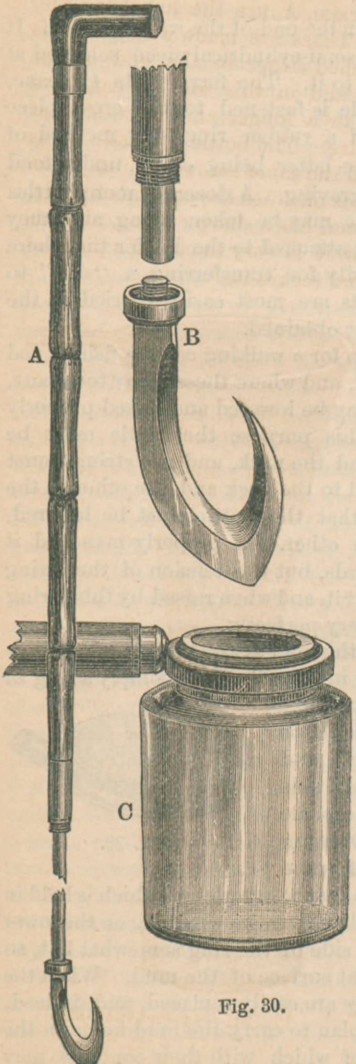


Fig. 30.

be easily packed in a tin box of small size. One of the boxes used by school children for lunch boxes answers very well, but any tin box with a lid or cover will answer. As it is important that a record should be kept of the locality from which the dip was taken, we carry a few slips of parchment paper, one of which is pinned to each cloth, after the necessary memoranda have been written upon it with a hard pencil. On returning home, the contents of each cloth may be transferred to a separate bottle. This plan saves the carrying of numerous bottles, and the water required to fill them.

An exceedingly coveni-ent traveling companion for those who are fond of collecting, is shown in the accompanying engraving, Fig. 30. The main part forms a very convenient walking cane of ordinary appearance. Like many fishing rods, however, it is hollow, and contains a second rod by which it may be extended to twice its length. This enables the user to reach the bottom of any ordinary pond, and to reach as far as is necessary from the shore. Accompanying the cane, A, are the hooked knife, B, and the ring and bottle, C. These are made with a double screw, so that they may be attached either to the end of the cane itself, or to the inner rod, and in this way we can have either a short and stout handle, or a longer and more slender one, as circumstances may require. The bottle is made so as to screw into the brass ring, and the same screw enables us to fit a wooden cap on it, which thus encloses the contents tightly. The hook is made of fine steel, and has a sharp cutting edge, as seen in the engraving, so that it is easy to cut off a piece of weed, drag it out of the water and secure it.

Those who carry such a cane do not attract attention by any unusual paraphernalia, and at the same time they are at all times ready to secure any valuable material that may present itself. Several bottles may be carried in the pocket, and screwed into the ring as required.

The collector who desires to make a thorough examination of the microscopic flora and fauna of any pool or stream, must not rest content with infinitesimal quantities of material. It is not necessary, however, to lug home a gallon of water for the sake of the objects contained in it, and so fully have microscopists been impressed with this idea, that the devices which have been prepared for straining out the valuable portions are almost endless. The best and simplest that we have seen is a modification of an

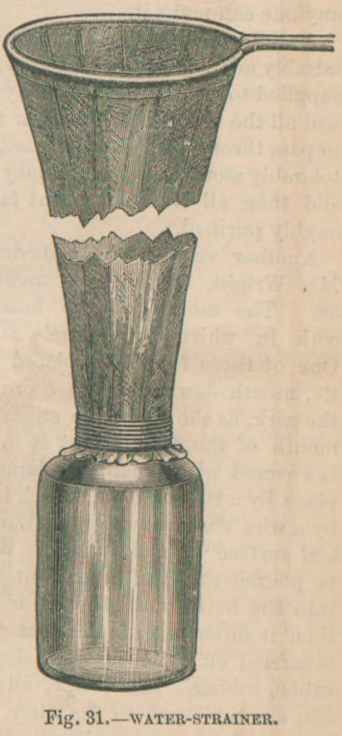


Fig. 31.—WATER-STRAINER.

arrangement, designed, we believe, by Mr. Highley, and figured in Beale's work on the microscope. It consists, as shown in the engraving (see Fig. 31), of a bag or net of some light material, to the bottom of which is attached, by means of twine, or a strong rubber ring, a wide-mouthed bottle. Any quantity of water may be poured into the bag, and all the objects which it contains will roll down the sides of the bag and fall into the bottle, while the fluid escapes through the sides. Delicate objects are consequently not exposed to pressure, rubbing, or any other violence, as they would be in an ordinary filter or bag, and the whole affair is so simple that any one can make it.

A slight modification of this arrangement will be found admirably adapted to the microscopic examination of the water supplied to cities. The bag may be attached to any faucet, and and all the water that is used in the household may be caused to pass through it. In this case, if the bag be made of some tolerably stout material, it may be firmly tied to the faucet, and then all the water that is consumed will be very thoroughly purified.

Another very excellent device is the bottle invented by Mr. Wright, of which a modified form is shown in Fig. 32. The mouth of the bottle is closed by means of a cork in which two funnels are inserted. One of these funnels is placed in the bottle, mouth down; the other projects above the cork, as shown in the engraving. The mouth of the funnel that is in the bottle is covered with muslin or flannel, held in place by a rubber band, which is prevented by a wire ring from slipping along the conical surface of the funnel. When water is poured into the other funnel, it passes into the bottle until the latter is full, and then it flows out of the first funnel, and is carried off by means of a short piece of rubber tubing. Meanwhile, all solid particles are held back by the filter, and as the latter is horizontal and with the filtering

Fig. 32.

surface downwards, most objects of interest fall away from it, and may be found in the water. A single bottle of this description is sufficient, as the cork is easily removed, so that the water may be poured into other bottles. As ordinarily made and sold, Wright's collecting bottle is an expensive piece of apparatus, costing four or five dollars, but as shown in the engraving it may be made for a few cents by any tinsmith.

Where it is desirable to keep the specimens thus obtained so that they may be examined, and their life-history studied, bottles and jars of almost any kind may be used, but those which we have found most convenient are what are known as "quinine" bottles, and may be had at most druggists. For ordinary objects they are just about the right size, and as they are made of tolerably clear glass it is easy to examine the objects through the sides of the bottle. A dozen or two of these little aquaria occupy very little space, and are easily handled. Great care must in general be taken to exclude from the vessels containing the finer organisms, such predatory animalcules as devour them. Water fleas, the larvæ of insects, etc., will soon make away with the finer specimens. On this account great difficulty is found in keeping the *Volvox Globator*, since it is greedily devoured by various rotifers, and these are exceedingly difficult to exclude. We have succeeded best in this case by partially filling a bottle with well-filtered water taken from the same pool as the specimens, and transferring the objects to it singly so as to avoid transferring their enemies too. For this purpose the dipping tube should be used. Some authors caution us against mixing the inhabitants of different pools, on the ground that being strangers to each other they will fight. This is more fanciful than accurate, though it has a basis of truth. It is not the circumstance that they are strangers that causes the difficulty, but the fact that the one is the natural prey of the other. The same thing occurs between inhabitants of the same pool. It must be remembered, however, that very slight changes in the conditions in which they are placed will often cause the destruction of these objects. Thus, we have seen some very fine gatherings totally destroyed by being removed from soft, boggy water to clear, hard well water. Therefore, in transferring either animals or vegetables to an aquariun, it is well to supply them with the same water, mud, etc., in which they were originally found. It will sometimes, however, be well to filter the water so as to remove all such inhabitants as are apt to eat up the others. Water, may be filtered through paper, or where filtering paper is inaccessible, the neck of a funnel may be loosely plugged with cotton. Even this does not quite free it from noxious eggs or germs, and we have sometimes gone so far as to boil it in a flask, the mouth of which we plugged with a loose wad of cotton after introducing the objects we wished to presserve.

When floating freely in these diminutive aquaria, many objects are as difficult to find and capture as would be a small fish in a large pond. The microscopist, therefore, requires special means for capturing them, and placing them on a slide. For this purpose nothing serves so well as what are known as dipping or fishing tubes. These are simply glass tubes of different diameters (from one tenth to one quarter of an inch), and of any convenient length. They are used by closing the upper end with the finger, bringing the lower end near the object (under the water), and then removing the fingers from the upper end. The water, in seeking to find its own level in the tube rushes in with great force and carries the object with it. By again placing the finger on the upper end of the tube, the latter may be lifted from the bottle, and the water with it, and by a little dexterous management it is easy to cause the object to flow out on a slide without allowing too much water to go with it. These tubes are made straight, curved, and with one end drawn to a point, but for most purposes the straight tube answers best as it is most easily kept clean. We prefer to grind the ends rather than to make them smooth by fusion, as the latter process generally contracts the opening, and renders the tube difficult to clean. The best plan, however, is to heat the upper end strongly before the blowpipe, and turn the edge outward like the mouth of a test-tube. It is then easily closed, and the tube is very strong. The lower end should be ground.

PREPARATION, PRESERVATION AND MOUNTING OF OBJECTS.

These three operations are so frequently applied as a single process to objects, that many writers have failed to make a sufficient distinction between them. By keeping the proper distinction clearly in mind, however, the student will not only save much valuable time, but he will secure vastly better results. Except by those who are more anxious to increase the number of objects in their cabinet than the amount of knowledge which they possess, a very large proportion of the objects examined will never be preserved or mounted at all. This however, should not prevent the utmost care being given to the process of preparing them for thorough examination. On the other hand it often happens that objects which have been carefully prepared and mounted, spoil because they have not been subjected to a proper preserving process. Hence the importance of treating these operations separately and fully.

The Preparation and Examination of Objects.— It is a common but very erroneous idea that the only thing that is necessary in order to examine any object under the microscope, is simply to place it on the stage, and get it into focus. With the exception of mounted objects, a very few transparent objects—such as the wings of insects—and some things that are viewed by reflected light, every substance requires to undergo careful preparation before it can be fit for profitable examination. A good example of the necessity for such preparation is seen in the common potato, a piece of which when simply placed on the stage of the microscope, and brought into focus, appears as a glistening mass, and reveals nothing of its true structure. If we now cut from this lump, by means of a very sharp knife, an exceedingly thin slice, place it on a plate of glass, moisten it with a little spirit and water, or better still, glycerine and water, and place over it a thin glass cover, it will disclose to us a most wonderful and beautiful structure. The entire mass will be seen to be composed of cells, these cells being filled with granules of starch of various sizes.

The operation which we have thus briefly described as applicable to the potato, is required for a great many other materials; for whenever a substance is to be examined under any except the very lowest powers, it is absolutely necessary to obtain it in pieces as thin as possible, so that the light may readily pass through them, and it is in general requisite to increase their transparency either by immersing them in a fluid, or by some other means. In preparing objects for the microscope, our aim is in general to examine either the ultimate structure of the substance under investigation, or the arrangement of its different parts; and the processes which are most available for this purpose may be classed under three heads: 1, Mechanical, such as section-cutting, dissection and injection; 2, Chemical, such as the use of iodine for detecting starch; of alcohol for hardening certain structures; of coloring substances for staining germinal matter, etc.; 3, Optical, such as the action whereby certain liquids change the transparency of some objects. Of some of these processes, such as injection, staining and the extended use of chemical tests, elaborate descriptions would be required in order to enable the student to carry them out with success, and we must refer him to the works of Beale and Frey, which are very complete on these points.

Thin sections of any soft substance are easily made with a very sharp knife—a good razor being probably the best available instrument. For work in the higher departments of microscopy, and for the preparation of fine objects *for sale*, special instruments known as section-cutters are employed, but for the ordinary work of investigation, they are not absolutely necessary though very convenient. Using a good sharp razor, it is an easy matter to shave off any soft substance a wedge shaped piece, the edge of which thins off to nothing, and which presents in its different parts all varieties of thickness, so as to afford a perfect opportunity to study the object under examination. In this way, which is known as the "free-hand" method, suitable sections of most animal and vegetable substances may easily be prepared, and the student will be surprised at the dexterity which a little care and practice will confer.

For cutting sections of very soft tissues a special knife, known as Valentin's knife, has been invented. It consists of two blades so arranged in one handle that their distance from each other may be easily regulated. When a cut is made with this double-bladed knife, a thin slice of the tissue passes between the blades, and constitutes the section. It is an instrument, however, which will hardly be used by beginners. Sections of substances of greater consistence, such as wood and soft bones, are most easily made in a regular section cutter. The patterns according to which these instruments are constructed are very various, but they all act on the principle of raising above the surface of a brass table, by means of a fine screw, the substance to be cut, and then passing a very sharp razor or knife over the table so as to shave off the projecting part of the object. The table is usually of brass, ground and polished. This gives rise to two serious defects. The metal is too soft in the first place, so that it is impossible to press with sufficient force on the razor without cutting into the table, and secondly, when any soft metal has been ground on a grindstone or emery wheel, the surface becomes so impregnated with gritty matter, that it very rapidly destroys the edge of the cutting tool. We avoid these difficulties by fitting to our section cutter a stout plate of hardened steel, the surface of which has been highly polished by means of buff leather. Quekett describes a cutting machine in which the difficulties we have mentioned are obviated by fixing the knife in a frame so that it is raised above the table, and does not touch the metal. Its edge is thus preserved from injury, and the blade itself cannot be affected by variations in the pressure exerted. Dr. Curtis, of this city, has adopted the same principle in his section cutter, the details of which are admirably carried out.

In making sections of wood and similar substances, the specimen is first well soaked in dilute alcohol, and is then fastened securely into the tube of the section cutter, either by wedges or by casting wax or paraffin around it. The process of raising it by means of the screw and passing the knife over it, is simple enough, and can easily be learned.

With the ordinary cutting machine, success in making thin sections seems to depend upon the perfect sharpness of the cutting edge, the thorough moistening of the knife and section, and the rigidity of the blade. The latter point frequently fails to receive the attention that it deserves. Where a thin, flexible blade is used, a moderate change in the amount of pressure employed will make a great difference in the thickness of the section, even so far as to double it. When the blade is stiff, a change in the degree of pressure has but little effect.

Soft substances must first be hardened either by immersion in alcohol or other means, and in general must be supported by being surrounded with melted wax or paraffin. Where the specimen is very slender (such as a hair) it must be carefully supported between firm and rigid clamps. Corks and similar yielding substances, which are recommended in most books, never give a cross section accurately taken at right angles. The same is true of the plan so much recommended for obtaining sections of hair, viz.: to pass the razor over the face shortly after shaving. We get sections it is true, but they are all oblique. The best way to get true sections is to imbed the substances in glue, gum, paraffin, wax or some such material.

Sections of bone are prepared by sawing off a thin slice in the first place, and cementing it to a slide by means of thick or old balsam; one side is then filed or ground flat, and polished on buff leather, after which the section is transferred to another slide so as to expose the other side, which is then filed down and polished as before. Great care must be taken so as to hit just the right thickness, and the operation of cementing to the slide must be performed expeditiously, so that the balsam may not saturate the section, and render it too transparent, as when this occurs certain very important features become invisible.

Very hard substances require special apparatus, and considerable skill. Still it is astonishing what may be accomplished by means of good files, whetstones and grindstones in the way of preparing thin and transparent sections even of such substances as rocks and stones.

In order to acquire correct ideas in regard to the structure of objects, of which sections are examined, the student should familiarize himself with the geometrical forms produced by cutting cylinders, cones, spheroids, etc., in various directions. Thus a cylindrical vessel, cut square across, shows a circle; when cut obliquely it shows an oval (ellipse) of greater or less length, and when cut longitudinally it shows two lines which have no apparent connection with each other. The truth is, however, that we should never deduce the form of vessels from sections alone. In every case it is necessary to examine carefully *dissected* preparations as well as sections.

The soft parts of animals and vegetables are frequently prepared for examination by careful dissection, that is to say the different parts are separated from each other, and freed from extraneous matter by means of knives, scissors, forceps, needles, camel hair pencils, etc. The knives used by the microscopist are similar to the scalpels ordinarily employed by anatomists, but smaller, and unless very finely tempered and well-sharpened, they are worthless. The knives sent out with low priced microscopes are in general the veriest trash, and the same is true of the needles. There are three kinds of scissors which the microscopist will find useful—plain, straight scissors, elbow scissors, and curved scissors. They must be small, sharp and well made. But the most useful, as well as the simplest instruments for dissecting are a pair of needles, or, rather, a needle and a very fine spatula. The needles used are those ordinarily employed by seamstresses; they should be fixed in a light wooden handle and carefully polished. The latter is a most important point, for it will be found that ordinary needles are too rough for delicate work, as may be easily seen by examining them under the microscope. For microscopical purposes needles are made both straight and curved—the latter being a very useful form. In order to bend a needle, it must first be heated in the flame of a candle, then bent by proper pliers, after which it must be carefully re-tempered. There is little danger of getting it too hard, provided it is not burned. After being hardened it must be carefully re-polished. The handles should be light and smooth. Ordinary penholders make good handles and cost but a trifle, but in case of need any piece of straight-grained, light wood will answer. Universal handles, handles with ferrules, handles wound with thread, etc,, look as if they were not common articles, and are purchased by many, but no working microscopist would give them table-room. All the so-called universal handles in market are too clumsy and heavy.

In using needles or knives for dissection, they are generally used in pairs, that in the right hand being used for teasing or cutting, while the one in the left hand is used for holding the object firmly in its place. For the latter purpose, however, we prefer a very narrow spatula, curved and highly polished. Curved needles, with the curve placed flat, answer very well, however.

For the removal of loose matter, and for arranging parts which have been dissected out, there is nothing more useful than good camel hair pencils. Indeed, they are indispensable, and with needles and pencils—two of the simplest and cheapest articles—it is possible to do almost everything.

During the process of dissection the object must be supported upon a glass plate or a dissecting pan, according to its size. Some of the finest preparations have been worked up on ordinary slides three inches long by one wide, and as it is almost always necessary to have the object covered with liquid, a single drop suffices in this case. But where larger objects are to be dissected, ordinary slides are not large enough, and besides there is no provision made for holding a sufficient quantity of liquid. Various kinds of dissecting dishes or pans have therefore been devised. Those used by the author are exceedingly simple and cheap, and are shown in Fig. 33. We use three kinds, two with opaque bottoms, and one in which the bottom is transparent. The latter is used for objects which are transparent, and is precisely like the others, except that a portion of the metal bottom is cut away and a piece of plate glass cemented over the aperture. Those used for opaque objects are simply oblong tin dishes, each two inches long, one and a quarter wide and half an inch deep. The bottom plate extends on each side, so as to form rests for the fingers, by which the pan may be kept steady. Into this pan is poured a mixture of equal parts of resin and beeswax, softened if necessary with a little lard. It should be just so soft that a pin may be easily stuck into it, and this affords us the means of pinning out the different parts of a dissection as we progress. In one dish the wax is colored black with lampblack, and this forms a wonderfully effective back ground for most objects; the wax in the other

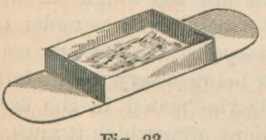


Fig. 33.

pan is white, chalk or sulphate of baryta being substituted for lampblack. The pan with a transparent bottom is of precisely the same size, except that the depth is but half as much—the extra depth in the other pan being filled with wax. A quarter of an inch is a sufficient depth of liquid for most objects, and when the sides of the pan are higher than necessary they interfere with the use of knives and needles.

Dissections may also be carried on in watch-glasses, though they are not quite as convenient as pans with perfectly flat bottoms. The kind known as *lunette* glasses should be chosen, as they are flat in the centre. When a watch-glass is used for this purpose, it is necessary to cement it into a hole cut in a thin piece of wood about four inches long, and of a width which is rather greater than the diameter of the glass.

Most of this work is, of course, done under a simple microscope. The Excelsior, when screwed to a larger base, as described on page 29, answers very well. Larger and more expensive dissecting microscopes are supplied by most opticians.

In addition to these general methods, which are applicable to a great variety of subjects, there are a few special processes which must be adopted in particular cases. In some instances, as when the line of investigation is a new one, the microscopist must work out his own processes, but the following special cases will probably prove interesting to beginners.

It frequently happens that the objects for which the microscopist is searching are found mixed with coarser materials, and in this case it will be found possible to effect a separation by the process known as *elutriation* or washing. Mix the matter thoroughly with water in a tall jar and allow it to settle. In a short time—say one minute—the very coarse particles will have fallen to the bottom, and if the liquid be now poured off and allowed to settle, the finer portion will be found in the second vessel. By graduating the time and carrying the process out to its full extent, a wonderfully perfect separation may be effected. Diatomaceous earth may frequently be treated in this way to advantage.

In some cases separation must be effected by burning, or the action of chemical agents. Guano and various organic matters yield interesting residues after everything soluble has been washed away and everything combustible has been burnt either with fire or nitric acid. So too the siliceous cuticles of plants may be procured by destroying all the other parts by chemical means. The best way is to heat them in nitric acid, and add to the hot liquid a small quantity of powdered chlorate of potash. The quantities used must be very small, and great care must be exercised.

It is frequently necessary to separate a small quantity of deposit from a large amount of liquid, filtering being inadmissible. For this purpose use a conical glass or a large test tube, allow plenty of time for the deposit to settle, and give occasionally a slight stir, so as to detach the particles from the sides of the vessel. Then pass a large dipping tube (one quarter of an inch in diameter) to the bottom, the upper end of the tube being closed with the finger. On withdrawing the finger the liquid and deposit rush in. Have ready a small ball of soft cement (resin and beeswax equal parts, softened with oil) and with it close the upper end of the tube, which may now be withdrawn, carrying the liquid with it. Place the tube in a vertical position, with its lower end on a slide or in a watch-glass, and support it either by means of the ring of a small retort stand or by a simple wire having a ring (horizontal) at the upper end, and a small piece of board for a foot. Beale directs us to *cork* the tube, but this is difficult unless the tube is made specially for the purpose with a mouth like that of a test tube. Tubes made in this way are, however, the most convenient, and a good velvet cork closes them perfectly.

There is a class of insect preparations, which are quite interesting, though they are not as instructive as inferior preparations made by the process of dissection. We refer to the whole insects found in most collections. They are prepared by soaking the insect in liquor potassæ, which may be had from any druggist; this renders the internal organs soluble and the outer horny skeleton transparent. The viscera are then expelled by pressure with a camel hair pencil, the insect well washed in pure water, soaked first in alcohol, and then in turpentine, and finally mounted in balsam. The points requiring attention are these: Soaking just the right length of time in the potash, for if the insect remains too long in this liquid it will be destroyed;

allowing plenty of time for the alcohol to displace the water, and for the turpentine to displace the alcohol; and manipulating the insect with great care, so as not to break any of the parts. The eyes of insects are prepared by macerating them in very weak potash, and, while still soft, pressing them between two slips of glass. If allowed to harden before being pressed they will split at the edges. The handsomest preparations of eyes are obtained by taking a thin slice from a large eye, such as that of a dragon fly, and treating it as directed.

The feet of insects are in general easily prepared. Moderate soaking in potash, careful washing in water, thorough soaking in alcohol and turpentine, and careful management in properly displaying them on the slide, are the secrets of success. The student who wishes to make a careful study of these objects, however, should place them in glycerine, after soaking them in potash and thoroughly washing them. They should of course be deposited in a cell filled with liquid, and then covered with thin glass, and examined. The so-called tongues, etc., of insects require no potash, being sufficiently transparent without it, and after being soaked successively in alcohol and turpentine, they may be mounted in balsam. When wanted for examination merely, immerse them in dilute glycerine, and if the student can succeed in mounting them in cells, in glycerine or some of the gelatinous media hereafter described, they will show their structure to far better advantage than in balsam.

In determining the character of what is brought into view by the processes detailed, great aid will be derived from the use of chemical tests. Thus, in the case of the potato, previously described, most persons who had read anything at all upon such subjects, would recognize the starch granules. All starch granules, however, are not of the same form as those found in the potato; indeed, some would hardly be recognized at all, except by those having considerable experience. But if a little of the tincture of iodine be brought into contact with them, they at once become deeply blue. This subject is too extensive to be discussed here, but those who desire to become proficient in the use of the microscope cannot safely neglect it.

In most cases after an object has been carefully brought into proper mechanical condition, in one of the ways we have described, it is necessary to immerse it in some suitable medium, so as to render it clear and transparent. The action of such media may be very well illustrated by the following experiment: Take a short piece of black human hair, place it on a slide, bring it into focus and examine it. It will appear as a dark cord with a light line running down the centre, and from this circumstance has arisen the erroneous popular idea in regard to the tubular structure of hair. Apply a drop of glycerine diluted with an equal bulk of water, and again examine it. The appearance will have entirely changed, having become clearer and more definite, so that the structure of the hair is more easily made out. This effect depends upon the refracting power of the liquid used. The following liquids are usually employed for this purpose, their efficiency being in direct ratio to their index of refraction, which we append to each. Water, 1.336; glacial acetic acid, 1.38; alcohol, 1.372; vitreous humour, 1,340; sea-water, 1.343; equal parts of glycerine and water, 1.40; pure glycerine, 1.475; oil of turpentine, 1.478; Canada balsam, 1.532—1.549; bisulphide of carbon, 1.678; oil of annis, 1.811. Alcohol and water, and solutions of various salts in water are also very useful. When a pure article of glycerine is not available, a solution of white sugar may be used with good results.

Great care must be exercised lest the fluid that is added should change the form or structure of the object. Upon this subject the remarks of Frey are very judicious. He says: "Theory requires that each constituent of the body should be examined in a fluid medium which resembles in respect to quality and quantity, the fluid which saturates the living tissue. Naturally this requirement cannot be completely fulfilled in practice; our aim should be to approach it as nearly as possible. Saliva, vitreous humour, amniotic liquor, serum and diluted albumen are generally recommended as suitable media for the investigation of delicate changeable tissues, and, in certain cases, they accomplish their object in a satisfactory manner. But do not expect them to suffice for every case. Not unfrequently one and the same tissue of different species of animals reacts differently with the same fluid medium, as may be seen with the blood corpuscles. M. Schultze has communicated to us an important and readily proved observation of Landolt's, that animal fluids may be preserved from decomposition for a long time by the addition of a small piece of camphor."

Schultze recommends as a neutral fluid, suitable for most tissues, a liquid which he calls "Iod-serum." It consists of the amniotic fluid of the calf, to which has been added a concentrated tincture of iodine or a strong solution of iodine in the proportion of six drops to the ounce. The color of the solution is at first wine yellow, but after a few hours it becomes paler; this paleness afterwards increases, and the subsequent addition of a few drops of the iodine solution becomes necessary. As the amniotic fluid is not always attainable, a good substitute may be prepared by mixing 1 ounce white of egg, 9 ounces water, and 40 grains chloride of sodium, with the proper proportion of tincture of iodine.

During the entire process of preparation, the greatest attention must be paid to cleanliness. Particles of dust, which to the unassisted vision are invisible, become offensively prominent under the microscope. To exclude these, and to protect the objects, it is important that the latter should be kept carefully covered when not actually undergoing some operation. Small bell glasses are recommended for this purpose by Dr. Carpenter, and they answer admirably. We prefer, however, as being cheaper and less bulky, watch glasses to which a handle has been cemented as shown in Fig. 34. The handle may be a little knob, turned out of a piece of wood, or where this is not convenient a small cork will answer. A little sealing wax serves for a cement, the watch glass being heated before the wax is applied. Flat plates of glass answer well to cover the dissecting pans previously described.

Fig. 34.

When a number of objects are to be protected for some time, we place them on a piece of plate glass eight inches square, cover each with a watch-glass cover, and protect the whole by means of a bell jar with ground edges. The latter fits closely to the plate glass and excludes everything, while the small covers protect the individual specimens when the large cover is raised for the purpose of getting at them.

Singular mistakes have arisen from the fact that foreign bodies which have accidentally found their way into a preparation have been mistaken for part of the specimen. The only way to avoid similar errors is to exclude all such intruders by means of proper covers, and to become familiar with them so that they may be instantly recognized when present. Dr. Beale gives the following list as those that are most apt to find their way into the preparations of the microscopist: Oil globules; milk; starch from the potato, wheat and rice; bread crumbs; feathers; worsted; fibres of flax, cotton and silk of different colors; human hair, cat's hair and hair from blankets; the scales of butterflies and moths, particularly those from the common clothes moth; fibres of wood, fragments of tea leaves, hairs from plants, vegetable cellular tissue and spiral vessels; particles of sand. The curious circumstances under which such bodies will find their way into a specimen was recently illustrated in the author's experience. In a liquid submitted for examination, and said to be pure, he found foreign matter. It proved to be brick dust, used to clean the tin funnel with which the vessel was filled, and which had been washed in by the passage of the fluid. The student can have no better exercise than to examine these intruders and familiarize himself with their appearance.

Preservative Processes.—The object of all preservative processes is to prevent any change either in the structure or composition of the object. An object may be most perfectly prepared and beautifully mounted, but if it be not so treated as to preserve it from change, the labor thus expended is wasted, as regards the preservation of a permanent record. And yet how many objects there are that we would like to keep for future examination and comparison, or to show to friends. This department of the treatment of objects is, therefore, of great importance, and success in it can only be obtained through a thorough understanding of the principles involved.

There are four methods in common use for the preservation of perishable animal and vegetable substances: 1, Constant exposure to temperature considerably below the freezing point of water; 2, the perfect exclusion of air; 3, reduction to a state of complete dryness; and 4, the employment of certain anti-septic compound. The third and fourth are the methods usually employed in microscopy, but the same principles which render the second method so successful in the preservation of canned fruits and meats, deserve the attention of the microscopist.

Drying, as a preservative process, can be applied to but few specimens, chiefly transparent insect preparations, and opaque objects. Blood and similar matters are also sometimes preserved by drying. Such preparations are so easily dried that no special directions are needed. Warming them over a lamp, or preferably on a water-bath, before applying the thin glass cover (as directed in the section on mounting objects) is almost always sufficient. Where the specimen is liable to be injured by heat it may be dried by placing it over sulphuric acid, and covering both acid and preparation with a bell jar having ground edges and resting on a perfectly flat plate of glass. The acid soon absorbs all the moisture and renders the object perfectly dry. Where a cell is used for an opaque object, and dryness is essential, great care must be taken to make the cell impervious to air, otherwise dampness will be sure to penetrate, and if the object be of animal or vegetable origin, fungi will be very apt to grow on it. We have found cells of cardboard peculiarly liable to this defect, and such cells should always be thoroughly saturated, and coated with varnish, such as gold size or Canada balsam.

The great dependence of the microscopist, however, is in the employment of certain preservative media, of the most important of which, the following is a list:

CANADA BALSAM.—Of all the media employed for the mounting and preservation of objects, Canada balsam is undoubtedly the most generally useful, and it is probable that more objects are mounted in this material than in all the other media put together. As a *preservative* it is perfect, and its action in rendering many objects transparent and clear is often of great value. Frey tells us that "several sorts of Canada balsam occur in commerce. To be good it should be of thick consistence, nearly colorless, and thoroughly transparent." One difficulty, however, is that much of the Canada balsam that is sold is factitious, being made of cheap resins dissolved in impure turpentine. Such balsam soon becomes cloudy, and is very apt to crack. Balsam that is too highly colored may be bleached by exposure to sunlight—a process applied by most opticians to the balsam used by them for cementing the lenses of achromatic combinations. Balsam when new is quite fluid, too much so, indeed, for the mounting of most objects. On the other hand, old balsam is thick, and is apt to crack. Microscopists generally keep balsam in wide-mouthed bottles, and take out what is wanted by means of a glass rod. As the process of evaporation, which makes balsam thick and viscid, goes on more slowly in narrow-mouthed bottles, we prefer the latter, and transfer the balsam to the glass slide by means of a fine wire with a small loop at the end. The wire is passed through a cork, or preferably a wooden stopper, and descends to such a depth as to be just below the surface of the balsam. As the latter is used up, the wire is pushed down, and if cemented in its place by the balsam, a little heat soon frees it. The latter remark applies also to the wooden stopper, which is very apt to stick in the neck of the bottle. A very slight exposure to the flame of a spirit lamp is sufficient to loosen it.

Solution of Balsam.—When the objects that are to be preserved in balsam would be injured by the heat necessary to melt it, it is advisable to use a solution of balsam in ether or chloroform. The balsam used for making the solution should be old and thick. This solution is frequently sold with the label, "Balsam for use without heat."

Colophony.—Thiersch recommends a solution of resin or colophony in absolute alcohol. The advantage which this material presents is that the preparation may be placed in it directly from the absolute alcohol, without becoming cloudy, and without prejudice to the durability of the specimen. He advises the microscopist to prepare the colophony himself from Venice turpentine, which is done by dissolving it in an equal volume of ether, filtering it through paper, and evaporating, until, when cold, it breaks with a conchoidal fracture. The material that remains is then to be dissolved in absolute alcohol until it is of a syrupy consistence.

Damar Medium.—Gum damar has been recently introduced amongst the materials used by microscopists, and with some it has found great favor. Carpenter speaks highly of it. Diatoms are said to show better in it than in balsam, and for delicate physiological preparations, especially transparent injections, it is very excellent. It is thus prepared: Half an ounce of gum damar is dissolved in one ounce of oil of turpentine, and half an ounce of gum mastic in two ounces of chloroform. The solutions are filtered and mixed.

Ordinary damar varnish, such as is used by painters, is sometimes sold for microscopical purposes, but it does not give satisfactory results.

Preparations which have been preserved and mounted in balsam or damar are very durable, while those that are mounted in fluids are a source of continual annoyance and loss.

Many microscopists, therefore, exclude from their cabinets all preparations mounted in liquid on the ground that sooner or later they will become worthless. And many of our best dealers refuse to have anything to do with them. Nevertheless, as Frey well says, "the natural condition of the tissues is completely represented only when mounted in a moist condition. This method permits of the most accurate recognition of delicate textural relations, pale cells and fibres, etc., and should not be omitted with any tissue in the production of histological collections."

Glycerine.—At the head of the list of preservative media for moist preparations stands glycerine. "Its strong refractive power, its property of combining with water, and of attracting the same from the atmosphere, render it an invaluable medium for mounting animal tissues containing water. It may be truly said, that what Canada balsam is to dry tissues, glycerine is to moist ones."—(Frey.) Much of the glycerine in market is very impure, and although the impurities do not show themselves very strongly at first, they soon become manifest by the darkening of the liquid, (owing probably to the presence of lead), and the formation of a cloudy precipitate. Dr. Beale strongly recommends Price's glycerine, and we have found it very excellent.

When employed as a preservative, glycerine is used either pure or diluted, according to circumstances. Equal parts of glycerine and water form a very excellent medium for most objects. It is alleged, however, that fungi are very apt to grow in glycerine and its solutions. We are inclined to believe that this may be avoided by adopting the precaution detailed at the end of this section. We have now before us specimens that were mounted in pure glycerine and water, eighteen years ago, and they are still quite perfect. If, however, there should be any danger in this direction, the addition of a little camphor will prevent the evil. Glycerine exerts a powerfully solvent action on many salts, particularly salts of lime, such as the carbonate, and hence it is employed for preventing scale in the boilers of steam-engines. This property renders it dangerous to use it for the preservation of structures containing compounds of lime.

GLYCERINE JELLY.—The original directions given by Lawrance are as follows: "Take any quantity of Nelson's gelatine, (any good gelatine will answer, however,) and let it soak for two or three hours in cold water; pour off the superfluous water, and heat the soaked gelatine until melted. To each fluid ounce of the gelatine add one drachm of alcohol, and mix well; then add a fluid drachm of the white of an egg. Mix well while the gelatine is fluid but cool. Now boil until the albumen coagulates, and the gelatine is quite clear. Filter through fine flannel, and to each fluid ounce of the clarified gelatine add six fluid drachms of Price's pure glycerine, and mix well. For the six fluid drachms of glycerine a mixture of two parts of glycerine to four of camphor water may be substituted."

Glycerine jelly is a very excellent medium, and is easily used. At ordinary temperatures it is quite solid, but when slightly heated it melts, and may be used like balsam, directions for mounting in which will be found in the next section. Objects that are to be mounted in glycerine jelly should be soaked until thoroughly saturated with a mixture of 7 parts glycerine, 6 parts water, and 1 part alcohol. It is also well, after immersing them in the melted jelly, to place the slide for a short time on a water bath heated to about 125° Fah. The jelly then penetrates every part of the preparation.

When intended for use in very warm climates the proportion of the gelatine to the other ingredients should be increased.

HANTZSCH'S FLUID.—Very beautiful preparations of delicate vegetable forms have been prepared with this liquid, even the coloring matter being left unaltered. It consists of 3 parts of pure alcohol, 2 parts of distilled water and one part of glycerine. The object, placed in a cell, is covered with a drop of this liquid, and then set aside under a bell-glass. The alcohol and water soon evaporate, so that the glycerine alone is left, and another drop of the liquid is then to be added, and a second evaporation permitted; the process being repeated if necessary, until enough glycerine is left to fill the cell, which is then to be covered and closed in the usual manner. We have used this liquid with gratifying success. It is easily prepared, is not difficult to use, and it gives very excellent results.

GLYCERINE AND GUM.—Of this medium Carpenter says: "For many objects that would be injured by the small amount of heat required to melt Deane's gelatine or glycerine jelly, the glycerine and gum medium of Mr. Farrants will be found very useful. This is made by dissolving 4 parts by weight of picked gum arabic in 4 parts of cold distilled water, and adding 2 parts of glycerine. The solution must be made without the aid of heat, the mixture being occasionally stirred, but not shaken, whilst it is proceeding: after it has been completed, the liquid should be strained (if not perfectly free from impurity) through fine cambric previously well washed out by a current of clear cold water; and it should be kept in a bottle closed with a glass stopper or cap (not with cork), containing a small piece of camphor. The great advantage of this medium is that it can be used cold, and yet soon viscifies without cracking; it is well suited to preserve delicate animal as well as vegetable tissues, and in most cases it increases their transparency.

DEANE'S GELATINE.—Before the introduction of glycerine jelly, Deane's gelatine was a favorite medium, and we still use it with success. Take gelatine, 1 ounce; honey, 5 ounces; water, 5 ounces; rectified spirit, ½ ounce; creosote, 6 drops. Soak the gelatine in water until soft, and then add it to the honey, which has been previously raised to a boiling heat in another vessel. Then boil the mixture, and when it has cooled somewhat add the creosote mixed with the spirit. Lastly, filter through fine flannel. When required for use, the bottle containing the mixture must be slightly warmed, and a drop placed on the preparation upon the glass slide, which should also be warmed a little. Next, the glass cover, after having been breathed upon, is to be laid on with the usual precautions. The edges may be covered with a coating of Brunswick black. Care must be taken that the surface of the drop does not become dry before the application of the glass cover; and the inclusion of air-bubbles must be carefully avoided.

ALCOHOL.—Mixed with water in various proportions, alcohol forms one of our best preservative liquids, for both animal and vegetable substances. The chief objection to it is the difficulty with which it is retained in the cell.

THWAITE'S FLUID.—Take water, 16 ounces; alcohol, 1 ounce; creosote, sufficient to saturate the spirit; chalk, as much as may be necessary. Mix the creosote and spirit, stir in the chalk with the aid of a pestle and mortar, and let the water be added gradually. Next add an equal quantity of water saturated with camphor. Allow the mixture to stand for a few days and filter. Used for preserving desmidiæ, and also animal substances.

BEALE'S LIQUID.—Creosote, 3 drachms; wood naphtha, 6 ounces; distilled water, 64 ounces; chalk, as much as necessary. Mix the naphtha and creosote, then add as much prepared chalk as may be sufficient to form a thick, smooth paste; afterwards add, very gradually, a small quantity of the water, which must be well mixed with the other ingredients in a mortar. Add two or three small lumps of camphor, and allow the mixture to stand in a lightly covered vessel for a fortnight or three weeks with occasional stirring. The almost clear supernatant fluid may then be poured off and filtered if necessary. It should be kept in well-corked or stoppered bottles.

GOADBY'S FLUIDS.—Goadby used two distinct fluids, designated by letters A and B, the difference being that alum was a constituent of one and not of the other. Of both fluids there were several degrees of strength, which were designated by numbers. A fluid, as usually employed (A2), consisted of rock salt, 4 ounces; alum, 2 ounces; corrosive sublimate, 4 grains; boiling water, 2 quarts. To make the B fluid take rock salt, 8 ounces; corrosive sublimate, 2 grains; boiling water, 1 quart.

PACINI'S FLUID.—Take corrosive sublimate, 1 part; pure chloride of sodium (common salt), 2 parts; glycerine, 13 parts; distilled water, 113 parts. This mixture is allowed to stand for at least two months. After that time it is prepared for use by mixing one part of it with three parts of distilled water, and filtering it through filtering paper. This fluid is very strongly recommended by Frey. It is used for blood globules, nerves and ganglia, the retina, cancer cells, and especially delicate proteinous tissues.

CASTOR OIL.—This is used for preserving certain crystals. The best cold-drawn castor oil answers the purpose.

There are a few general rules which we have found essential to the successful use of these media, but which are often neglected, the result being the ultimate destruction of the specimens. One of the most important points is the use of an abundance of the medium (we are now talking of *preserving*, not *mounting*) and the *gradual* saturation of the object with it. A piece of fresh muscle, simply mounted in a shallow cell with a drop or two of Goadby's fluid, will spoil in a very short time. The same object, properly treated, may be preserved indefinitely. The proper course is to completely immerse the object in a considerable quantity of the liquid, and if necessary change the liquid several times until the substance to be preserved has been thoroughly subjected to the action of the medium. For this purpose the quantity contained in ordinary cells is altogether too little; small cups, basins, large watch-glasses, etc., are needed. It must be remembered that the substance acted upon generally absorbs certain constituents of the preserving fluid, and hence the latter is left either very weak or there is an unequal distribution of the constituents as regards the substance itself and the surrounding fluid. Moreover the fluids contained in many objects are displaced by the preserving medium, and tend to dilute the latter. In most cases, therefore, where the preserving medium is a liquid, the desired result is best attained by soaking the substance in the fluid for several days before mounting, changing the liquid two or three times, and finally mounting in fresh fluid of regular strength. We would lay great stress upon this point, having seen many fine preparations spoiled by pursuing a different course. The late Dr. Goadby, whose skill in this department was well known, always insisted upon this course, and during a somewhat extended intercourse with him, and observation of his methods and processes, we became fully convinced of its importance.

With many preservative liquids, it is well to begin with a diluted article, and gradually increase the strength at each change of fluid until the proper strength has been reached. This course is specially recommended with glycerine and saline solutions.

Another point which demands attention is the entire exclusion of air, especially of oxygen. Now air adheres with great tenacity to most surfaces, such as those of glass or metal, and it dissolves to a considerable extent in all watery solutions. To get rid of it, the surface of the cell and cover should be either well warmed, and then allowed to cool just before being filled, or washed with alcohol (after which it may be dried). To expel the air from the liquids, they should be boiled, and to prevent the absorbtion of a fresh dose of air, they should be kept well stoppered. But as air *will* find access to the liquids so as ultimately to saturate them, it is necessary to boil the fluids at frequent intervals, so as to get rid of this element. Without strict attention to these points it is almost impossible to preserve animal substances for any length of time in saline fluids.

Mounting Objects.—For the purpose of conveniently exhibiting and comparing objects, and arranging them in cabinets where they can be at all times accessible, it is necessary to *mount* them securely in such a manner that they may be easily handled. For purposes of mere examination and study, mounting is unnecessary, but when the objects are to be kept for future reference it is indispensable. It is true that where the specimens are large they might be kept in bottles in a preservative fluid, and taken out when wanted. This would be very inconvenient, however, and with very minute or delicate objects it would be almost impracticable.

There are three modes in which objects are mounted: 1. Dry, the object being simply attached to the slide and suitably protected. 2. In balsam, the object being immersed in Canada balsam, damar medium, copal varnish, or some similar material. 3. In fluid, the object being mounted in some of the preservative liquids previously described. Specimens may be mounted in any of these ways, so as to be viewed either as transparent or opaque objects, and the instruments and materials required are neither numerous nor expensive. With those named in the following list almost any *ordinary* object may be neatly put up, though it is of course to be expected that occasions will frequently arise when *special* instruments and methods, which are not described by any author, will be needed. Experience alone can enable the microscopist to treat such cases successfully.

SLIDES.—Most objects are mounted between two pieces of glass, one of which is called the *slide* and the other the *cover*. As it is convenient to have these slides all the same size, so that they may be easily arranged in cabinets, the Microscopical Society of London has adopted a slide three inches long by one inch wide as the standard size for use amongst their members, and this size has been generally adopted by microscopists throughout the world. All the best slides that are found in market are of this size, and the microscopist who fails to adopt it will be subject to great inconvenience when he desires to exchange objects with others who are pursuing similar studies. Several other sizes are employed by the French, most of them being quite small ($2\frac{5}{8}$ by $\frac{3}{4}$ and $2\frac{3}{4}$ by $\frac{5}{8}$), but as these small slides are the only ones that can be used with some French microscopes—the stages of which are too small to take a slide 3 by 1—they are usually kept in stock by dealers in microscopic apparatus. Small slides have this advantage, that they cost less, and take up less room in a cabinet. Large slides look best, and afford more room for descriptive labels, which is an important point. But since slides 3 by 1 have been adopted by common consent, the microscopist who mounts specimens, or who buys objects mounted on slides of a different size, commits a mistake for which the advantages offered by the small slides are but a slight compensation. The only exceptions to this rule are where the objects are too large to be mounted securely on a slide of standard size, or where a large number are to be prepared for the purpose of illustrating some special series of investigations. It is to be presumed that such a series will never be broken up and separated, and as it will in all probability be assigned to its own cabinet, it is sometimes of advantage to have it upon slides of a size other than that in common use. As the objects composing such a series will probably be numbered and catalogued, there is no necessity for extended descriptions on the labels, and therefore slides of half the usual size (1½ by 1) will serve very well. The cabinet may thus be reduced in bulk by one-half. We have a special cabinet, illustrative of textile fibres, mounted upon slides of small size, and find it quite convenient.

The glass from which slides are cut should be free from air-bubbles, scratches and that wavy appearance which is due either to inequalities in the surface or to irregularities in the composition of the glass itself. Ordinary window glass is entirely unfit for the purpose. The most suitable kind is plate glass, the surface of which has been ground and polished, so as to be perfectly even and smooth. Glass of this kind is used for looking-glasses and by photographers, and when other material could not be had, we have made very excellent slides out of broken looking-glasses and photographer's plates, though it is difficult to get the latter thin enough. Slides of good glass are, however, manufactured in quantity and sold at a reasonable price, so that under ordinary circumstances it will hardly pay the microscopist to cut out his own slides. Moreover the slides sold by the dealers have the edges neatly ground, an operation which the microscopist will find tedious and troublesome.

As procured from the manufacturers, the slides are always dirty, never having been washed after the process of grinding and polishing the edges. If this dirt were soft it would not matter so much, but it is in general hard and gritty—being in fact the grinding sand—and the consequence is that the surfaces of the slides are very apt to be scratched and injured. There is but one firm that exports slides to this country, and they are very careless in this respect. Out of a gross of slides it is often difficult to find two dozen that are not so scratched as to be worthless for the finest class of work. Having procured the slides, however, the first thing to do is to clean and assort them. They should be cleaned by being rinsed in water containing a little washing soda; the dirt being removed if necessary by the use of an old nail brush or tooth brush. Until this has been done they should not be wiped with cloth or leather, for by so doing the particles of sand are dragged along the surface, making a deep mark. They should then be washed in pure water, carefully wiped with a soft cloth, and assorted for thickness and quality. It is in general best to sort them into three classes—thick, medium and thin—the latter being used for test and other very delicate objects. Elaborate instruments have been devised for measuring the thickness of the slides, so as to assort them accurately, but they are entirely unnecessary; the eye is a sufficiently accurate guide. To determine their quality, they must be examined under the microscope, and as it is only the central portion that is of any consequence in this case, we place them on a brass plate, 3 by 1, with the edges slightly turned up, and having a hole five-eighths of an inch in diameter in the centre. That part which lies over the hole is the only part which it is necessary to examine. Slides which contain air-bubbles, striæ or scratches, are at once laid aside to be used either for opaque objects or those of a very coarse kind. Those that are perfect are carefully stored away where they will not be subject to injury.

Covers.—After being properly arranged on the slide with a suitable preservative medium, the objects must be covered with a small piece of thin glass. Glass intended specially for this purpose is made in England, and imported either in sheets or cut into squares and circles of suitable sizes. Directions for cutting these covers would be out of place here. The beginner will always find it most economical to buy them ready cut. Of the two kinds—round and square—the former are, for all ordinary purposes, the most convenient, as covers of this shape are best suited to cells made with the turn-table, and they may also be finished more easily and neatly than the square ones.

Covers should be carefully assorted for thickness, since the thickness of the cover exerts a material influence on the performance of all lenses except those of the lowest power or quality. Where objectives which do not adjust for thickness of cover are employed, the microscopist should find out the exact thickness to which they have been corrected by the maker, and use glass of this thickness in covering all objects that are to be examined by means of these lenses.

The inexperienced student will be apt to find some difficulty in cleaning these covers. They are so fragile that it is difficult to rub them, so as to remove dirt, without breaking them. The best method is to soak them in a weak solution of potash, rinse them off carefully several times with clean water, and after pouring the last water off, give them a final rinsing by taking them up in a pair of forceps and moving them about in a tumbler of clean water. They should then be laid (singly, of course) on a wiping block and wiped. Wiping blocks are made by covering a flat block of wood with chamois leather or linen, drawn tightly so as to present a flat but somewhat soft surface. These blocks are generally made round and with handles, but we prefer them oblong (4 by 1½ inches) and *without* handles. One of them is laid on the table face up; upon this face the thin glass is laid and wiped with the other block. In this way the thinnest glass can be cleaned without risk of fracture.

CELLS—TURN-TABLE.—All objects that are mounted dry or in fluid should be placed in cells, as unless this is done it is difficult to arrange the object properly or to secure the thin cover permanently. In the majority of cases these cells consist of little more than a ring of cement laid on the glass slide and allowed to harden, and their depth does not exceed the thickness of a sheet of paper. Such cells are in constant demand,

and are almost always made by the microscopist himself by means of a little instrument known as a *turn-table* or *whirling table*, of which there are several different forms in market. A cheap and efficient form is shown in Fig. 35. The table is supported by a spindle upon which it turns, motion being communicated by means of a milled ring. The slide is held in its place by two spring clips, and it is brought to the centre by means of a guide or bar, *c*, with a square projection. This is carefully arranged, so that a slide 3 by 1 shall be accurately centered. Hence it follows that the rings and cells on all the slides put up by the owner may be instantly and accurately

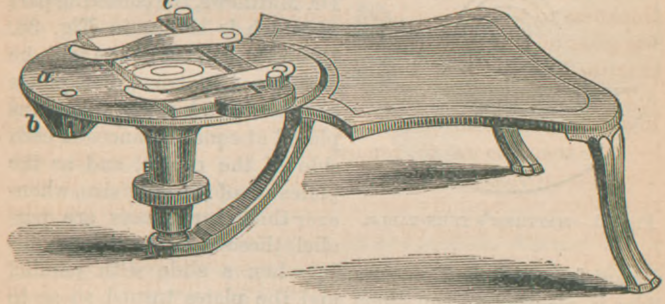


Fig. 35.—TURN-TABLE.

centered by simply placing them on the table and bringing them up to a firm bearing against the guide. This bar or guide may, however, be instantly removed when desired, and when this is done, *any* cell may be truly centered by the usual methods. This turn-table, therefore, enables us always to bring cells of our own make instantly to a perfectly accurate centre, while other cells can be centered at any time with very little trouble.

To most turn-tables there lies the objection that the devices for centering and holding the slide make one side heavier than the other, and consequently, as every mechanic knows, irregular and eccentric motion is the result. On many otherwise well-made instruments it is, from this cause, impossible to make a true cell, particularly if we attempt to work at a high speed.

In the turn-table just described, provision is made to obviate this difficulty. A heavy-headed screw, of the precise weight necessary, is screwed into the under surface of the table, and gives a perfect balance to the wheel. It then runs smoothly and truly.

Numerous attempts have been made to produce a self-centering table, *i. e.*, one in which the slides would be truly centered without requiring care and skill on the part of the operator. One of the earliest forms was that of Dr. Matthews, the centering part of which is shown in Fig. 36. Upon the surface of the table he arranges two triangular plates of brass, which rotate upon pins placed at equal distances on each side of the centre, and as the plates are of the same size, whenever their inner faces are parallel, these faces must be equidistant from the centre. Hence, when a slide with parallel sides is placed between them, and the plates turned so as to press upon the sides of the slide, the slide will be truly centered so far as its width is concerned. It is centered for length by a stationary pin, against which the end is always brought. Slides of irregular size are therefore centered only one way.

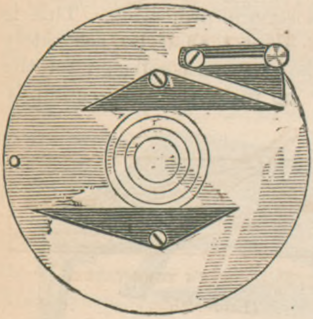


Fig. 36.—MATTHEW'S TURN-TABLE.

There are at present, however, before the public, two tables which centre slides accurately in both directions. One was invented by C. Mason Kinne, of San Francisco, who describes it as follows: "As will be seen from the engravings, Figs. 37 and 38, which are reduced one-half, the slide will be grasped automatically, upon removing the finger from the lever, the spiral spring causing the clutches to instantly clasp the slide, and retain it in a central position. One corner of either end of the slide projects sufficiently for the purpose of taking hold with one hand, while the other is pressing the lever, and can be fixed or removed without pushing along a circular disc to its edge. The slots are made to allow movement enough, so that the clutches can grasp any piece of glass from 1½ to 3½ inches in diagonal length, and the table is made of brass about a quarter of an inch thick, which gives weight sufficient to secure stability of movement. The whole rests on a small spindle 4 or 5 inches long, screwed into the centre of the brass stud, which is the fulcrum of the lever, and can be removed at pleasure to pack away. The pointed lower end of the spindle is stepped into a counter-sunk metal rest, and with a collar placed at a suitable distance above to allow of free movement of the hand, I find that a steady motion can be obtained with the thumb and finger, of any required velocity, and is under greater control than with any milled-head device."

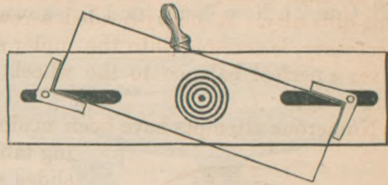


Fig. 37.—KINNE'S TURN-TABLE. (Upper side.)

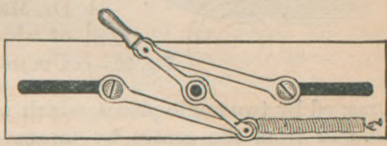


Fig. 38.—KINNE'S TURN-TABLE. (Under side.)

Mr. Kinne suggests a very simple method of constructing a home-made table on this plan: "The spindle can be fitted into any appliance, primitive or expensive, at the option of the worker, and I find that an old cigar box, with a portion of one end removed, is just as useful as anything else, though if made for sale, a cheap varnished box could be furnished, and in which the table and spindle could be packed when desired. If fitted up with the cast iron stand, the whole might present a neater appearance, but the additional expense would not add to its utility."

Slides which have been imperfectly centered on other tables, are recentered for varnishing by the use of two rectangular triangles and a little wedge. The inventor uses the corners of a broken slide and a piece of match.

The other self-centering turn-table was invented by Mr. C. F. Cox, of New York, and is shown in Fig. 39. The slide is

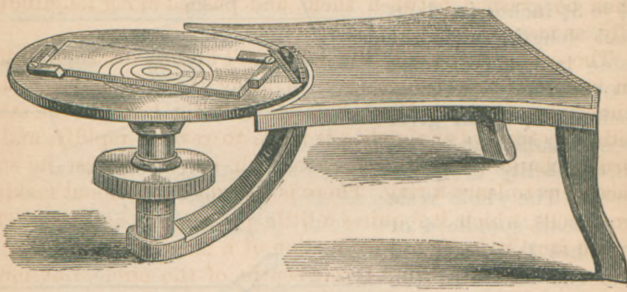


Fig. 39.—COX TURN-TABLE.

grasped by two angle-pieces, which are simultaneously moved to and from the centre by means of a right and left hand screw. When it is desired to re-varnish slides which have not been accurately centered in the first place, a pair of spring clips, attached to a stout bar, are fastened on. This can be effected in an instant. The arrangement is shown in Fig. 40.

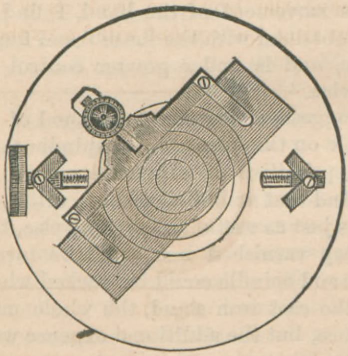


Fig. 40.—COX TURN-TABLE.

There is also a very ingenious device for placing a row of small cells along the middle of a slide. This consists of two equal right-angled triangles, the square corners of which fit into the clutches, thus allowing the long sides to lie parallel to each other, and at equal distances from the centre. A slide may thus be grasped between them, and pushed along longitudinally, as may be desired.

Those who once see a turn-table, will find no difficulty either in understanding the method of using it, or in putting this knowledge into practice. The slide, being held on the table either by springs or clutches, is made to revolve rapidly, and a brush, charged with cement or varnish, is held against its surface so as to leave a ring. There is a slight knack about making good cells, which it requires a little practice to acquire. The brush must be held in the direction of a tangent to the ring—that is, it must not point to the centre of the circle, but must lie so that the ring, as it revolves, will *draw* the cement away from the brush. Practice alone can give expertness in doing this, and we would advise the beginner to work steadily for a few hours at making cells on pieces of common window glass, strips of which can be had for nothing from any glazier. The chief points to be attended to are the position of the brush and the consistence of the cement. If the latter be too fluid, it spreads and does not form a well-defined circle. If too thick it does not leave the brush as freely as is necessary. The method of preparing the cement will be explained under the proper head.

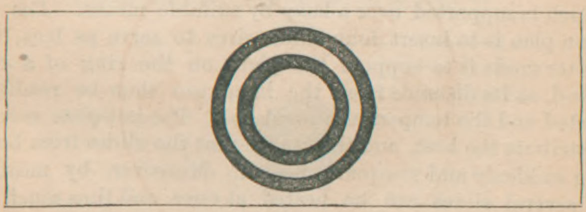


Fig. 41.

Where a turn-table is not at hand, very good cells may be made as follows: On a card draw the outlines of a slide with a series of circles in the centre, as shown in Fig. 41; lay the slide on the card so that the centre of the circles will be at the centre of the slide, and then paint a circle of cement on the slide by hand, the rings beneath serving as a guide. Very good cells may be thus made, but the process is of course more tedious than that with the turn-table, and does not give as neat results.

A few precautions are necessary in order to insure the permanent adhesion of the cells to the glass. In addition to providing cement of good quality, we must see that the slide is dry and *recently heated.* It is difficult, with most cements, to use *hot* slides, as the cement is apt to flow; but the slide should have been recently heated, and after the cement has partially hardened, the cells should be baked by exposure to a temperature as high as they will stand. This is easily done by placing them on a board or plate, and leaving the latter for a short time in an oven.

Where cells of greater depth are required, rings of various materials are cemented to the slide. For objects mounted dry, rings of leather or cardboard answer well, provided they are carefully varnished so as to be impervious to air and moisture. For liquids, rings of glass, tin, ebonite, etc., are used. Rings of rubber and gutta-percha have been suggested, but they do not answer, as they soon become rotten. Full directions for making and using deep cells may be found in the works of Quekett, Carpenter, Beale, Frey, etc.

HOT-PLATE.—This is simply a stout plate of brass or iron, which is supported over a lamp by suitable means. The common plan is to insert four stout wires to serve as legs, but a better mode is to support the plate on the ring of a retort stand, as its distance from the lamp can thus be readily adjusted and the temperature regulated. The hot-plate serves to distribute the heat, and thus to prevent the slides from becoming suddenly and unequally heated. Moreover, by means of it several slides can be heated at once, and thus much time may be saved. It should be tolerably heavy. The one we use is of cast iron, six inches long and three inches wide. The upper surface has been ground so as to be tolerably smooth, When a hot-plate is not at hand, a good substitute may be found in a smooth brick, or, better still, a plate of soapstone. These may be heated in the fire and will retain their heat for a long time.

LAMP.—Any lamp, or even candle, will answer, but we prefer a spirit lamp, the flame being free from smoke and easily managed. At night the kerosene lamp used for giving light will answer. Where gas is used, the Bunsen burner is a great convenience. Whatever lamp or burner be used, it should be surrounded with a chimney or shade, so as to prevent the flickering of the flame by currents of air. The best shade is a tin cylinder, with rows of holes at top and bottom for the admission and exit of air.

RETORT STAND.—A suitable retort stand is a very simple affair, and is best made at home. Ours consists of a board of hard wood, 5 inches by 4, into which is screwed a rod fourteen inches long, and a quarter of an inch in diameter. The rings have no screws, but are simply pieces of wire, one end of which is twisted round the rod, while the other is formed into a ring of the required size. Rings formed in this way are easily moved on the upright rod, but no weight placed on them in the usual manner can cause them to slip down.

CARDS FOR CENTERING THE OBJECTS.—Unless the objects are placed on the centres of the slides, the latter have a very awkward look. By drawing the outlines of a slide on a card, and marking out the centre, this difficulty is easily overcome. A card marked off in this way is shown in Fig. 42.

Fig. 42.

It is well to have two cards, one black with a white centre, and the other white with a black centre, as some objects, when immersed in the medium in which they are to be mounted, show best against a dark ground, while others are most easily seen against a light one. Those who use the self-centering turn-tables may readily centre their slides by painting on them a ring of some water-color, which is easily washed off. The ring is, of course, laid on the side opposite to that which receives the object.

Mounting Needles.—These are similar to dissecting needles, but being used in balsam, varnish and similar substances, they cannot be used for dissection, and should be kept by themselves. They are most easily cleaned by being warmed over the lamp, and wiped with a piece of soft leather. When the balsam is burned on them, as recommended by some, it leaves a crust which is not easily removed.

Cover Forceps.—In placing the cover on the object, the ordinary forceps are very inconvenient. We have long used a pair of forceps bent as in Fig. 43, and with the points carefully adjusted. The mode of using the instrument will be obvious from the engraving. A very ingenious device intended to answer the same purpose has been invented by Dr. Fletcher. These forceps are self-closing, so that the thin glass cover is held without any effort. After the cover is in position on the slide, by pressing on the blades they open and allow it to slip out.

Fig. 43.

If the cover should stick to the forceps in the slightest degree, it may be prevented from moving when the forceps are removed by inserting a common pin in the slit seen in Fig. 44. When using the forceps shown in Fig. 43, the same end may be attained by means of a wire fork (a hair-pin is as good as anything), which may be made to straddle the nose of the instrument.

Fig. 44.

SLIDE HOLDER.—The hot slides cannot be comfortably held in the fingers, and therefore a pair of wooden forceps become a necessity. Those usually sold are made by screwing together two thin slips of wood with a piece of brass or lead inserted between them at one end. To admit the slide, the slips are forced apart by pressing on pins arranged as in the stage forceps. When placed on a table the metal counter-balances the slide, and keeps it from touching the surface on which it is laid—a very important point. The English forceps, being all wood, frequently tip with a heavy slide.

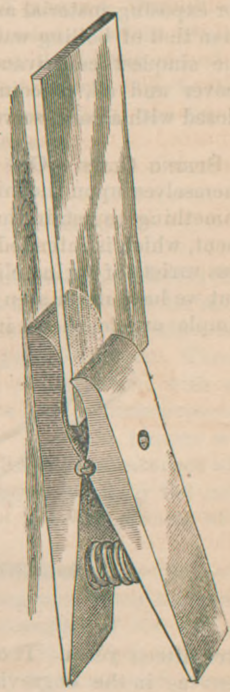


Fig. 45.—HOLDER FOR HOT SLIDES.

A common spring clothes-pin is frequently used, but when we come to lay the slide down, the clothes-pin holds it in an awkward manner. The end of the hot slide is sure to lie on the table, and if fluid balsam or other medium should be present, the fact that the slide is not level produces bad results. By cutting off about half an inch from one of the limbs of the forceps part of the pin, however, this difficulty is avoided. The slide may then be grasped in such a way that when the clothes-pin is placed on the table, the glass will be held in a perfectly level position. A glance at Fig. 45 will show what we mean. A great advantage of this form of holder is that it costs but a trifle, so that the microscopist can supply himself with an abundance of them, and thus several slides may be cooling, while work on others is going on. When very heavy slides are used, it may become necessary to screw a plate of sheet lead to the under side of the clothes-pin, so as to prevent tipping.

WATER BATH.—A water bath is indispensable in those cases where a certain very moderate degree of heat is not to be exceeded. Few persons fully appreciate the difficulty of regulating or even estimating the temperature of an object held over a naked flame, and mischief is often done before the operator is aware of it. A serviceable water bath is easily extemporized out of an old fruit can and a small beaker glass. This serves for exposing material and preparations to a temperature lower than that of boiling water. Where slides are to be so heated, the simplest contrivance is a flat tin box, with all the joints (cover and all, of course,) tightly soldered. A small tube, closed with a cork, serves to admit the water.

SPRING CLIPS.—One of the first of the needs which impress themselves upon the mind of the beginner, is the necessity for something to retain the thin cover in its place, until the cement, which is intended to hold it permanently, dries. An endless variety of spring clips have been invented for this purpose, but we have never seen anything that we liked better than the simple article shown in Fig. 46, and which we have used for

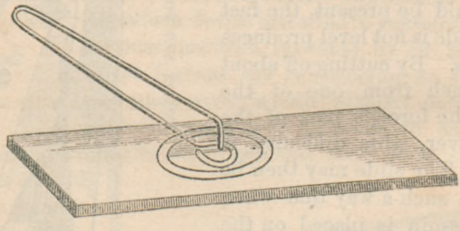


Fig. 46.

over fifteen years. It consists simply of a piece of brass wire bent as in the engraving. The slide being held in the left hand, the clip, held by the upper wire, is brought so that the projecting part of the ring is placed under the edge of the slide. The upper part is then lifted up so as to open the clip, which is then slid on to the slide until the vertical point is in the right position. When a broader surface than the point of the wire is needed, a piece of cork may be stuck on it, and if there should be need for greater pressure than that which the spring of the wire affords, this can be obtained by sliding a small brass ring on to the clip.

Various other forms of spring clip have been invented, but none that we consider more simple, or that we like better than the above, which has this great merit, that any one can make it for himself out of materials that may be obtained at any hardware store. It must be borne in mind, however, that all clips constructed upon this plan are apt to cause a slight displacement of the object, from the fact that the movement of the point is not quite perpendicular. With delicate objects this is a matter of importance. The only remedy is to use the end pressure of a rod moving in fixed guides.

CEMENTS AND VARNISHES.

A supply of carefully selected cements and varnishes is indispensable to the microscopist, and it is also well that he should understand the nature and properties of the materials used, otherwise he will be liable to make gross blunders. Thus, of the different articles in use, some are easily mixed with each other, while others separate as soon as left to themselves; some dry in one way and some in another. It would require a volume to detail the properties of the different substances which enter into the composition of the cements used by the microscopist. We have space for only the following hints, which, however, we hope will prove useful.

Cements become hard in three different ways—cooling, evaporation and oxidation. Shellac, sealing wax, electrical cement, etc., when melted by heat, furnish examples of the first process. Shellac and sealing-wax dissolved in alcohol, and asphalt and damar dissolved in turpentine, dry by the second process—the solvents evaporating and leaving behind the material which they had dissolved. Drying oil in all its forms, such as gold size, paint, etc., becomes hard by oxidation—not, as is generally supposed, by evaporation.

In the case of varnishes which dry by the evaporation of some of their constituents, it is obvious that if a fresh layer be laid over an old one, the old layer will be softened, and if there should be any tendency to a vacuum in the cell, the softened cement will be unable to resist the outside pressure, and will creep in and spoil the object. So, too, with varnishes or cements formed chiefly of drying oil or gold size. If the different coats be laid on too thickly or too rapidly, the part that is beneath cannot easily harden, but will remain for a very long time in a semi-liquid condition. We have just removed some brass rings from slides to which they were attached four months ago by means of gold size, and although the outer surface of the cement was hard and dry, the interior was quite liquid, freely soiling the fingers.

Gold Size.—The most extraordinary recipes have been given for the preparation of this cement, which is in reality nothing but good linseed oil rendered very drying by the usual methods. Gilders frequently make it into a semi-paint by adding coloring matter, thus forming a ground of a shade similar to the gold they use, and this seems to have misled some of our best writers. There is no ochre, litharge, or anything of the kind present in good gold size. It does not pay to prepare gold size in small quantities, and it may be obtained from any color dealer. The older it is the better, and it is well, therefore, to lay in a good stock, which must be kept carefully corked. The working supply should be kept in a small bottle. This is the favorite cell making material employed by Dr. Carpenter, and it is certainly the most reliable cement we have. It adheres firmly to glass, and if laid on in very thin successive layers, tolerably deep and very durable cells may be built up, but the process requires considerable time, otherwise the under layers will remain soft. It has this great advantage over asphalt, damar, and other cements composed of solid materials dissolved in some menstruum, that fresh coats have but very slight action on the old layers on which they may be laid. It mixes with turpentine, and consequently with most materials soluble in turpentine, but when once dry and hard, turpentine, alcohol, ether, etc., have little or no action on it. It does not mix with alcohol, and therefore cannot be mixed with the solution of shellac in alcohol in any of its forms.

Black Japan.—When this can be procured of good quality, it makes a very excellent cell. It adheres very firmly to the glass provided the latter be exposed to a moderate heat after the cement has become dry. Black Japan dries up and thickens when kept, but may be thinned with turpentine.

Brunswick Black.—This is simply a solution of asphaltum in turpentine. Occasionally it is rendered very black by the addition of a little lampblack. When good, it makes a very excellent cement. Its quality depends chiefly upon the character of the asphaltum that is used in its preparation. Now there are several varieties of asphaltum in market, the most common kind at the present day being that obtained from coal tar. This seems to be entirely unfit for the purpose. The proper kind is that which is found native in several parts of the world. The two kinds are easily distinguished by their odors.

Shellac.—This well known substance, when dissolved in alcohol, forms a varnish or cement of great value to the microscopist, and is the proper one to be used when glycerine is employed. Much of the shellac in market is artificially made from resin and wax, and makes a poor varnish. Real shellac must be employed if failure would be avoided.

Bell's Cement.—Carpenter states that this cement is merely shellac dissolved in alcohol. With us it has presented no advantage over other cements.

Sealing Wax Varnish.—This is prepared by dissolving the best sealing wax in alcohol. It unfortunately happens that all the fancy colored sealing wax in market is of inferior quality. Very excellent red wax may be obtained, but we have never been able to obtain good blue, black, green or other colored wax. We therefore make varnish of these colors by dissolving in alcohol the materials used for making the best red wax, substituting some other color, however, for the vermillion.

Colored Shellac.—Bleached shellac, dissolved in alcohol, and colored with aniline blue, red, etc., makes a very fine transparent varnish.

Damar Cement.—This is a mixture of equal parts of damar varnish and gold size, mixed together. It should stand for some time before being used. It is said to be very excellent. It is very tough, and serves well as an outer coating over such brittle cements as shellac and sealing wax varnish.

Marine Glue.—This is undoubtedly the strongest cement in use for joining pieces of glass or glass and metal together. Skilful microscopists make great use of it; beginners do not find it so easy to manage as some others. In using it, the simplest method is to cut it in small pieces, lay it on one of the surfaces that are to be joined, melt it by heat, and apply the other surface, making sure of perfect contact by rubbing the two pieces upon each other, if they will allow of it. Marine glue may be obtained from most dealers in microscopes.

The cement known as *liquid glue*, is simply a solution of shellac in alcohol.

For attaching labels, paper covers, etc., to the slides, nothing is better than good dextrine. After having mixed the dextrine with water to the proper consistence, add six drops of glycerine to the fluid ounce of dextrine. This will prevent the labels or covers from cracking off.

Having provided himself with the necessary tools and materials, the next step is to learn how to use and apply them, and this will probably be most easily taught by describing a few characteristic examples. And first of all, selecting the most easily mounted of all objects, we commence with the scales on the butterfly's wings. Having prepared a cell of proper size, and allowed it to dry, the first step is to select a cover to suit it, and give a final cleaning to both slide and cover. When every particle of dust has been removed, breathe gently on the slide, and press the wing lightly against it, and within the cell. A large number of scales will at once adhere to the slide, and the next step is to attach the cover. Place the slide on the hot-plate, (which must not be too hot, however,) and when it is thoroughly dry, and the cement somewhat soft, lay the cover on by means of the cover forceps. Press it into contact with the cement, and the operation is completed. It is not difficult to see when the cover and the cement are in perfect contact, and great care must be taken to close the cell all round in this way. It is true, this point is not of so much consequence with the particular object under consideration, but with some objects it would be quite important. The scales are now mounted dry, and may be kept for any length of time; no dust can soil them, and they are not liable to be injured by contact with other bodies. It only remains to label and "finish" the slide as hereafter directed.

Next to the above in simplicity is the mounting of such objects as the wings of insects in balsam. Suppose we wish to mount one of the smaller wings of a bee or wasp, so as to show the curious hooks with which it is armed: Place the warm slide on the centering card, drop a little balsam on the centre, and again warm the slide, so that any air that may be present may collect in fine bubbles which can be removed by means of a cold mounting needle. When the air-bubbles have been removed, seize the wing (previously well cleaned with a camel hair brush) with a pair of fine forceps, and lower the tip of it into the warm balsam. Then slowly lower the wing until it is entirely immersed. Drop, very little more balsam on it, warm the slide again (slightly this time), and remove air bubbles if there should be any. Then take a clean cover in the cover forceps, make it quite warm, and place it over the object by allowing it to first touch one edge of the balsam, and then to gradually fall down so as to exclude all air bubbles. In the case of the bee's wing it does not answer to apply much pressure as this would tend to distort the hooks. Press the cover into place as much as it will bear and no more, lay the slide in a warm place for some time until the balsam hardens, and then clean and finish the slide.

In mounting objects in balsam and fluids, the great difficulty to be encountered is the presence of air bubbles. Careful and judicious management, however, readily enables us to avoid them. In the first place see that they are entirely removed from the balsam on the slide. This is much more easily done before immersing the object in the balsam then afterwards. Next see that the air is expelled from the object. In the case of the wing, this is effected by *slowly* immersing the object in the balsam. Lastly see that no air enters with the cover. To do this see that the cover is hot, and that it is lowered on the balsam slowly, and from one side. If in any case there should be a vacant space under the cover as at *a* Fig. 47, and it should be desired to fill it, do not apply the fresh balsam directly at *a*. To do so would certainly be to inclose a large air bubble. Drop the balsam at *b*, warm the slide, and the balsam will creep in by capillary attraction, and expel the air.

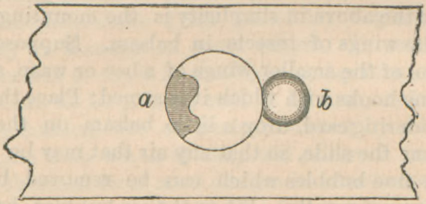


Fig. 47.

Let us now suppose that we have some small insect which we have prepared by soaking in potash, and which we desire to mount in balsam. Such a preparation if immersed directly in balsam, would be spoilt, since the balsam and watery solution would not mix. Therefore, proceed as follows: Wash the insect in pure water, and drain off the water; wash with strong alcohol, drain off the alcohol, and soak for twenty-four hours in the strongest alcohol you can get. Pour off the alcohol and soak for twenty-four hours in turpentine. The object may now be immersed in balsam without difficulty.

Air pumps and similar contrivances are generally recommended as the best means for removing air bubbles, but we never use them. If the object be dry, we soak it in alcohol until all the air has been expelled, then transfer to turpentine, and finally to balsam. This requires time, it is true but it does not occupy the time of the microscopist. The soaking process goes on without any attention from him, and while it involves far less labor, with us it has always given far better results, though we have used very fine air pumps, and followed the best published directions. Take the case of a dry shaving of wood, many of which are well worth mounting. It would be very laborious to get the air out of this by means of the air pump, while by soaking successively in alcohol and turpentine, it can be mounted with great ease.

Let us now take the case of an object mounted in fluid in a cell. Suppose it is the so-called tongue of a fly, which of course has been soaked for some time in the liquid in which it is to be finally mounted, viz., dilute glycerine. We make a cell of suitable thickness, which in this case may be made with shellac dissolved in alcohol. Several coats will be required, and as shellac alone does not adhere well to glass, we prefer to lay on first a coat of gold size or Japan, and when this is thoroughly dry, to lay the shellac on it. No difficulty will be found in making a cell of sufficient depth. The cell is now to be filled with the liquid, the object placed in it, and the whole carefully examined for air bubbles, which must be removed if they exist. The cover is now applied, all superfluous fluid removed by means of a camel hair pencil, which has been moistened and then squeezed dry, and finally the edge of the cover is to be coated with a thin layer of cement. After a day or so another layer of cement should be laid on, and this process repeated until at least three layers have been applied.

We give no directions for the construction and use of very deep cells as this is work that will hardly be attempted by beginners.

When opaque objects are to be mounted either in balsam, or in fluid, the process required is the same as that employed for transparent objects. Very many opaque objects are, however, mounted dry, and in this case all that is needed is to attach them to a slide, and see that they are properly protected. When thin they may be readily mounted in cement cells, and this is altogether the neatest and most secure plan where it can be used. Thicker objects require deeper cells, which may be made of card, ebonite or electrical cement. (3 parts resin, and 1 of wax, colored with ochre or any similar matter). Cells of card are made by first punching out a disc like a gun wad, and then punching a hole in this so as to leave a ring. The ring is to be cemented to the glass slide and carefully varnished.

Wooden slides with a cell bored in the centre, are recommended very highly, and seem to answer a very good purpose. The cells are not bored quite through the wooden slip, and as they are blackened on the inside, any small object that may be cemented to the bottom of them shows very well. For seeds, small shells, and similar objects, they answer admirably. In most cases it will be found unnecessary to cover the cells with thin glass. Several slides may be packed together face to face, and if held in firm contact by means of a rubber ring, dust will be entirely excluded. Or they may be arranged in the drawers of an ordinary cabinet, face down, the labels being placed on the backs. This will effectually exclude the dust.

Some years ago we mounted a large number of specimens of minerals on leather discs, which were cemented to glass slides. These leather discs were three-quarters of an inch in diameter, and we had a lot of pill-box covers which exactly fitted them. These covers, when slipped on to the discs, protected the objects perfectly, and the whole formed a very cheap, convenient and excellent mode of mounting.

A very ingenious cell for opaque objects, the invention of Prof Pierce, of Providence, R. I., is shown in Fig. 48. It consists of a metallic cell, having a broad flange like the rim of a hat, which is cemented to an ordinary glass slide, as shown in section in the lower figure. To this cell is fitted a metal cap, which covers and protects the object. The object may be placed directly on the glass, or raised by means of a disc of any required thickness, so as to be more easily illuminated. The slide, with cell uncovered and containing an object, is shown in the upper figure. Uncovered objects may in this way be very perfectly protected from dust and mechanical violence.

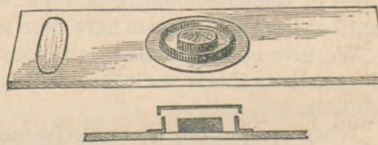


Fig. 48.

Where it is desirable to cover objects with thin glass, the method devised by Prof. H. L. Smith will be found very excellent. He takes a circular disc of thin sheet wax, which is easily cut with a punch from the sheet wax ordinarily used for making flowers, and attaches it by means of heat to the centre of a glass slide. A brass ring, of which the interior is the same size as the disc, is then attached to the slide, and the object is fixed to the wax by slightly moistening the surface of the latter by a minute drop of turpentine. When dry, a cover, which exactly fits into the bevel of the ring, is attached with a little cement, and the whole may then be finished off on the turn-table. The appearance is very elegant, and the specimens are perfectly preserved.

A cell which we have found very durable, easily and quickly made, and very neat, is constructed as follows: Having procured some good gold size and pure litharge, grind the latter to a very fine powder. Mix the litharge and gold size to the thickness of cream, and color either black or dark olive by adding lamp-black. With this paint, as it may be called, make as many cells as are wanted, and when made, dust finely powdered litharge over them until they are covered a sixteenth of an inch deep; allow them to stand a few minutes, and then shake off all the loose litharge by means of a few smart taps. The surface of the cell will now be quite rough. Allow it to stand a few hours, and then press it against a plate of glass. If this be done carefully, a smooth, solid ring will be left on the slide. If the edges should not be as smooth as they ought to be, it is easy to trim them off on the turn-table by means of a small chisel. Such cells, after a few weeks, become very hard, and may be finished so as to be very neat. By introducing a few obvious and unimportant modifications, we have, in this way, made cells of some depth which held liquids quite well.

Finishing the Slides.—After the objects have been mounted, the slides may be finished in one of two ways: they may be covered with paper, or they may be left without any covering, the labels being attached directly to the slide. In the latter case the edges of the slide must have been previously ground and polished, and, as a general rule the thin cover is circular and not square, and is finished with a neat coat of varnish on the edge. This varnish serves to do something more than merely ornament the slide; it secures the cover in its place, and prevents the drying up of the medium used for mounting. Even in the case of Canada balsam it is of use, for if gold size be used as the varnish, it prevents the evaporation of the turpentine, and the ultimate drying and cracking of the balsam. Where glycerine jelly, glycerine, or glycerine and gum are used, it becomes indispensable.

The process employed for finishing slides in this way is as follows: The objects having been mounted, the slides are laid away until the balsam, cement, etc., have been hardened, when all superfluous matters of this kind are easily removed with a small chisel made out of a brad-awl ground thin and sharp. A small chisel-pointed piece of hard wood, and a little water, will remove the last traces of balsam or varnish, and if necessary a final cleaning may be given with a rag moistened with alcohol. The slide is then placed on the turntable, and a neat ring of varnish, either plain or colored, is run around the edge.

The proper labeling of the slides is an important matter. Our system is as follows: As soon as the object is mounted, the slide is labeled on the *under side* with a very thin gummed label, and it is also numbered on the upper side with a writing diamond. Of this number a record is kept, so that even if the label should fall off or get soaked off, a new label may be provided. As soon as the slide is finished, the regular label is attached, and the small label removed. As regards designs, etc., for labels, the variety is endless. Each microscopist will probably select the one that accords most nearly with his own taste.

The Maltwood Finder.—This is a most important accessory to every microscope, as it not only facilitates interchange of notes between microscopists living at a distance from each other, but it enables observers to make sure of the identity of the objects under examination at different times. It consists of a glass slip, a little wider than an ordinary slide,

Fig. 49.

upon which is a photograph occupying a space 1 by 1 inch. This space is divided into 2,500 squares (50 divisions on each side) and each of these small squares is designated by two numbers, one of which indicates its position from bottom to top, while the other marks its position from right to left. Thus the square which lies on the tenth line from the bottom, and the fifteenth from the right hand side, would be $\frac{10}{15}$. Placing on the stage an object mounted on an ordinary slide, with its lower edge against a ledge of some kind, and its left hand edge against a stop (the stop and ledge being movable as regards the stage), we bring some particular spot into view. Removing the slide, we now place the finder in its place, and read off the double number. It is now evident that if at any future time we should place the finder against the ledge and stop, and bring the same number into view, then on removing the finder and placing the slide on the stage, the precise spot originally under examination will be in view. We can therefore easily register anything of interest, and so be certain of finding it at any future time.

The finder cannot be used with microscopes fitted with clips only. An object-carrier, provided with a ledge and stop, must be used. Such object-carrier may either be the usual form of the glass stage, or, with the plain stage, a thin plate of brass with a hole in the centre, a stop at one end, and a ledge at one edge, may be made to answer.

Hitherto the Maltwood finders have been made only by one firm in London. They are now made in this country, however, very successfully. A dozen which we recently examined did not vary as much amongst themselves as those obtained from London.

FINIS.

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