A HANDBOOK OF BIOLOGICAL ILLUSTRATION

by

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Director of Thesis Date
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SIGNED:

Frances A. Himsett
Plate 1. Collared lizard, Crotaphytus collaris. Stippled colored ink employing retinal mixture phenomenon.
PREFACE

The advanced biology student who is unacquainted with art may suddenly find himself faced with the problem of illustrating his own paper or thesis. He may not wish to employ an illustrator to do the work in order to keep down the cost of the project or because another person will not understand the problem at hand well enough to depict the important points. The artist who is asked to illustrate a biological paper will know how to draw and use color, but he may not be familiar with the instruments, special drawing techniques and conventions associated with scientific illustration.

This work is intended for the use of the two above-mentioned types of readers as well as for those who have done some biological illustrating and who would like to know of techniques other than those they have been using.

This handbook does by no means include every material and technique used in biological illustration, but only those which are considered primary or essential. Photography is not covered at all except where photographs are retouched or are used as the bases for drawings.

Most sincere appreciation is expressed towards those many persons who have patiently contributed so much help and constructive criticism; to Mr. Robert M. Quinn and Dr. William H. Brown; to Dr. Charles H. Love, Jr. and Mr. Donald B. Sayner; to Mr. L. Chester Bryant, Mr. Andreas S. Anderson, Mr. Mark Voris, and Dr. John F. Lance, for their criticism, help and interest. Thanks are due also to Bausch and Lomb.
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INTRODUCTION

The idea behind a biological illustration is to communicate what is seen, and the extent to which this is accomplished determines the usefulness of the illustration.

The primary requisite for any artist, and especially for the science artist, is a well-developed power of observation. Fully as much time should be spent in observing the subject, that is, getting the "feel" of its planes and curves, its pattern of lights and darks, and its texture and character, as is spent in attempting to make a drawing of it.

"Drawing is a method in which success is a matter of following the rules." Learning to draw can be compared with learning to play the piano. Certain rules must be observed and when these are mastered, then the artist can go beyond; but breaking the rules before they are learned will not lead to good illustrating or artistry. A would-be pianist who attempts to depart from the fundamental rules before he has learned basic harmony will not succeed in becoming an artist nor even a good piano-player. Just so, the illustrator who wishes to draw without learning or observing the rules of drawing will experience undue difficulty in trying to achieve a satisfactory illustration and will lose much time in making corrections.

Original art has some definite advantages over photography.

A photograph can be the most accurate illustration but sometimes the correct focus and/or lighting may be difficult to achieve and as a result the photograph may impart a false impression. When proper contrasts are lacking, a structure such as a blood vessel or a nerve may be obscured and difficult to trace, whereas a drawing may include only what is desired in the way of important details and "landmarks" and thus direct emphasis and avoid confusion. Another deciding factor in the favor of original art work may be that photographs are more expensive to reproduce than line-cut illustrations.

Some books on drawing especially recommended to the biological illustrator are mentioned below:

Nicolaides, Kimon, The Natural Way to Draw, Boston, Houghton Mifflin Co., 1941. This book offers the fundamentals of drawing for any art student, biological or otherwise.


Clarke, Carl Dams, Illustrations: Its Technique and Application to the Sciences, Baltimore, The John D. Lucas Co., 1940. This book is more advanced than the two mentioned above and is mainly concerned with medical illustration, but most parts of it are extremely useful to the biological artist.
I

REQUIREMENTS OF ILLUSTRATIONS

Because the illustrations of a text, by their very nature, first capture the reader's attention, it is necessary that they be well-executed; otherwise, the reader may lose interest and abandon the textual material. Illustrations must be neat, informative, and artistic in order to arouse a greater desire to read the article than if illustrations are poor or are completely lacking.

The primary purpose of a biological illustration is to clarify or demonstrate what is contained in the written work. A poorly executed drawing or a badly arranged, confusing graph may prove to be a handicap.

Accuracy is, of course, the most important consideration of the biological illustrator. An inaccurate drawing is worse than useless because it perpetuates misinformation. Mueller says that "...one of the greatest difficulties in drawing lies in the tendency to represent what is known or believed about the object, instead of what is actually observed." The illustrator often has an inclination to exaggerate a point under discussion, but this may lead to a false impression and should be avoided. By use of special techniques (cropping of photographs, special lighting, use of color), prominence

may be given to certain features and thus capture attention without distortion. In drawing comparisons between two or more subjects, it is suggested that the illustrator emphasize differences not through exaggeration, but through accentuation by darkening lines in critical areas, by using shading and highlights, and by employing similar devices.

An omission or any other kind of inadequate depiction may constitute as great an error as an exaggeration. All the points being discussed should be adequately shown or at least properly indicated; otherwise the reader will not be able to formulate valid opinions.

Ranking in importance with accuracy in biological illustrations is artistry. A drawing may be correct in every detail and yet be completely inartistic, lifeless, and uninspiring. Good arrangement, composition of lights and darks and lively drawing are essential to render a picture aesthetically satisfying and capable of holding the reader's attention. A "dead" picture is more likely to be forgotten than an artistic one, except as a generally unpleasant impression. It is not too difficult to attain at least a minimum of artistry in an accurate biological illustration, and the lack of it is deplorable. Methods by which an illustrator may achieve artistry, all of which are within the range of the person with average skill, together with the different illustrating techniques, will be discussed in a later chapter.

Certain conventions in scientific illustrations should be observed for ready understanding on the part of the reader. Among
these are certain signs and symbols used on maps (see plate 8) and
certain ways of showing light and shadow on an object. While this
latter convention may seem unimportant, it serves a definite pur-
pose. In general, an object is shaded as if the light source (or
main light source) were placed out of the upper left corner of the
picture. The reasons for such lighting are that (1) this is the
usual position of the actual light source when one is comparing a
specimen with an illustration and (2) there should appear to be a
common light source for several different illustrations which may be
grouped on one plate. This shading is represented either by a darker
line on the shadowed side of an outline drawing or by heavier shadows
in a fully-shaded drawing or photograph. Occasionally, special light-
ing is required in order to show some particular detail, in which case
the shading convention is recognized for what it is—a convention, not
a law.

The latitude allowable in scientific illustration may permit
the artist to deviate somewhat from absolute precision except in sig-
nificant details. For example, if a certain point is to be demonstrated
on a coyote skull, its general structure may be suggested as compiled
from several actual skulls or from other illustrations of skulls, but
the detail under discussion must be rendered with absolute accuracy.
Also, the purpose that the illustration is to serve dictates the
latitude permitted. A picture used as an embellishment or to show an
animal in general may be drawn much more freely than an actual illus-
ration depicting a certain type of cell found in a particular specimen.
Common sense will determine how much freedom may be exercised.
There are three general types of scientific illustrations. The first of these is a drawing. It may range from a simple outline to a completely finished, detailed rendering. It may be done in line, wash, or color. The two principal divisions under this type of illustration are renderings of macroscopic objects and renderings of microscopic objects.

A second general type of biological illustrations is the photograph and may be in black and white or in color. It may be necessary to retouch a photograph before it is usable in order to bring out obscure details or minimize features which are too prominent.

The third type of illustration used in scientific articles comprises maps, graphs, and tables.
II

BASIC SUPPLIES AND SPECIAL EQUIPMENT

DRAWING MATERIALS

There is a great variety of materials which can be used to make illustrations. They can be done in ink, pencil, wash, crayon, watercolor, oil paint, pastels; on paper, cardboard, plastic, chalkboard, wood, glass, canvas, to name a few. However, some of these materials are not practical for most biological illustrations, and therefore, the artist should choose a list of basic supplies to fill his needs.

Pencils

Lead. Both hard and soft lead pencils are used in illustrating. A medium hardness (HB) pencil is useful for sketching in the field and for putting on paper the first idea of the future picture. Preliminary drawing is usually done with a soft pencil (Hb-2B) which can be erased easily and smudged with the finger or a smudger. (Smudgers may be purchased from art supply stores or they may be made by tightly rolling a strip of paper so that one end of the roll is pointed.) Hard pencils (2H-6H) are useful for drawing fine, clear lines in sketching on final paper, and will not smudge easily.

Lithograph. A lithograph pencil (a type of black crayon) is used on Coquille board and on Ross stipple board to give a deep quality black which may be reproduced by line cut.
Charcoal. Charcoal pencils are used to produce a soft effect, which can be quite dark when pressure is applied. Sketching in the field, preliminary laying in of values on rough drafts, and retouching mat surface photographs are some uses for charcoal pencils in biological illustrating.

A straight penholder with an assortment of points is the most useful drawing instrument. Lettering points, writing points, stubs, crow-quills, stiff and flexible points are serviceable and each gives a different quality of line. A drafting (ruling) pen and the free-hand penholder that is included in the Leroy lettering set will prove very useful, especially in constructing maps and graphs, since they will produce a line of uniform thickness.

Brushes

The highest quality brushes are the most economical. The hairs will fall out of inferior brushes, the shape will be lost after one or two usings, and the quality of the stroke will be poor. Red sable water color brushes, made by a reputable manufacturer and receiving normal care, will last for years. Several sizes will be needed for dry brush ink drawings, water colors, gouache and wash drawings. Round as well as wide flat brushes are required for all brushed media.

Oil painting brushes are made of ox hairs or pig bristles (except the very finest in size, which are made of red sable). They are rounds, flats, and brights (shorter bristles than the flats), and all shapes are used for painting.
Inks

Black waterproof India ink is best for ink renderings since it is black enough to photograph well if the lines are drawn densely enough. It will evaporate and become gummy, however; the bottle must be kept stoppered tightly and the pen wiped frequently. Carter's black drawing ink in tubes is handy for filling ruling pens and for drawing in the field. Higgins American Drawing Inks come in a wide range of colors and are waterproof when dry. This enables the artist to use one color over another, use water color with ink, and so forth. Colors of one brand may be mixed safely, but different brands of ink should not be mixed.

Pigments

Water Colors. Water colors may be purchased in pans or in tubes. Any color desired may be used, but if the illustrator wishes his picture to retain its original color for more than a few months, he should use only permanent pigments made by a reputable manufacturer.

Gouache. Gouache pigments (opaque water colors) come in many hues and are available in tubes and jars (tubes are more satisfactory in hot and dry climates).

Oils. The color range of oil paints is very wide, and they may be permanent or fugitive. Some pigments are poisonous and

2. Loc. cit.
must be used with caution or avoided entirely if children are nearby.

**Pastels.** Pastels are sticks of finely ground pigment in a great range of colors and are applied to dry paper in the manner of colored chalk.

**Wax Crayons and Colored Pencils.** Wax crayons may be used in some illustrations; when they are smudged with a swab moistened with an appropriate solvent such as benzene, special shading effects may be obtained. Colored pencils may be used in the same manner.

**Grounds (types of paper, canvas, glass, and so forth)**

The illustration may appear in several stages on as many different grounds before it is finally ready for printing. Each medium may require a particular ground for best results. The illustrator, therefore, should be familiar with a variety of grounds in order to meet his special needs.

**Paper.** The rough drawing is planned on a lesser quality paper such as newsprint or bond. Bond can withstand a reasonable amount of erasure and, because of its comparatively low cost, it can be discarded later without compunction.

Tracing paper is available in several grades and is sold in sheets, tablets, and rolls. A high grade of tracing paper is strong and will take erasures well, but is not so strong or permanent as tracing linen which has been starched to the stiffness of paper. Sheets of transparent acetate are occasionally used in tracing.

A supply of graph paper is a necessity. Light blue or lavender lines will not ordinarily reproduce photographically,
whereas orange, red, brown and green lines will appear in the copy.

The paper for the final rendering must be of good quality. Bristol board is a smooth paper which will take both pencil and pen well. Two- or three-ply plate finish drawing paper is excellent for ink work because the ink will not spread or "fuzz" on this type of surface. The three-ply is the stiffer grade and although it may be handled for convenience in drawing, it will not store well in rolls as will the two-ply paper. Illustration board is quite stiff and will crack if bent. It has an excellent surface and is a good, all-purpose final paper ground unless a rough or plate surface is required. The advantage of using illustration board is that, unlike thinner papers, it will lie flat and need not be mounted.

The illustrator may have occasion to use scratchboard and perhaps also Coquille board and Ross stipple board. These are somewhat expensive and are employed for special effects; the last two are labor- and time-saving devices (vid. p23).

Water color renderings require the use of special paper which may be had in several weights and textures. If the paper is not bought in a block, glued around the edges, it should be moistened and stretched before painting.

Pastel and charcoal drawings are done on a type of paper which is textured to hold the powdered pigment or charcoal. Such paper comes in different sizes and degrees of roughness and also in several colors other than white.

All drawings done on thin, flexible paper must be mounted for the publisher and to preserve them in good condition when filed
away. The mounting cardboard usually recommended is poster board since it is inexpensive and white on at least one or both sides.

**Oil painting grounds.** Oil painting is done on canvas, Gesso panel, or wood. Canvas board may be bought in many sizes from art supply dealers. Pre-stretched canvases are available unless the illustrator prefers to stretch his own canvas, in which case he may buy yardage canvas and must have the use of a set of stretchers. Gesso panel (plaster board) may be bought and cut to size at a lumber yard; it is usually more expensive in an art store.

**Rules**

The biological illustrator should have several rules close at hand. An accurate centimeter rule is an absolute necessity, of course, in measuring small specimens. An eighteen-inch, metal-edged rule will be invaluable for ruling lines on graphs and maps. The raised strip of metal will prevent the ink's running under the straight-edge and being smeared across the paper. A set of parallel rules is desirable but not essential. A T-square, however, will be found to have many applications in addition to its usual one—the drawing of parallel and perpendicular lines—if it is extra long. An ordinary meter stick usually cannot be used as a straightedge. A serviceable type of metal rule is one which has a strip of non-slipping material on the underside. The drawing edge should be slightly raised from the surface of the paper.

**Erasers**

Several erasers, each for a different purpose, should be on
hand. An art gum eraser will remove most pencil lines without unduly roughening the paper. A charcoal (kneaded rubber) eraser is even safer and will also remove most non-oily finger smudges. A glass eraser (to erase ink) must be used with care, as must a knife or razor blade, in order not to roughen the fiber surface of the paper. A roughened surface may be rubbed with pumice stone to restore its original finish. To remove faint pencil lines from inked drawings, gentle wiping of the work with a piece of cotton moistened with carbon tetrachloride may be satisfactory. Too-enthusiastic rubbing will lighten the ink lines as well as the pencil marks, as will any other means of erasing. It may be expedient when dealing with errors in ink drawings to cover the part with super-white gouache paint or a pasted piece of paper.

Miscellaneous Aids

There are many small items which help to make the work of the illustrator easier and faster. Some of these are discovered sooner or later through necessity; others are learned from fellow illustrators. A few of the more useful articles should be mentioned.

A drawing board with truly perpendicular sides will save time and effort in constructing parallel and perpendicular lines. A T-square is used with the drawing board.

A supply of sharp, slender teasing pins may be used to perforate paper, handle small objects, fix points, and so on.

Masking tape (drafting tape), Scotch tape, paper clips, and rubber cement are indispensible items.
A small piece of chamois is used to wipe the drawing pen (paper tissues and ordinary cloth leave lint on the pen, adding trouble instead of removing it). The chamois may be washed in warm water and soap and rubbed soft again when dry.

A set of proportional dividers (vid. fig. 1) is most desirable, as this will save much time in measuring proportions and in drawing to an enlarged or reduced scale. This instrument is quite expensive, however, and plain dividers will serve the same purpose with a little more work.

Typewriter eraser shields with their differently shaped holes serve as excellent stencils. These should be backed with a strip of poster board which will raise the stencil from the surface of the paper and prevent the ink from running under the edge and being smeared. The stencils can be used for making locality markers on maps and graphs. The illustrator will be wise to collect other items which can be used as stencils. A piece of plastic or metal with circles, squares, and triangles cut in graduated sizes is sometimes sold in art stores.
Also useful is a large piece of plywood or Upson board, some thumb tacks, and a ball of string. By tacking a length of string to the end of the board and fastening a pencil or pen to the free end of the string, the illustrator will be able to draw curved lines (vid. fig. 2). Such a board or a portable mapping board is also useful for drawing while in the field.

A most important aid in biological illustrations is a reducing lens. Since almost every illustration is reduced in size for publication, it is helpful to be able to visualize the drawing as it will appear in print. By using a reducing lens, the artist will be able to determine how close he may draw his lines, how much shading he should use, and so forth. The printed illustration will not be quite as fine as the drawing appears under the reducing lens because this device makes all the lines and dots proportionally finer as they are reduced, while the printing process may thicken them; but an indication of the course of action to take while drawing is
afforded by the use of the reducing lens. A hand magnifying lens of moderate working distance is also a valuable aid in seeing more clearly minute details which must be drawn.

SPECIAL MACHINES

The illustrator may have access to machines and instruments especially designed as drawing aids. Some of these follow.

Pantograph

The pantograph is an instrument which enables the illustrator to trace an outline larger or smaller than given and to a desired proportion (vid. fig. 6). With the usual instrument, a frequent check for accuracy is indicated.

Camera Lucide

The camera lucide, by means of a mirror and proper lighting, can be made to cast an image on a sheet of paper upon which it is traced. The microscope camera lucide (vid. plate 2) is described on page

Projectors

Projectors may be used to cast an image on a screen or sheet of paper for the purpose of tracing directly.

Microprojector. A microprojector (vid. plates 3 & 4) will enable the artist to trace a microscope slide too large to use with the microscope camera lucida, or to be enlarged to a scale not feasible with the camera lucida.

Standard Projectors. A standard projector is
used for objects which are larger than those accommodated by the above projectors.

**Baloptican.** The baloptican is used to project opaque objects, such as maps, pages of books, and the like, on a wall or screen. The use of this instrument makes it possible to trace a drawing or graph in a large enough scale to be used as a classroom demonstration. Some models of the baloptican will project slides as well as opaque objects. *(vid. plate 5).*

**LETTERING SETS**

If the illustrator cannot hand-letter adequately, he will want to use a mechanical lettering device. The three in most common use are the Ames Lettering Instrument and the Wrico and Leroy lettering systems. *(vid. p69).*
INTRODUCTORY MATERIAL

Among the many techniques available to the biological illustrator, he will find that some are intended for particular purposes. Selection may depend further on such factors as skill, materials at hand, and cost of reproduction.

Technique as Determined by Expense

Since the work of the biological artist is mainly for publication in journals, the technique he chooses for his illustration may be determined by the expense of reproduction.

An illustration to be reproduced in small quantities, as for a thesis or for distribution in a classroom, may be mimeographed, blue printed, or photostated (vide p. 90). Drawings to be reproduced by any of these methods must be clearly black and white on pure white paper. The lines and dots must be firmly made, not sketchy; and the drawing should be "open," that is, not too dark or closely worked.

A line cut is the least expensive method of reproduction for a printed work. Illustrations to be reproduced by this means must be clearly black and white without greys in shading. Pen and ink work is reproduced in this way, by zinc or copper etching, depending on the fineness of line. Copper etching is more costly than zinc etching, but results in a higher quality reproduction.
Half-tone engravings are several times more expensive than line cuts, and appear to have a screen effect unless the more expensive fine screens are used. Photographs and wash drawings are usually reproduced by half-tone engraving. Only good photographs or expertly retouched ones and clear, clean drawings will reproduce well. The wash drawings should not contain clear white areas because these must be tooled out by hand, adding to the expense.

In general, pencil drawings do not reproduce well by half-tone engraving and must be done by a more expensive method, the photogelatin process, which has as an advantage the showing of detail without a screen effect.

Colored illustrations are the most expensive to reproduce. As each color requires a separate plate, the illustrator should avoid finely-graded colors in order to keep down reproduction costs. Illustrations which contain only one or two colors in addition to black, or in place of black, can be reproduced by line cut if the color is solid or in lines or stipple. (vid. p. 47)

Technique as Determined by Ability and Time

Besides the cost involved in reproduction and suitability to the purpose, other factors will influence the illustrator's choice of a technique. Time may be limited, and he will want to use the most rapid way to achieve a satisfactory illustration; he may not have the ability to properly apply some techniques nor the time to learn them, or he may lack special materials and will have to use whatever technique is feasible.
General Remarks

Every drawing, even a simple outline, should show the direction of the source of illumination. This may be indicated in an outline drawing by drawing the line on the shadowed side of the object heavier than on the lighted side. Lights and shadows model a drawing, giving it form. The same purpose is served in more elaborate drawings by shading.

The amount of light a surface receives depends on its angle in relation to the direction of the light source and on its distance from the light source. A sharp change in the surface of an object will show a correspondingly sharp change in value (light and dark), whereas a curved surface will show a gradual transition from light to dark.

As indicated in an earlier section (vid. p. 3), the source of illumination of an object being illustrated is at the upper left corner. This should be the main source of light in the event there is to be a second source. In general, double lighting is desirable because it makes a picture more interesting in value and form and keeps it lighter than would a single source of illumination. The illustrator should keep his illustration light in tone in order to draw and see the details clearly and because the illustration will appear darker after reduction for publication. Shading should be kept simple in order not to hide the form in a mass of camouflage. It is very difficult to trace sutures and curved lines through an area of deep shadow or a field of gloomy-shaded depressions; the
illustrator must keep his reader's problems in mind as well as his own.

Everything in nature exhibits the effect of aerial perspective, by which there is an apparent change in value, color, and texture of a subject caused by intervening atmosphere. Mountains at close range, for example, contain more intense, warmer colors, a pattern of light and shadow, and obvious canyons and crags, whereas distant mountains appear to be blue or violet with no distinguishable highlights or shadows and very little apparent texture. If a smaller subject, such as a frontal view of a skull or some other object which recedes from the viewer, is not drawn within the laws of aerial perspective, the drawing will appear flat and lifeless, and perhaps confusing. Fainter lines for distant parts as opposed to heavier lines for closer parts, together with greatest detail and richest values in the foremost part, will create the impression of form and recession.

Linear perspective concerns the apparent change in size of an object with an increase of distance between it and the observer; it is dealt with in greater detail in a later section (vid. p. 11).

All illustrations, except photographs, should be prepared larger than the desired printed size for several reasons—(1) reduction will diminish irregularities in the drawing, such as slight fuzziness or wavering of line and printing; (2) by drawing larger than desired for the final product, errors and misproportions will be more easily perceived and corrected. Usually the illustration is
made one and one-half times the desired final size, so that when it is reduced one-third (one-third off), a cleaner picture is obtained without loss of detail. (A reducing lens will be of help in drawing for publication). No matter how many times a poorly done or untidy drawing is reduced, it will still look poorly done or untidy. Reduction makes a good drawing better; nothing short of burning can help a bad one.

1 TECHNIQUES

2 Pen and Ink

The materials needed to produce a drawing in pen and ink include paper for rough sketching; sometimes tracing paper; and final drawing paper, such as Bristol board, illustration board, or plate finish drawing paper. Some special final papers are scratchboard, and Ross stipple board and Coquille board on which ink is used together with lithograph crayon. Soft and hard pencils and several penholders with an assortment of points will be used to draw. Art gum, pencil erasers, and super-white gouache paint will also be useful.

The drawing is planned on lower quality paper, which may be ordinary yellow or white bond, in soft lead pencil. The outline

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1. The illustrator may wish to read the valuable and informative booklet, Techniques, 5th ed., published by the Higgins Ink Co. (Brooklyn, 1948), for helps not mentioned here.

of the subject is drawn to correct proportions with the structure carefully placed (vid. p.46). Depending on the nature and purpose of the illustration, the final rendering may or may not have a drawn outline, but the pencil sketch will. The values are carefully executed in the rough drawing. Then the drawing is transferred to final paper where it is inked (vid. p.58).

Each person will develop his particular method of drawing; there are no fast rules to follow. Some methods of using the pen, however, are better than others in order to obtain certain results. If the pen is held too loosely or too tensely, or pressure is greater on one nib than on the other, or if it is held at too acute an angle to the paper, the resulting line will be ragged and blotchy. Firm but not excessive pressure and a wide angle between the pen and the paper, so that only the point touches, will give a smooth, clean line. The pen should be wiped at intervals with a chamois, as a pen sticky with dried ink tends to produce a broader and less clean line.

The subject is drawn lightly in hard lead pencil on the final paper. This faint pencil outline is the basis for the ink rendering. The outline, if one is desired, is then drawn with the pen, varying the width of the line for interest, and emphasis. This may be accomplished by using a flexible drawing point and varying the pressure, or by using a broad point and rotating it slightly while drawing (vid. plate 5). If no drawn outline is to be shown, the lines of the subject are drawn to the pencil outline or shaded to it (vid. plates 6 & 7). The drawing should not proceed spot by spot; on the contrary, the whole picture should be worked over simultaneously,
adding detail and shading more in a layer-by-layer fashion rather than piece-by-piece like a jig-saw puzzle. If one area is finished at a time, there is a greater chance for error; a completed area may be quite dark, and, in an effort to fit the whole picture to this spot, the illustrator will make the work too dark. It is better to keep the drawing lighter and more open than one thinks he desires because the reduction and engraving process will thicken lines and close up the drawing, thereby darkening the picture in general. By using a reducing lens from time to time, the illustrator will have an indication of the shading and detail he must use for the best results.

A pen and ink drawing may be shaded by means of lines or dots; these are called hatching (hachure) and stipple, respectively.

Hatching lines should run with the contours and/or the grain when possible. The strokes should never end with "hooks"; these are avoided when the hatching is done with care, picking up the pen at the end of the stroke and then moving into the next stroke. Long lines must be planned exactly, in pencil, before the inking is begun. By varying the pressure on the pen, the line may be drawn more heavily in the darker and thinner in the lighter areas (vid. fig. 3). It may be advisable to fade a line into a clear area by breaking it into dashes before dropping it.

The illustrator may wish to use hatching lines all of the same width, in which case the number of lines, instead of their width, must be increased in the darker areas. In deeply shaded parts, cross-hatching may be employed; this is done by hatching across previous hatching (vid. fig. 3), but it should be used sparingly in order to keep the tone of the picture light.

Stippling is easier for the beginner than hatching because it requires less care to achieve good results since it is not necessary to draw with the grain; there is less danger of hooking the short strokes; and one imperfect dot is less obvious than one imperfect line. But stippling by hand is extremely time-consuming, even though the results are usually good if the illustrator exercises patience. It is worth the trouble to learn to use hatching lines for the added
speed and convenience over stippling. In some instances stipple may be preferred to hachure, as in the representation of a specimen in which it is important to delineate pigmentation, shading, and such structural lines as scales, bone sutures, and the like.

In stippling by hand, the illustrator, using a somewhat rigid pen point, should employ a light touch, holding the pen vertically and not lifting it more than two or three millimeters from the paper. This technique will give even, round dots which should be evenly spaced for smooth shading. In darker areas, the illustrator should simply place the dots closer together, not use bigger dots. (A rough texture may be suggested by stippling which is uneven in both spacing and size of dots). If larger dots are desired, a larger pen should be used since too great a pressure on a small pen to produce larger dots will result in triangles instead of round dots and may result in spattering the paper as well. The use of the Leroy freehand pen with various points will give a wide range of dot sizes. The stipple dots in general should not touch one another, except where this is unavoidable in darkly shaded areas. The stippling should be done at random, unless a pattern is desired for another effect. The illustrator should keep in mind that the amount of reduction and the kind of reproduction his illustration will undergo will determine the fineness and closeness of his stippling.

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4. The illustrator should consult the illustrations in Robert C. Stebbins, Amphibians and Reptiles of Western North America (New York: McGraw-Hill, 1954), in which the author-artist has shown excellent use of line, hachure, and stipple as well as mechanical shading devices such as Zipstone and Coquille board.
Coquille board is sometimes used to produce a stipple effect without the painstaking work of stippling by hand. The surface of Coquille resembles silk crepe material or finely-wrinkled paint with tiny ridges and depressions and may be had in several degrees of roughness. The illustrator uses a lithograph pencil to shade as in a pencil drawing. The finished work may be reproduced by zinc cut or, if very fine, by copper. Ross stipple board is used in the same manner as Coquille, but gives a slightly different texture. The Ross board is available in several degrees of fineness and in various patterns (vid. fig. 4). An advantage of the Ross board is that areas may be scratched out, as in scratchboard drawings (vid. p.26). Ink lines may be drawn on Ross and Coquille board. The combination of ink line and lithograph crayon stippling can be quite effective as well as time- and labor-saving.
On simple drawings, the illustrator may wish to use a Zipatone pattern in the shaded areas. Zipatone sheets are clear film with patterns of dots, lines, life forms, and the like; they may also be had in solid colors and black. The film is removed from its tissue backing and placed over the area to be shaded. It is then pressed into position with the thumb or with a wooden burnisher; and the outline of the shaded area is traced with a teasing pin or needle or, using care, with a razor blade. The wax coating on the back of the sheet of film adheres it in place on the drawing so that the sheet may be lifted away from the cut-out piece on the shaded area. Zipatone is more often used on maps and graphs than on shaded drawings, although Zipatone with a graded pattern is sold.

Scratchboard is a stiff drawing paper coated with a chalky substance on one side. The drawing may be begun as a silhouette, the white areas being scratched out with a knife or with a special scratchboard tool which fits an ordinary penholder. A combination of line drawing and scratching out can be very effective and has been used with much success. If the scratching has been done lightly, the scratched area may be re-inked and scratched over again. Deep scratching may have gone through the chalk surface to the paper beneath; in this case it cannot be redone.

5. Made by Para-Tone Inc., 512 W. Burlington Ave., La Grange, Ill.

Pencil lines should be removed from the finished ink drawing in a way that will not lighten or smear the ink. A kneaded (charcoal) eraser is one of the safest means of erasing. Wiping the drawing very gently with a clean cloth moistened with carbon tetrachloride will safely remove pencil marks and smudges provided the pressure is not so great as to remove the ink lines as well.

Errors in ink drawings can sometimes be removed by a glass eraser or by gentle scraping with a very sharp knife, taking care not to dig the paper while scraping. By rubbing a piece of pumice (soap stone) over the slightly roughened erased area, the illustrator can smooth the surface sufficiently to redraw the erased line. Erasure occasionally is not advisable or necessary, as in the event of large blots of ink and of accidental lines which do not mar the drawn lines themselves or which appear in areas without drawing. This type of error may be covered with super-white gouache paint or with a small strip of paper pasted over the mistake. Covered errors will not be apparent in the reproduction if the corrections are made carefully.

Artistry in pen and ink drawings depends on many factors such as composition, value, pattern, liveliness of line, and so forth. The illustrator should not overlook the artistic possibilities of the suggested form as opposed to the completely defined outline. Distant mountains will appear more distant if barely suggested; a minor part of an animal picture rendered in less detail will tend to focus attention on the animal. If a subject is not completely depicted, the viewer will fill in the familiar details in his own mind and will find greater satisfaction in his mental picture based on the artist's
suggestions than in a finished-to-perfection drawing. In another situation, too much detail may be distracting. The important part of the picture must be rendered exactly, but if the surrounding parts and background are also detailed, the viewer has a right to expect these parts to be as accurate as the central portion and may find a quarrel in a minor error. In less important parts of the drawing, therefore, the illustrator should allow enough latitude so that any apparent errors are products of the viewer and not of the artist.

**Dry Brush**

By using a brush holding only a small amount of ink on a rough-surfaced paper, the illustrator can make a black and white illustration which may be reproduced by line cut or photostat. Interesting textures are achieved by means of the rough surface of the paper catching ink on the raised parts and leaving the depressions white, and by the "frayed" action of the nearly-dry brush. This technique is useful for animal and habitat illustrations, for textures such as fur and tree bark, and for some landscapes. It is generally not suitable for exactly detailed renderings. With practice, the illustrator will become quite adept and will acquire speed in using the dry brush technique.

**Wash Drawings**

Liquid India ink, a dry block of ink, Chinese ink, or a pan or tube of good quality black water color is used in making a wash drawing. Several water color brushes, both flat and round, are necessary. The wide flat brush is used to apply the broad areas of wash
while the round brushes are used for details and should be had in medium and small sizes. A wash drawing is done on water color paper, the surface of which is textured to hold the ink or the color washed over it. This paper is strong enough to be soaked in water and stretched. A drawing board (which may be Upson board), and a roll of strong gummed brown paper tape are necessary to stretch the paper.

An outline of the subject is drawn lightly in hard pencil (4-5H) on the dry water color paper. In a wash illustration the illustrator must use a light touch when drawing since pencil lines will show in the final product. The entire paper must be damp in order to apply a wash properly. There are two usual methods of preparing the paper. (1) The paper is fixed firmly to the drawing board with gummed paper tape and then is wet with a wide brush, using clear water. The paper is allowed to shrink flat before proceeding with the wash. (2) The paper is soaked in clear water for half an hour or more; then it is removed and taped to the drawing board. If desired, the wet paper may be pressed between slightly damp blotters before being taped down. The latter method of preparing the paper is recommended for generally better results. The paper must not be shiny with excess water or have puddles of water on its surface; blotting or gentle wiping with a dry brush may remove any excess moisture.

The ink is mixed with clear water to the desired shade, the lightest wash being applied first. (The entire picture should be covered with at least a light wash because it is very expensive to reproduce wash drawings containing pure white areas.) If two or more illustrations are to be printed together in a paper or book, it may be well to do all the backgrounds with the same wash mixture in order
to establish a measure of uniformity.

When applied, a wash should be a little darker than desired, for it will dry lighter. The paper should be less damp to receive the darker washes and quite dry for small dark areas. A lighter-toned picture is generally more pleasing than a darker one, but the range of values should be sufficient to represent the subject well and to make the drawing interesting.

Areas to be kept white may be covered with rubber cement before applying a wash. The rubber cement can be rubbed off later, and ink lines or color added to the white areas if desired.

Stippling and line work done with brush or pen must be applied after the paper is dry. The illustrator must remember that solid lines will appear broken in a wide-screen half-tone reproduction, and should avoid them unless a fine half-tone screen is to be used.

A subject sometimes may be rendered by a wash drawing better than by any other technique because the texture, curvature, and detail of the specimen may be represented faithfully without the problem of photography, in which proper lighting may be difficult to achieve and important detail be obscured by a cluttered field. Once the wash technique is mastered, the drawing may be done quickly, which is an advantage over the pen and ink drawing. The mastery of the wash technique, however, requires time and practice; it is no easy matter to achieve a finely-graded wash or to apply
tones without blurring the edges. Black and white renderings are often chosen in preference to wash drawings as the latter must be reproduced by the half-tone process or the even more expensive photogelatin process.

Pencil Drawings

The illustrator should equip himself with several pencils of varying hardness and softness, an art gum eraser and a kneaded eraser, a piece of fine sandpaper, and a supply of appropriate quality drawing paper.

The preliminary lines are drawn lightly with a hard, well-pointed pencil. Softer leads are used after the outline has been established, the softest lead producing the darkest and widest line.

Shading may be done solely by line, as hatching, or the lines may be smudged with the finger or a rolled-paper smudger (vid. p. 5) which can be pointed for use in very small areas. Finger smudging is more difficult to erase than paper smudging because of the small amount of oil from the finger mixed with the graphite.

Most erasing can be done with the art gum eraser. The kneaded eraser is softer and therefore safer to use on thin paper.

Pencils are kept pointed by rubbing on the piece of sandpaper. The pencil lead can also be flattened against the sandpaper if broad lines are desired.

Paper with a slick surface will not hold the graphite well; therefore, one should not use plate-finish paper for pencil work. Illustration board will take pencil well and can be safely handled for ease in drawing. Any good, fairly smooth drawing paper may be suitable, even white bond. Pencil drawings will smear easily and must be protected by a sprayed fixative (vid. p.99) or by glass.

An advantage of the pencil drawing is the ease and speed by which it can be executed. Pencil drawings have a soft and pleasing quality and yet may show detail accurately. Disadvantages of this technique are the great possibility of smearing or smudging while drawing, the care which must be taken to keep the paper clean during and after drawing, and the expense of reproduction.

Colored Illustrations

Illustrations in color are the most expensive to reproduce. For this reason not many colored pictures appear in scientific papers. The frontispiece of a book may be reproduced from a painting or colored photograph; more often certain maps, graphs, and diagrams may contain one or two flat colors.

The illustrator should be familiar with at least the fundamentals of color theory before attempting a colored illustration. For instance, if complementary colors are used in a picture, the one will make the other appear brighter, that is, red next to green appears super-red. Warm colors advance, while cool colors seem to recede. By using color, as well as values, the illustrator can give an illustration depth.
Water Color. The illustrator will use the same brushes for water colors that are used in wash drawings, and the paper is prepared in the same manner. (vid. p. 29). An assortment of pan or tube water colors may include any color desired (vid. p. for information on permanent and fugitive colors). As in wash drawings, the outline or guide lines are drawn lightly on the dry paper with a hard pencil; and the color is applied to the dampened, firmly fixed paper. The paper should be less damp for putting in smaller areas and must be completely dry for pen or brush line work. Application of one color over another generally lessens the brightness of both, making the painting "muddy" in appearance. Again, as in wash drawings, areas to be left white are covered with rubber cement before applying a wash, and rubbed clean when the painting is dry. The illustration should be allowed to dry thoroughly before it is removed from the drawing board.

Colors are mixed in a white dish or enamel tray (the white background is essential so that the colors may be seen as they will appear on the white paper), but the artist must be careful to use as few different hues as possible in mixing a color since more colors in the mixture will lower the chroma and value. The values of the freshly-applied colors will differ slightly when dry.

A combination of techniques, such as color wash and pen line or transparent water color and gouache, will often give good and artistic results and may enable the illustrator to gain an effect

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impossible by wash or line alone. By experimenting with paper wet-
ness, lines, technique combinations, and anything else that comes to
mind, the artist may surprise himself with a "lucky accident."

A water color painting is the fastest way to make a full-
color illustration. The luminous freshness of a water color skill-
fully done cannot be found in any other color substance. The
technique, however, requires time and practice to master, and a mis-
take in a water color painting may effect a new start.

Colored Ink. Many striking and successful
colored illustrations have been done with colored inks. The range
of colors offered is wide, and inks made by the same manufacturer
may be mixed for an even wider range. (Mixing of different brands
is not recommended.)

Some colored inks are waterproof when dry, enabling the
artist to apply ink over ink or a water color wash over whole ink
drawings, thereby increasing the illustrating possibilities.

Colored ink illustrations may be done with brush or pen
or both. The paper should be damp if a wash type drawing is de-
sired. Dry brush may be done with colored ink as well as with black.
Paper with a smoother surface, such as illustration board or Strath-
more kid finish drawing paper, will give good results.

The line, stippling, and hatching techniques employed in
black and white pen drawings can also be used with colored ink
(vid. frontispiece plate). Plate finish drawing paper takes this
technique very well. An advantage of stippling and hatching, over
painting with colored ink, is that the artist can make use of the
phenomenon of retinal mixture in which the eye mixes the colors. For instance, to obtain a brilliant orange, the illustrator may stipple an area with yellow and red. Mechanically mixing the colors would produce an orange of lower value and chroma than either the red or yellow used, whereas the orange of the retinal mixture is lively and brilliant. The nearer to the picture the viewer stands, the smaller should be the stipple dots and the finer the hachure lines. As the illustration will be reduced during reproduction, the illustrator must remember to make his dots and hachure lines the correct size so that they will be neither too obvious nor disappear altogether.

Colored ink illustrations are clear and bright if done with care. The hatching and stippling are time consuming, however, even more so than in black and white work.

By careful planning beforehand, the illustrator will be able to keep the number of separate colors low, especially if he makes use of retinal mixtures. The fewer the colors, the fewer the separate plates that will have to be made, and the lower will be the cost of reproduction.

Gouache. By gouache is meant a quick-drying, opaque water color. The paint quality of gouache is between oil paint and transparent water color. It is fairly easy to handle and may be "worked over" to some extent as may oil painting, but this requires knowledge of the medium.

9. Vid., the paintings of Seurat, Signac et. al.
The ground used in gouache painting should be stiff enough not to warp when wet. Illustration board and Gesso panel have good smooth surfaces and enough absorbency for the use of gouache. The best quality red sable brushes, flat, round, and bright, are necessary. (The very wide brush for large areas may be of ox hair.) The paint itself may be had in many colors and also may be called by different names, such as poster paint, artist's opaque, designer's opaque, or show card color.

There are many different methods of painting with gouache and the possibilities of combinations of gouache with other media are almost endless. Generally, however, gouache painting is not suited to the exact and detailed representation of a scientific subject, being a free-style manner of painting.

**Pastel Drawing.** Pastels are sticks of powdered pigment bonded with various substances, harder and finer than ordinary colored blackboard chalk. The range of colors available is very great. Pastel paper must have a roughened surface, and the special paper is made for this purpose and may be had in white, grey and several colors.

The preliminary outline is drawn with a pastel stick, the color chosen to blend with the other colors used. Ordinarily, the lighter colors are applied first. The colors may be smudged with the finger, a rag or chamois smudger, or applied so that each stroke will

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show. If the illustration is done on a large enough scale, details may be shown accurately. Smudges and finger prints may be erased with a clean kneaded eraser.

Pastel is one of the easier color techniques for the beginner, but, like pencil drawings, the pastel drawings must be protected against accidental touching and smudging while working. Also, the paper will take only so much pastel and no more; therefore, the drawing cannot be "worked over" very many times. The pastel drawing must be preserved with a sprayed fixative, which will darken the colors, or with glass. Washed and dried Seran wrap may be used for a short time if glass is not available (fresh Seran wrap clings to the pastel drawing and lifts some of the pigment when removed).

Crayon Drawing. Crayon drawings may be simple or elaborate. The technique of the fine crayon drawing is mastered through long experience. The more simple crayon drawing may be of crayon alone or crayon with ink and is suitable for classroom demonstration charts and diagrams. The subject is drawn with crayon or ink and is colored and/or shaded with crayon. One method of obtaining a flat, smooth effect with crayon is to apply it lightly and evenly and then to rub it gently with a swab of cotton moistened with benzene or other such solvent. Smooth shading transitions are accomplished in this manner.

Oil Painting. The range of color that may appear in an oil painting is almost unlimited. The texture of the medium enables the artist to work in different ways for soft as well as sharp or rough textured subjects, with a "feel" of the medium in the picture
The brushes used are hog bristle and sable flats, rounds, and brights of varying sizes. Oil painting is more difficult with a small brush than with a larger one; brushes a half-inch and a quarter-inch wide will probably be as fine as will be needed. An inch wide brush is necessary, and perhaps also a wider one for large paintings. Seldom will the illustrator use a brush as fine as a small sized, round sable hair; this may be useful in painting individual hairs or highlights on an insect's eye. The possibilities of using a painting knife in oil painting should not be ignored; tree trunks and other rough-textured surfaces, as well as smooth planes, may be done easily with the palette knife.

A white palette is best so that the colors may be seen without reflection from another color. Glass over white cardboard or an enamel tray are suitable.

The ground on which the oil painting is done is a well-stretched canvas, canvas board (canvas over cardboard), wood, or Gesso panel. Linen or cotton canvas is far better than a mixture of the two, and jute canvas is poor.

The pigment can be bought in an extremely wide range of colors (vid. p. 100 for information about permanent and fugitive colors). The paint is mixed with linseed oil or a mixture of oil and turpentine on the palette to the desired consistency. General hardware store linseed oil and turpentine will serve as well as the more expensive art supply store variety.

The preliminary drawing is made on the canvas with charcoal.
or pencil which should be sprayed with fixative before applying the paint, or with paint thinned with turpentine. The major areas of the painting are then covered with a thin turpentine wash of the underly ing color of each area in order to leave no white space on the canvas. This is important in order to see the colors in proper relation to one another as they will appear in the final painting. The first layer of paint should contain less linseed oil than the outer layers because the oil will tend to seep through to the top. The picture should not progress in parts, one area painted at a time, but the artist should work over the whole picture, building it up gradually.

Using as few separate hues as possible to obtain a desired color will keep the colors brighter. Wiping the brush with a rag and cleaning it in turpentine from time to time will also help to preserve brightness and will help to avoid a “muddy” appearance.

Oil painting has many advantages over other methods of color illustration: it can be worked and reworked; a mistake can be corrected easily; the color range is all that can be wished for; the painting need not be completed at one sitting; it may be as detailed as required; if done correctly and using permanent pigments, it may last for centuries; the beginner can obtain a creditable result without too much strain and disappointment. The disadvantages of oil painting are: it is a technique that requires expensive materials; the paintings take a long time to dry, from weeks to months (a drier added to the paint will make it impermanent).

Special effects have been achieved by using a combination of gouache, oil painting and ink,
Color by Line Cut. A picture containing one or two colors in addition to black or instead of black may be printed by line cut, provided the colors are not shaded. These illustrations may be prepared in two ways. The older method is to make a separate black and white drawing for each color. For example, if a picture is to contain green, black, and white, the black parts are drawn on one sheet of paper, complete with hatching and/or stippling. The parts to be green are then drawn on a second sheet (which may be tracing paper) in black ink, also complete with hatching and/or stippling. The two sheets must coincide exactly; therefore, cross marks (registration marks) are made in the corners outside the picture area. A pin pushed through the center of each top cross mark must touch the center of the cross mark below. The printer is sure to print the colors where the illustrator has indicated if these reference points coincide. Coquille and Ross stipple board may be used for stippled color if the above method is employed. Black-marked Zipstone may also be used to show color areas.

A second method, and an easier one, is to do the black areas as desired on paper or scratchboard and then to use "colo-tone" sheets. These are sheets of clear plastic colored on one side. The color can be wiped off with a special solution or it may be scratched out as on scratchboard, using a plastic or wooden stick. (For a very small area of color, the illustrator may buy small bottles of colo-tone color to paint on a clear plastic sheet.) By using this method instead of the former, the illustrator will be better able to follow
the design. Registration marks must be made on both the black-and-white sheet and the colo-tone sheet.

The use of two colors of colo-tone may be used to produce a third color with only two color plates, if the illustrator wishes. For example, when using red and green in a picture, the illustrator need only to overlap the red and green sheets to produce brown.

CARE OF MATERIALS

The best materials are usually more expensive and warrant proper treatment. One should be especially careful with borrowed materials, of course.

Grounds

The ground is that surface which receives the paint, ink, pencil, etc. The illustrator should avoid rolling his drawing paper when this is possible. Space is often very limited, however, and for this reason the author prefers two ply paper to three ply paper because it will unroll more easily. Grounds should be stored flat, in paper covers, until ready to use. Dust is sometimes difficult to remove from drawing paper and canvas, and crumpled edges and corners on new grounds are aggravating.

Pens and Brushes

Pens should be kept free from dried ink by wiping with a chamois while the ink on it is still wet or by scraping the clotted, dried ink off the pen with a penknife or scratchboard tool. Points may be cleaned by soaking them in a solution of soapy water with a
little ammonia added. The pens may be left in the solution for a few hours or overnight, depending on their condition. Too long a soaking may cause damage to the pen. If a pen has been spread by dried ink or by misuse until the nibs are forced apart, it may be returned to service by turning the pen over and pressing the top side of the nibs against a hard surface. If this does not snap the nibs back into place, the pen should be abandoned.

Brushes are expensive and must receive good care to be useful for their ordinary life expectancy. Ink brushes should be washed with Ivory soap and cool water, taking care not to get soap into the ferrule (that part of the brush which holds the hairs). Water color brushes should be rinsed with cool water until clean. Gouache brushes are washed with lukewarm water and Ivory soap before the paint dries on them. Paint or ink drying in any brush will cause the hairs to break. Hot water will take the shape and spring out of the hairs. Oil paint brushes are first wiped with a rag, then cleaned in turpentine, working the bristles with the fingers. (Paint and turpentine should be kept out of the ferrule.) A soap and water wash follows. Paint remover should never be used on any art brush.

Media

Ink bottles must be kept tightly stoppered as ink will evaporate and thicken on exposure to air. Pan water colors may be kept clean by wiping with a damp cloth. Gouache paint will be kept moist on the palette for a short time if covered with a damp cloth. Inverting jars will lessen evaporation during storage. Oil paint may remain
moist overnight, but the palette should be placed in a tray of water
if the paint is to be kept for a longer time, or each dab of paint
may be removed to a cup in a muffin tin and covered with water.
IV

DRAWING LARGE OBJECTS

Large objects include ordinary skulls and other good-sized bones, large teeth, whole plants and animals, large leaves and flowers, and other objects that do not require special instruments to be seen clearly.

POSITIONING

The subject may have to be held in a certain position while being drawn, either to elevate it to the illustrator’s eye level, or, in the case of round or irregularly shaped objects, to keep it from rolling away. The stand itself may be a box, a pile of books or a sculptor’s stand. It should be covered with a white material if reflected lights are desired on the object, or with a neutral or black material if no reflections are desired. There should be enough room behind the stand to place a lamp or other light source in the proper position for optimum lighting. The light usually originates from the upper left unless this is unsatisfactory. The object may be propped in position with wads of paper or pencils and erasers, but these will slip or be borrowed and the objects may fall and break. Paper towels may be used if they are wet and crumpled into a more or less solid mass and allowed to dry in the position they must maintain, but

1. vid. p109 for immobilization of live animals.
ordinary child's modeling clay, the kind found in first grade classes, is the best material to use for holding a specimen firmly and safely. This will not dry out, so it may be used many times over. White, grey or tan is recommended, as colors may stain or cast undesirable reflections.

OUTLINE

The general outline of the subject should be drawn after a suitable length of time has been spent in studying the form, contours, lighting, etc. If desired, the proportions of the object may be measured with the fingers, or with a pencil held at arm's length, or with a grid, in order to gain a clearer impression of the general outline. This outline should be sketched lightly and quickly without loitering too long over any one part in order to keep the drawing "alive."

The illustrator must determine how large he wishes his picture to appear in print. If the picture is to be reduced when printed, he must reckon with this and draw it larger. (In general, a one-third reduction is used, as this will minimize small imperfections without losing detail. For a one-third reduction the picture should be planned one and one-half times as large as it will be printed.) After deciding how large he must make his illustration, the artist draws on his drawing paper a line the length the picture is to be, or a rectangle of the dimensions of the finished drawing, and draws the object within these limits.
PROPORTIONS

After sketching the outline, the illustrator must check the proportions. One of several instruments may be used to do this.

The illustrator may hold a grid in front of the specimen, drawing the subject in coordinate squares marked on his paper (vid. fig. 9). A grid may be made by driving tacks equal distances apart into a wooden frame and stretching string or rubber bands on and around the nails until the inside of the frame is divided into squares. A sheet of glass or plastic will serve as a grid if marked into squares with grease pencil or India ink in a thick soap solution. The grid should be held firmly in position with modeling clay or some other means, and not moved until the illustrator has finished checking the proportions.

The proportions also may be checked arithmetically by means of a rule and paper for figuring. The line representing the total length of the picture is marked into halves. Half the length of the subject is measured and compared with one-half the drawn line. Assume that half the line is six inches, and half the length of the subject is four inches (so that a one-third reduction will give a natural size illustration). The distance from the forward end of the specimen to some particular detail is two and one-half inches. This distance will be called distance "x", and is to be located along the drawn line in proportion to the difference in length between half the line and half the length of the specimen. \( \frac{4}{6} = \frac{2.5}{x} \), and \( x = 3.75 \), or three and three-quarters inches should be measured along the drawn line to correspond to the two and one-half inches on the specimen. Thus the chosen
detail can be located accurately. Width measurements are taken in the same manner.

Proportional dividers are used to enable the illustrator to reproduce certain dimensions proportionately larger or smaller than the original (vid. fig. 1). The dividers may be set to the desired ratio by means of a sliding screw, so that a measurement taken at one end will be magnified or reduced as desired at the other end. If the dividers are adjusted to double the original measurement, for example, the subject is measured with the smaller end and this measurement is found to be twice as long at the larger end of the dividers, without the illustrator's having to resort to arithmetic and rule. Proportional dividers are expensive, and if they will not be used in further work, the illustrator may wish to use another method of enlarging or reducing the original scale.

Simple dividers and a piece of graph paper may be used in place of proportional dividers. Two points are found on a horizontal line of the graph paper (vid. fig. 5, points A and B). Directly above the second point, another point is located (point C) and directly below, a fourth point (point D) is marked, twice CB or whatever the desired multiple of scale is to be. Using the simple dividers (or a compass if no dividers are available), two points are measured on the specimen to be drawn or the drawing to be enlarged. This measurement is then located on the new scale between lines AB and AC (points 1 and 2). By leaving the lower point of the dividers in place (point 2) on line AB and swinging the upper point from line AC to a position (point 3) on line AD directly below the fixed point (point 2), the
original measurement is doubled (or multiplied according to previous plan). Thus, the distance between points 2 and 3 is twice the distance between points 1 and 2. The second measurement (2-3) is used in making the drawing.

When using any dividers to measure a rounded object, the illustrator must take all measurements in the same plane (picture plane, vide. p. 1/4), or errors will be introduced into the drawing. If desired, he may use a pane of glass in front of the specimen to maintain the chosen plane.

By viewing the specimen through a sheet of glass, the eye maintaining a constant position by means of a sight, the object can be copied in correct proportions on the glass. If the distance between the object and the glass is changed in relation to the distance between the observer and the glass, the ratio between the size of the
object and the tracing of it will also change.

The pantograph (vid. fig. 6) has also been used successfully to trace the outlines of large, three-dimensional objects. Ridgway placed the specimen to be traced on a box below the level of a table which supported the pantograph and used a long tracer which reached the object. He was able to trace the outlines and details of the specimen, producing a drawing one-third natural size.

A balopticon (vid. plate 5) may be used to project the images of flat or nearly flat specimens on a screen, from whence the outlines may be traced. A large camera lucida is used for the same purpose, but will project images of rounder objects as well as flat


objects on a table top where they can be more easily traced.

Absolute precision can be obtained by photographing the specimen, enlarging or reducing the photograph as required, and tracing the outline from this (vid. p. 63).

SEEING DETAILS

A hand lens will aid the illustrator to study the details in order to draw them with understanding. When drawing large objects, it is inconsistent to show both very large features and minute detail in the same picture. If a part is to be shown very exactly, the picture should be drawn to a large enough scale to do this properly, or the part should be drawn at greater magnification than the rest and so indicated.

PROCEDURE

The drawing should progress from the general to the specific, from form to details. By working over the entire drawing constantly instead of completely finishing one part at a time, the illustrator will be better able to avoid proportional errors and unnecessary erasures, and will be able to judge what is needed by way of lights and shadows. Drawing large and covering the paper will bring out the errors so that they may be corrected easily. The lines should not be erased until the drawing is completed in order to keep the paper as smooth as possible and to avoid repeating erased lines.

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If the illustrator will reduce a regular pattern to its geometric scheme (vid. fig. 7), the details may be fitted in with little trouble. Fish and reptile scales, flower heads, animal shells and other repetitious patterns may be rendered in this manner with comparative ease.
DRAWING SMALL OBJECTS

By "small" objects is meant specimens so small as to require the use of special instruments to be seen well enough to be drawn and yet not microscopic. Small teeth and bones, flowers and plants, seeds, etc., are some items in this category.

A difficulty arises in the use of special instruments for drawing small objects. The entire specimen may not be covered at one time in the instrument field, and so the outline may have to be pieced together from several drawings or it may have to be drawn without any magnifying aid, adding smaller features and details later.

SPECIAL INSTRUMENTS

Dissecting Binocular Microscope

A dissecting binocular microscope (also called the stereoscopic microscope) may be useful in seeing and drawing a particular specimen. The outline may be sketched before placing the specimen under the microscope, or, if the object is small enough, while viewing it through the microscope. The problem of dis-proportioning by the dissecting binocular microscope may be encountered in the second instance, however. An illustration was to be made of the scale pattern on the dorsal side of a lizard head. The lizard was small enough so that a special instrument was required in order to see the individual
scales clearly, but when the head was placed under the stereoscopic microscope, it was observed that the whole head could not been seen at one time. The general outline was drawn without the use of a magnifier, and the head was again placed under the microscope in order to draw the scales. This time it was seen that the scales in the edges of the field appeared blurred and distorted, so the proportions of the head such as eye and ear positions and natural divisions of groups of scales had to be indicated on the outline drawing, again without magnification of the head. Finally the dissecting binocular microscope could be used to draw the individual scales in proper proportion and position. Piecing separate drawings to make a whole would not have been feasible here because of the distortion at the edges of the microscope field.

Camera Lucida

1

Some models of the camera lucida will cast a magnified image of the object, and may be found useful in drawing small objects.

Baloptican

The baloptican (vid. plate 5) may be used in drawing small objects. By varying the distance of the screen from the instrument, the image (and consequently the drawing) may be made the desired size.

Magnifying Lens

The hand magnifying lens may enable the illustrator to see

1. Not meaning the microscope camera lucida.
the small specimen well enough to draw it, but unless it is mounted so that it can be held while drawing, the ordinary magnifying glass is not feasible.

These instruments all require bright light nearby or within them. The light will be warm, of course, and will tend to dry out a damp specimen; the illustrator must remember to moisten the preserved specimen in alcohol or other preservative solution frequently while working.

PROCEDURE FOR DRAWING

As in any illustration, the drawing should proceed from the general to the details. The illustrator should work on all parts of the picture simultaneously rather than finish one part before going on to the next. An adequate range of values, thoughtful composition, a clean and lively line and neat work are important in all illustrations, whether of huge objects or tiny ones.

In drawing of small objects, proportions may be checked by the same methods used in checking the proportions in drawings of large objects (vid. p.46).
VI
DRAWING MICROSCOPIC OBJECTS

A microscope is used in order to see objects not discernable with the unaided eye. A conventional microscope with a scanning lens is useful in locating the portion of the slide to be illustrated; lenses of greater magnification are then used to see the desired part in greater detail. Differently colored filters used with the microscope will enable the student to see certain particulars more clearly by bringing out one stain while subduing another.

MECHANICAL AIDS

There are instruments especially designed to facilitate the drawing of microscopic objects. As illustrations of microscopic specimens usually must be exact, it is well to use one of these instruments if it is available in order to conserve much time and painstaking work.

The microscope camera lucida (vid. plate 2) is a device attached above the eyepiece which, by means of a mirror, will superimpose an image of a sheet of paper and a pencil on the field of the microscope. The image of the specimen is traced by following the movement of the pencil point while looking into the microscope. The light on the specimen must be equal to the light cast on the paper, or one image will be obscured by the other. The angle of the mirror must be forty-five degrees in order to avoid distortion. By varying the objective and eyepiece magnifications, the drawing may be made
larger or smaller. The outline is traced lightly with a hard pencil, after which the ink and/or color may be used.

A micro-projector (vid. plates 3 & 4) may be used to project a microscopic object directly on a drawing surface. The drawing may be accomplished much more easily if the projector can be made to direct downwards. A photographic enlarger stand has been adapted to this purpose, and has proved quite satisfactory since the height can be easily adjusted. A wooden stand has been made which is also adjustable in height and enables the drawing to be done on a horizontal surface.

A carbon arc slide projector (micro-projector) is used in combination with a conventional microscope and produces a very bright light. The drawing surface or screen is in an upright position; the tracing of the projected image, therefore, must be done on a vertical plane.

FREESAND DRAWING

Some projectors and instruments may not be available to the illustrator, so that he may have to make do with other devices. Moving the eye from the microscope to the paper and back again may be an advantage over the use of special instruments in some instances as when a generalized, functional illustration is required; but this freehand rendering will not be as exact as a traced outline. A

freehand drawing will usually be more lively than a traced drawing unless the latter is gone over with swinging strokes of the pencil after the careful tracing is completed. By using an ocular micrometer in the microscope and coordinate squares marked on the drawing paper, a microscopic specimen may be drawn with a greater degree of accuracy than when done completely freehand.

DETERMINATION OF MAGNIFICATION

A scale for the determination of size and magnification of microscopic specimens may be constructed by using a stage micrometer and a microscope camera lucida. The micrometer scale, which is divided into units of ten $\mu$ is focused in the microscope, and the image is cast on a piece of paper by the camera lucida. The illustrator can then trace part of the projected scale. Knowing that each square projected on the paper represents ten $\mu$ in actuality, he can then divide this square into ten equal parts, each part representing one $\mu$. The specimen can then be cast upon this drawn scale and measured (vide fig. 8). The illustrator must always use the same microscope magnification in measuring the specimen as he used in making the scale.

The magnification of the projected specimen can be found by simple arithmetic proportions. One $\mu$ equals $1/1000$ of a millimeter. If the projected specimen measures six $\mu$ on the drawn scale, and measures three centimeters on a centimeter rule, divide the six $\mu$ into the three centimeters (30,000 $\mu$). Thus, the specimen which is actually six $\mu$ long is magnified 5,000 times. The illustrator must
consider the amount of reduction his drawing will undergo in printing when labeling the magnification of the specimen on his illustration.

Fig. 8
Any illustration to be used for publication must be transferred from the rough sketching paper to the final paper. Sometimes an illustrator may wish to use part or all of another's illustration. This can be reproduced in several ways.

TRANSFERRING WITHOUT INCREASING OR REDUCING THE SIZE OF THE ORIGINAL ILLUSTRATION

Carbon

A drawing can be easily reproduced by placing a sheet of carbon paper between it and the final paper, and pressing a pencil over the lines of the original drawing. The use of typewriter carbon paper is not recommended, however, as the lines produced by this paper are difficult to erase. Some artists make a carbon from the original sketch by blackening the back side of the sketch with a soft lead pencil. The drawing is then placed black side down on the final paper, and the lines of the drawing are traced. If one wishes to save the original sketch, he may black one side of a separate sheet of paper with a soft lead pencil, and use this as he would use a typewriter carbon. A type of graphite paper which has the transferring qualities of the soft lead carbons may be bought from art supply dealers.
Tracing

It may be more practical or desirable to trace an illustration than to use the carbon method of transference. The tracing sometimes may be mounted on stiffer white paper or cardboard after the drawing is completed and sent to the publishers this way, or it may have to be transferred to final paper by the carbon method or by use of the tracing table, discussed below.

There are several kinds of tracing paper. Generally, the finest grade is the best to use, as it is strong, very transparent, and will take erasures well. Besides tracing paper, tracing linen is used. This is more expensive than the paper but is stronger and more transparent and will last a long time. It may be had in white and pale blue, in sheets and rolls. For tracing illustrations from books, some libraries will allow only acetate to be used. This clear plastic sheet is slightly grained on one side to receive the pencil or ink marks. Because it is pliable and tough, acetate sheets will be useful in tracing patterns from flat-surfaced, rough-edged objects such as sliced fossils.

An instrument used to facilitate tracing illustrations with no change in size is the tracing table. This consists of a box fitted inside with a bright "frosted" light and topped with a plate of ground glass. The picture to be traced is placed on the ground glass, and the tracing paper placed over all. The lines to be traced may be seen easily because of the light beneath them, even through relatively thick paper. (Two-ply, plate finish Strathmore drawing paper has been used as the tracing paper with complete success, obviating the use of an
intermediate tracing in making the final illustration.) When tracing maps which are printed also on the reverse side, it is sometimes difficult to distinguish the lines needed since all the printing on the map is seen so clearly.

There is a method of transferring a "rough" illustration to final paper without the intermediate pencil drawing. This is the point system of transferring, and is used chiefly in transferring graphs and tables. The graph is drawn to scale on any chosen graph paper. This is placed over the final paper or board and held firmly in position by drafting tape. Then, with a teasing pin, needle or other suitable pointed instrument, the reference points are punched through the rough paper to the final paper. When the rough graph is removed, a drafting pen is used to draw ink lines from one pin point to another on the final paper with great accuracy and without having to draw and erase pencil lines. Caution must be exercised in marking the points, as pinholes which are too large and deep in the final paper are likely to catch the penpoint and blot or smear.

TRANSFERRING WITH REDUCTION OR ENLARGEMENT OF THE ORIGINAL ILLUSTRATION

Coordinate Squares

By using coordinate squares, simple drawings and maps may be reproduced to a different scale. If the original illustration may

1. The point system is a variation of "pouncing", the old method of tracing. The whole outline of the drawing to be traced, as well as the lines of detail, were punched very lightly with a pin so as not to damage the second paper beneath. These lines of pin pricks on the second sheet were then followed with brush or pen.
be defaced, it is ruled into squares. Corresponding squares, larger or smaller as desired, are ruled on a separate sheet of paper. Then the illustration is copied square by square. If the illustration to be copied may not be marred, a transparent overlay is placed over it, and the above procedure is followed (vid. fig. 9).

Pantograph

When a more complicated illustration must be enlarged or reduced, the use of the pantograph will be of help. This instrument is made of metal or wooden rods with a metal point to trace the desired lines and a pencil point to reproduce them on a separate paper (vid. fig. 6). The pantograph may be adjusted to reproduce a given dimension either larger or smaller than drawn; depending on the fineness of the
instrument, the original illustration may be reproduced more or less exactly in proportion.

Camera Lucida and Baloptican

By using a large camera lucida or a baloptican, an image of the illustration to be reproduced larger may be projected on a paper and then traced (vid. plate 5). These instruments are used when detailed drawing is done.

Photograph Enlargements and Reductions

If a great degree of exactness is required, it may be necessary to photograph the illustration, enlarging or reducing it as necessary, and trace the photograph over a tracing table.

Glass Tracing

An older method of enlarging an illustration is the glass tracing method. The illustration to be enlarged must be drawn on a sheet of glass which is held upright in a special frame, and the enlargement is drawn on a second sheet of glass behind the first. This method entails the use of a sight to keep the eye in constant position and an awkward reaching of the arm around the first piece of glass to the second. Glass tracing in general has been replaced by the other methods of tracing and enlarging mentioned above.

CAUTION IN TRANSFERRING

It will be noticed that when transferring a drawing by any means, the spontaneous feeling of the original is usually lost in the reproduction. The tracing or carbon copy, therefore, should be done lightly, and after being transferred, the new copy should be gone over with light pencil strokes to give it the swing and life of the original illustration. (This going over with light pencil strokes will also help in the instance in which there is no swing and life in the original illustration.) Exactness is required, of course, but a lifeless illustration lacks artistry which is an equally desirable feature in a scientific illustration.
VIII
THREE-DIMENSIONAL ILLUSTRATIONS

Illustrations in three dimensions are not too often available nor necessary to students doing graduate research, but in special instances the method might prove useful. A series of drawings does not always convey an understanding of the relationships of the internal structures of an animal or plant, and the student may wish to build a model for his own study, or he may use photographs of his three-dimensional model in a thesis or other paper. The relatively high cost of equipment and the expenditure of time involved in making three-dimensional illustrations doubtless have contributed to the notable lack of this excellent means of demonstration in science classes and lectures.

EXTERNAL ANATOMY MODELS

Clay of the kind used in kindergarten and first grade classes can be used if the model is not to be handled or kept for very long, since this clay will not harden. Sculptor's clay will become hard when it is dry, and may be handled if it is varnished or fired in a kiln (the biological illustrator should consult a book on sculpting and firing, or better still, a sculptor, if he wishes to produce a permanent model). Blocks of plaster may be carved effectively. The possibilities of soap and commercial products
such as sculp-metal for carving simple subjects should not be overlooked.

PLATE SEQUENCE MODELS

To build a plate sequence model, the sectional microscope specimen is drawn to dimensions on a suitable ground by means of a camera lucida or microprojector. The thickness of the ground must correspond to the known thickness of the section multiplied by the microscope magnification. Thus, if the section is one-tenth millimeter thick and it is to be magnified thirty times, then the chosen ground must be thirty times as thick as the section, or three millimeters thick. An image of the section to be drawn is cast upon the ground by the camera lucida or microprojector and the outline of the specimen and internal structures are traced. Grease pencil or black India ink mixed with soap is used to draw on glass and lucite sheets; carbon paper under ordinary drawing paper is used on thin sheets of wax; and dark pencil is used on blotting paper. The cut-out sheets are stacked in proper sequence. They may be held in place by an appropriate cement or by means of stapling. Glass and plastic models will last indefinitely, but the wax and blotting paper models will deteriorate after a while. The edges of the model may be smoothed by emory paper or file or, in the case of wax, by a hot knife. The effective use of color is limited only by the skill of the operator.


2. See Michael E. Guyer, Animal Micrology, (University of Chicago Press, 1946), Chapter XIX, for a complete description.
of the operator and the pigments available.
LETTERING

The biological illustrator will be required to letter some or perhaps all of his illustrations. Parts and points of interest in drawings will be labeled; graphs and maps will require numbers, place names, explanations and titles; and tables will have to be lettered for some scientific publications. The less lettering the printer is required to do, the lower will be the cost of printing. The illustrator should examine several copies of the publication in which he wishes his work to appear in order to determine how much lettering will be required of him. Some editors require titles and explanations to be lettered by the illustrator while others prefer the printer to set these in type.

SIZE OF LETTERING

Lettering may be of any desired size, except that it should be no smaller than one millimeter in height when the illustration is printed. If a graph is to be reduced one-third, therefore, the smallest letters should be not less than one and one-half millimeters high so that the reduction for printing will not bring them below one millimeter. The lettering should not look out of place by being either so large as to crowd the field or so small as to leave useless and distracting blank areas. Lettering can actually contribute to the attractiveness of an illustration if used with some thought and taste, whereas careless or badly arranged lettering can completely destroy...
the artistic merit of an otherwise good illustration. Usually the lettering is done on separate paper and cut out and pasted in place on the illustration. The shadow lines at the edges of the pasted labels may be painted out of the photostated or etched reproduction, but will remain in photographically reproduced illustrations and in pencil illustrations.

**FREEHAND LETTERING**

There are many advantages to freehand lettering over that done with a mechanical device. It is done more quickly than mechanical lettering, the result is lively, and any style desired may be used. If the illustrator is unskilled, however, his hand lettering may not be uniform and therefore will be unattractive.

Guide lines are required for neat freehand lettering. The lines should be carefully measured to be equidistant; the use of a railroad pencil, which draws two lines at once, will greatly facilitate the ruling of guide lines as only the base line will have to be measured. The railroad pencil is most helpful when the lettering must curve, as it sometimes must on maps. A Keuffel & Esser lettering triangle may be used with a set of ship curves or French curves to produce parallel curved guide lines when a railroad pencil is not available. Generally, all lettering is parallel to the edge of the illustration, horizontal and/or vertical. Letters and words should be carefully and evenly spaced and should fill the allotted area comfortably.

The printing must be absolutely black in order to reproduce clearly without broken or absent letters and numbers. Erasing of
guide lines, unless done carefully, may lighten the inked lettering as well. In this case, the illustrator will have to retouch the unsatisfactory letters or parts of letters. To do this he should use a smaller pen than was used to make the original letter, and should draw in the middle of the previous line. This will flood the line without widening it as the use of the original width pen might. The use of a smaller pen to strengthen lines is recommended also for mechanical lettering and any ink drawing.

MECHANICAL LETTERING SYSTEMS

The advantage of using a mechanical lettering aid is that the lettering will be uniform, and one unskilled in freehand lettering can produce neat, acceptable work with just a little practice. As the mechanical lettering proceeds in a straight line, the base line need only be marked at the margin, not completely drawn. The disadvantages cannot be ignored, however; lettering with a mechanical aid cannot be done as quickly as freehand lettering, and, to date, the mechanical type styles show little imagination and artistic sense in their selection, being somewhat lifeless and tasteless. Lettering in a curved line is tedious when done with a mechanical aid, as the printing must be traced, moving the top or bottom of the sheet for each letter.

There are a number of mechanical lettering aids on the market. Three of the most commonly used devices follow:
Ames lettering instrument

This instrument consists of a clear plastic disc with punched holes, and moving within a frame. The illustrator must mark dots through these holes, then draw the letters following the dots.

Wrico Lettering Guides

The letters are drawn by means of stencils cut in pliable plastic.

Leroy Lettering

This type of mechanical lettering device employs the use of templates and a scriber. One arm of the scriber is tipped with a metal point which fits into the letters and numbers depressed into the template; another arm, also with a metal point, fits into a guide line in the template; the third arm of the scriber holds an ink-well point which may be had in different sizes. By moving the scriber within the letters in the template and moving the template along a stationary guide bar (a long ruler or other flat guide held by weights, adhesive or screws), a straight line is lettered with comparative ease. Distances between lines should be measured and marked beforehand along the left margin. With practice the illustrator will be able to judge the word and letter spacing adequately without measuring each letter.

The scriber may be had with a swinging arm which permits


2. Made by the Frederick Post Co., 3650 N. avondale Ave., Chicago 18, Ill.

slanted lettering, equivalent to italics in print. This movable arm is prevented from slipping by tightening a screw on the underside of the scriber.

The templates are available with different sized letters, numbers, and symbols.

Leroy lettering sets may be bought complete or piece by piece. The freehand pen included in the complete set is an invaluable aid in all ink drawing, as it may be used to rule lines, mark through stencils, apply stipple dots of uniform size, and so on. The points which fit the scriber also fit the freehand pen.

The Doric lettering set is an inexpensive, student model of the Leroy system; it is equipped with one template having three sizes of lettering and numbers. The templates and scribers are not interchangeable in Leroy and Doric sets, but the Doric points may be used in the Leroy freehand pen.

Wrico Scriber Lettering Set

This operates like the Leroy lettering system, but it has a different type style.

India ink is used with all lettering devices, and because it clots as it dries, the points must be cleaned thoroughly after use. If ink has clogged a point, it must be soaked in pen cleaning fluid

4. All lettering of illustrations in this work has been done with a Doric lettering set.

5. Made by the Frederick Post Company
which may be bought ready-made or else made by adding a little ammonia to a strong solution of pure soap, diluting this half with water (the prepared cleaning fluid should also be diluted one-half). Prolonged soaking of the point may ruin it; overnight is quite long enough to soak a badly-clogged point. Usually the point need only be rinsed in running water and put away after use. Replacements are costly, and it is well worth the time taken to give lettering devices proper care.

PASTED LETTERING

Sheets of letters and numbers may be purchased from a printer, and the letters cut out and pasted in place on the illustration. Any size and style of type may be used. Letters and numbers cut from magazines will be found useful in an emergency.

An easier method of using individually-applied letters is a commercial product in which the letters are printed on transparent cellophane. One of these is Para-tipe; another is called Artype (There are other similar products). Letters, numbers, signs, borders, arrows, lines, electrical and musical symbols, etc., are printed in black. To make a line of lettering, the illustrator draws a guide line in faint pencil on his paper and cuts the desired letters from a large sheet of adherent cellophane with a

6. Made by Para-Tone Inc., the manufacturers, also, of Zip-a-Tone.

7. Made by Artype Inc., 549 W. Randolph St., Chicago 6, Ill.
teasing pin or needle, pressing or burnishing them in place. Some symbols, dots, arrows, etc., may be had in opaque white with black background or the black with opaque white background, outline, or shading. The range of sizes and styles of print is very wide. The illustrator may choose any style of print to make a chapter heading or picture title; he may use a fancy border; symbols may be quickly and neatly applied to maps and graphs. Elaborate lettering which would require many hours to do by hand may be done in half an hour by using a modern lettering guide.
A large percentage of the illustrations in a scientific journal consists of maps, graphs and tables. These are intended to organize and clarify the information contained in the text and therefore must be made thoughtfully and carefully. These graphic illustrations should be simple and uncluttered and yet complete.

**MATERIALS**

Special paper and drawing instruments will be used to construct graphs, maps and tables.

**Paper**

*Graph Paper.* Graph paper may be had with the divisions drawn in various sizes, and divided into different-sized fractions. Graph papers are made for many purposes such as cross-section, logarithmic, and mathematical graph papers, and those made for business purposes with divisions by hours, days, months, etc. The illustrator chooses the paper most suitably ruled for the graph or table he must construct. For the rough draft any grade paper with any color of lines may be used, but if the final copy is to be done on graph paper, the illustrator must use pure white, good quality paper printed with light blue or violet lines. Red, green, brown and black printed lines will all reproduce photographically, whereas light blue and violet will not, necessitating the redrawing, in ink,
of any printed lines which are to appear in the reproduction of the graph or table.

**Unlined final paper.** Bristol board, illustration board or any good white posterboard may be used for the final draft. The diagram is constructed on graph paper and transferred to the unlined paper by the carbon method or by pouncing (vid. p. 27).

**Special papers.** Single-tone and double-tone Graf tint may be used to construct bar graphs in which three or four different tones are needed (vid. fig. 10). The tones are hidden in the paper and are made visible by painting on a special developer. There are many available patterns; the Graf tint pattern chart indicates the reduction limit of each. Graf tint top sheet shading film is a transparent overlay film used to give shading effects. It may have a black or an opaque white pattern and is applied like Zipatone (vid. p. 26). It is usually not advisable to draw a wide bar or a series of bars in solid black for this may be too great a contrast with the other parts of the illustration, and because much care must be taken in order to have a solid black area reproduce evenly. The use of Graf tint or Zipatone will facilitate the patterning of the bars.

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1. Made by The Graf tint Manufacturing Co., Cleveland 10, Ohio.

Pens and Ink

Ruling pens. A drafting pen may be used to rule straight lines or graphs, maps and tables. The width of the line may be changed by adjusting a screw on the pen. To make a very wide line, the illustrator may have to rule the line twice; the pen is likely to blot if the points are too widely separated.

The Leroy freenhand pen with various size Leroy points will be found very useful for ruling both straight and curved lines.

Ink. The ink used in constructing maps, graphs, and tables should be absolutely black. Higgins waterproof India ink or an ink of similar quality is suitable. A special non-wrinkling ink is available for covering solid areas without causing warping of the paper.

Pencils. Hard lead pencils (H-3H) will be used
to draw on final paper, while a medium pencil (HB) will be used in constructing the rough draft. The pencils should be kept pointed to insure accuracy.

Rules

**Standard rules.** An eighteen-inch, metal-edged rule will be found very useful since many of the lines to be ruled on a graph or table will be quite long; it is somewhat difficult to join short lines smoothly. The raised metal edge will aid in preventing the ink running under the straightedge and being smeared (vid. p. 10).

**Parallel rules.** A set of parallel rules will be found useful when drawing parallel lines. Other methods of ruling parallel lines are given below.

**T-square.** A T-square, when used with a drawing board, will greatly facilitate the ruling of parallel and perpendicular lines. An extra-long T-square may be used as a rule if care is taken to prevent ink from running under its edge.

When using any rule, the illustrator should remember not to slide the straightedge away from the wet line, but to lift it free of the paper to change its position. The safest procedure is to leave the rule in position until the inked line is completely dry. The rule should never be placed over a wet line. Attempting to draw a new line to or from one which is still wet may cause a blot at the point of the junction. Lines should not be drawn through point symbols on a graph, but to the symbols or separated
from them by short breaks.

DRAWING PARALLEL LINES

The use of the T-square and parallel rules for drawing parallel lines has been mentioned above. Some other methods follow.

Compass

A line may be drawn parallel to a given line by using a compass. At any two points along the first line, the compass point is fixed and two arcs are drawn using the same radius (vid. fig. 11). The second line is drawn as a tangent to the arcs.

![Drawing Parallel Lines, Using a Compass](image)

**Fig. 11**

Graph Paper

If the graph or table is constructed on graph paper, parallel lines may be drawn by simply ruling over the printed lines.

Drawing Parallels By Using Diagonal Lines

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One diagonal and a T-square. In some instances lined paper is not available or suitable and the illustrator may wish to rule evenly-spaced, parallel lines without using odd fractions. The desired rectangular space is delineated (vid. fig. 12, rectangle ABCD). This rectangle is to be divided into eleven equal parts. Lines AB and CD are extended as EAB and DFC. After finding eleven convenient divisions such as eleven inches on a rule, this distance is diagonally located between lines EAB and DCF, and the eleven divisions (G-P) are marked along the diagonal. If side AD is parallel to the edge of the drawing board, lines parallel to DCF may be drawn through points G-P with a T-square.

Two diagonal lines. There is a simple method of drawing equally spaced, parallel lines without using graph paper or a T-square. A rectangle (vid. fig. 13, rectangle ABCD) is to be divided into seven equal parts. Seven convenient divisions are
found on a rule and this distance (line ab) is located between lines EF and GH. Another line (cd) equal in length to line ab, also located between EF and GH, will be parallel to ab. The divisions, previously located on the diagonals, are connected; the connecting lines will be parallel to EF and GH.

Simple Curves

String and drawing board. By tacking a length of string at one end to a drawing board ( Upsom board or plywood) and attaching a pencil or pen to the other end of the string, a simple curved line may be drawn (vid. fig. 2).

Freehand. The illustrator may draw a curve on rough draft or final paper by making light, sweeping strokes of the pencil until the desired curve is obtained. Inking should be done by the following method.

Stencil. After the curve has been drawn freehand
on thin paper, the paper should be pasted to a piece of posterboard and the curve cut out with scissors. This will produce a smooth curve, and, if the stencil thus cut is elevated from the drawing paper by means of a small runner pasted beneath, a clean curved line may be ruled in ink.

**French curves.** A set of French curves made of clear plastic will usually take care of any curved lines that must be drawn. The instruments should be elevated from the drawing paper by strips of thin cardboard or drafting tape to prevent ink from being smeared over the paper.

**SOME MAP TECHNIQUES**

4

**Scale**

The scale of a map may be designated in one of several ways.

**Words and figures.** The scale may be written out as: Scale: 2 inches = 1 mile.

**Graphic representation.** The actual scale may be drawn on the map, usually near the direction (north-south) marker. The direction marker itself should be simple and clear. If the map is to be reduced, this bar scale is the only scale designation feasible (vid. fig. 14).

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Representative fraction. This fraction gives the numerical ratio which exists between the ground and the map:

\[
\text{Representative fraction} = \frac{\text{map}}{\text{ground}} = \frac{3.168}{15,840} = \frac{1}{5,000}
\]

R.F: \(1 = 5,000\)

One inch on the map equals 5,000 inches on the ground.

To figure a scale for a map of unknown scale, the true distance between two points as found on another, authentic map, should be determined. This distance may be 15.3 miles, for instance, and is represented by line \(AB\) in fig. 15. 15.3 convenient units are found on a perpendicular erected at point \(B\). A line (AC) is drawn from the top of the perpendicular to point \(A\). Subsequent lines drawn from the unit points on the perpendicular parallel to line \(AC\) will delineate proportionate measurements on line \(AB\).

Conventional Signs

Certain symbols have been adopted by map makers to designate physical features of the surface of the earth. A few of these standardized symbols are shown in plate 8.

Lettering On Maps

Hand lettering. Accurate guide lines must be
used when lettering by hand (vid. p. 70). A railroad pencil is indispensible in making guide lines for curved lettering. The smallest numbers and letters should be no smaller than one millimeter when the map is reduced. The place name or symbol number should be placed to the right of and not on a line with the map symbol in order to avoid confusion. Lettering should not be printed over lines on the map; the lines should be broken to permit the lettering to proceed unimpeded.

Mechanical lettering. Neat lettering may be done on separate paper (of a quality equal to that on which the map is drawn) and cut out closely and pasted in place on the map. (A map to be blueprinted or ozalided cannot have pasted lettering, vid. p. 97). It is difficult to do curved lettering by means of a mechanical device because the paper or the device must be moved to make each letter. The edges of the cut and pasted pieces of paper will not show in a black and white reproduction.

Area Differentiation On Maps

By line. Areas on a map may be differentiated by varied outlines (solid and hatched lines, and lines broken into dots, dashes, and combinations).

Toned areas. Differentiation of areas may be accomplished by applying a tone to the area such as stippling or hatching or a life-form pattern. This can most easily be done using Zipatone film overlays which may be had in a wide variety of patterns (vid. p. 26).
MISCELLANEOUS MATERIALS

Correcting Devices

**Erasers.** Art gum, rubber, and kneaded erasers will be found useful in map and graph construction (vid. p. for other erasers).

**Covers.** Super-white gouache paint and pasted white paper are used to cover errors, straighten lines and sharpen corners in diagrammatic illustrations.

Small Tools

**Cutting tools.** A pair of sharp scissors is needed to cut the small pieces of paper for covering errors and to cut out lettering which is to be pasted to the map or graph. A
cutting table is useful for trimming the finished illustration as well as to cut to size the drawing paper and the mounting cardboard. X-Acto knives and single-edge razor blades are also useful cutting tools.

**Forceps.** A pair of forceps or tweezers is useful in handling small pieces of paper which are to be pasted on a map, graph or table. Teasing pins will aid in putting very small numbers, letters and symbols in place.

**Symbol stencils.** Eraser shields may be used as stencils to draw locality marks on maps. Some Leroy lettering set templates have various symbols in several sizes; these may be drawn on separate paper and pasted on the map or table.

**Adhesives**

**Glue.** Rubber cement is most often used to hold diagrams drawn on thin paper in place on mounting cardboard. It is recommended for gluing titles and small numbers and symbols into place since paper pasted with rubber cement may be removed without tearing or leaving a spot if reasonable care is exercised. For more permanent mounting, the illustrator may wish to use Wilhold glue or Elmer's glue; but this may cause thin paper to warp or buckle. The most permanent mounting is done with dry mounting tissue (vid. p. 107).

**Gummed tapes.** Drafting tape (or masking tape) is recommended for holding the drawing paper in place while working.
It is also used to prevent ink bottles from tipping, to hold straight-edges in position while lettering, and so on. Gummed cellophane tape may tear the paper when it is removed whereas drafting taps is quite safe to use.

OVERLAYS

In order to show distribution of different plants and/or animals on the same map, the illustrator may wish to use a transparent overlay. This overlay may be done in black and white or in color; it may be line only or it may have a patterned tone or graded color.

Materials

Tracing paper. The overlay sheet should be the same size as the map. The best quality tracing paper or white tracing linen should be used. The lines on the overlay may be inked in black or in color, or an area may be patterned with Zipatone.

Acetate. Transparent sheets of acetate may also be used to construct overlays; ink lines and Zipatone may be applied to this plastic as well as to paper. If one side of the acetate is slightly roughened (like "frosted" glass), ink and pencil may be used readily.

Glass. A grease pencil or ink mixed with a rather thick soap solution is used to draw on glass.

Indication of Color

If the map is to be printed in black with colored lines,
the illustrator may indicate this by making a separate overlay for each color. Each overlay should be drawn in black, with the desired color written on the overlay sheet. Toned color areas are indicated by means of black patterned Zipatone.

Line drawings of biological specimens may also be represented with lines and/or areas in color; the above method should be used to indicate the color to the printer.

Registration Marks

The illustrator must mark any overlay in such a way that the printer will reproduce all the lines in the right places. A registration mark is made on the map in each corner. All overlays are marked in the same way so that when these cross marks coincide the overlaid drawings fit exactly into place on the map.
XI

DUPLICATION FOR RESTRICTED USE

The artist may be required to prepare an illustration which will be reproduced in small quantities such as for distribution in a classroom or to appear in a thesis for which there may be only four copies made. It would be terribly time-consuming and labor-wasting to make four or thirty copies of the same illustration by hand; there have been several devices invented which render this unnecessary.

MIMEOGRAPHING

To mimeograph printed or drawn work, a stencil is "cut" on special wax-coated paper. Printed stencils are made by typing without using a typewriter ribbon. Special tools permit solid, broken and dotted lines to be drawn. A drawing may be shaded by stippling, hatching, or by using special pattern screens which, when pressed into the stencil, will leave a pattern of dots, etc. Ink is applied to the stencil which will penetrate the exposed paper but not the areas still waxed. This stencil is then placed on a revolving drum and as many as several hundred copies can be made. Mimeograph ink is available in several colors.

HECTOGRAPH

The hectograph consists of special ink in a gelatin plate. a "master" sheet is made with any color hectograph ink, applied to the plate of gelatin, and allowed to "set" for a short while. When
the master sheet is removed, the gelatin plate has absorbed the ink and will transfer this to other paper placed on it. One treatment of the gelatin plate will not print as many copies as will a mimeograph machine. The "Ditto" machine is a variation of the hectograph, without a gelatin plate. The master sheet is marked by pressing hard on a special paper which picks up ink from an attached "carbon" paper. It is then placed on a drum which when revolved and fed ink will print copies.

DUPLICATED BASIC DESIGN

The biological artist may wish to illustrate minute but significant differences in several species or subspecies of a plant or animal. He may not want to draw an entire new plant or animal for each variation, and indeed, this might serve only to confuse the issue; instead, he may draw a generalized specimen and reproduce this as many times as there are separate differences (vid., plate 9). In this way he will call attention to the point under discussion and also save unnecessary work. The generalized outline may be reproduced by the carbon-back paper method or by tracing (vid., p. 59), and the variations indicated on these.

BLUE PRINT AND OZALID

The illustration to be blue printed must be done on good quality tracing paper. The blue printing process depends on the passage of light through a transparency, any opaque marks being printed. A correction on a blue print, therefore, must be erased from or cut out of the tracing paper. Blue printed illustrations
are not enlarged or reduced, and are printed on special blue print paper coated with a blue or black emulsion. (Blue coating generally makes a better print than black coating.)

Blue printing is a dye stain process, and consequently is not permanent. Brown printing is more permanent than blue printing, and also more expensive. The cost of blue printing ranges from eight cents to seventeen cents per square foot, depending on the weight of the paper and the type.

Ozalid is a dry process, and is more permanent than the blue printing.

The student should check with his thesis committee before having blue print work done, as blue printed illustrations in theses may not be acceptable.

PHOTOSTATING

Any illustration which is definitely black and white without intermediate greys can be photostated. This includes maps, graphs, tables, pen and ink drawings, and half-tone proofs that have been printed already. The photostat machine will not reproduce a grey line or area, so anything to appear in the print must be clearly black before photostating. The photostat machine reproduces photographically, making a paper negative from a given illustration. This negative is "right reading," not reversed as is a transparent film negative, as the usual reversal caused by the action of the camera lens is counteracted by a prism in position before the lens. A standard photostat machine will enlarge an illustration up to twice
its original dimensions (four times the original area) or reduce it to one-half the original dimensions (one-fourth the original area), and will reproduce to any size between these limits. For ease and generally best results, an illustration should be prepared one and one-half times the desired final size, as the one-third reduction will clear lines and reduce imperfections without losing detail.

Illustrations to be photostated should be done on good quality, pure white Bristol board, illustration board or plate-finsh drawing paper. By "pure white" is meant photographically white which includes light blue but not "cream white." The drawing should be clean and open, with purposeful lines and stipple, not sketchy and weak. Too fine lines are apt to break or close up when photostated. The illustration may be done on blue-lined graph paper if this is firmly mounted on a white cardboard (poster board). Errors and parts to be omitted from a photostated illustration are painted black on the paper negative. Corrections may be indicated on the proof, therefore, and are painted out of the negative, as blotches of ink, shadow lines from pasted titles, etc. The artist should draw a circle around the part to be omitted, or an arrow to it, in blue pencil, or should discuss it with the photostat man beforehand. To make a positive print, the paper negative must again be photostated. Some slight reflection of light from the surface of the negative into the camera is unavoidable, making the lines on the positive somewhat blurred. For this reason, a photostat is not as clear as a photographic print.

The average cost of a photostat is thirty-five cents each,
with slight reduction for larger quantities of prints.

PHOTOGRAPHIC PRINTING

If a wash drawing or a photograph is to be reproduced in a small quantity, it can be photographed and a contact print made from the film negative. This is done on special photographic paper which is thin enough to be used as a page in a thesis. Shadow lines from pasted titles and corrections will appear in the print as faint, grey lines unless opaqued on the negative by the photographer.

Illustrations to be printed photographically can be enlarged and reduced as in photostating. The approximate cost of a photographic print is thirty-five cents, but each negative to be made will cost up to three dollars. It is more economical, therefore, to use already-existing negatives whenever possible.
ILLUSTRATIONS FROM PHOTOGRAPHS

The illustrator may wish to use a photograph which contains one or more faults which render it unusable as it stands.

Some photographs are not suitable as illustrations because retouching is impossible or so extensive or difficult that it is not worth the expense or time. Brown-printed photographs must be rephotographed and printed in black and white; photographs with large burned out areas generally should be discarded; photographs showing little value differentiation may require retouching of the whole picture. Sometimes merely cropping the photograph will improve it by bringing the important part into prominence, as when an uninteresting sky or a black or burnt-out foreground is cut out. If only one corner is very bad, it may be cropped and the title or explanation set in. The illustrator must decide which photographs are worth retouching; he will be guided by the necessity of the illustration and his skill as a retoucher.

1 RETOUCHEO PHOTOGRAPHS

It is desirable to have two copies of the photograph, printed on mat surface paper, in order to use one as a reference while working on the other and to have one in reserve in case the

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1. J. L. Ridgway, Scientific Illustration (Stanford University, 1938), pp 54-61.
first is spoiled. The retouching may be minor, when it is desired to emphasize or cover a small part, or it may be extensive. Unless the illustrator has access to an air brush and knows how to use it, he should not attempt to retouch photographs that require covering large areas.

Hard and soft pencils and a white Conte pencil as well as charcoal pencils are used to bring out shadows and light areas, to emphasize or minimize textures, to throw obscure portions of the picture into relief, and so forth. A very light touch should be used; a kneaded eraser will remove undesired lines. Individual pencil lines should not be apparent on a retouched photograph; smudging, therefore, is employed, but sparingly.

Glossy prints will make sharper illustrations, but they are decidedly more difficult to retouch. If the illustrator is unable to obtain a mat surface photograph, he will have to retouch a glossy print by means of gouache paint. (Sometimes the gloss can be diminished by gently rubbing the surface with drafting powder.) The paint is mixed from pure black and absolute white to the desired grey; any cream or brown tint will be very obvious in the printed photograph. The value of the paint should exactly match the part of the photograph to which it is applied. The gouache paint should be applied carefully and sparingly, and should not be too thin. Blotting the wet paint with an absorbent tissue will lessen the "painty" appearance, or the damp paint may be blended into the picture with the finger. Gouache also may be used to retouch mat surface photographs. It may be "erased" by washing it out with a brush and clear water, but the wet paper
should be blotted immediately to prevent warping.

India ink mixed with Ivory soap will adhere to glossy prints, if the illustrator does not wish to use gouache. The ink-soap mixture is used to draw very dark lines, dots, and so forth.

Numbers and letters may be drawn directly on the photograph using a lettering device or by hand, or they may be drawn on separate paper and pasted into place, in which case the number or letter will appear in the center of a clear space. If the illustrator is in a hurry or his hand lettering or mechanical lettering is not satisfactory, he may cut letters and numbers from magazines and calendars. Lettering done directly on the photograph or put on with Artype or some similar system may disappear into the background unless it is "shaded" on one side, with white in dark areas if the lettering is black, and with black in light areas if the lettering is white.

Retouched photographs should be reduced for publication, whereas reduction is not usually necessary for unretouched photographs.

The illustrator should strive to make his retouching as unobtrusive as possible. The highest praise that can be given for a retouched photograph is to receive no credit at all (vid. plate 2, an example of a retouched photograph).

DRAWINGS FROM PHOTOGRAPHS

Photographs, retouched or not, must be reproduced by the half-tone method. In order to reproduce a picture at a lower cost or to leave out unwanted and unnecessary details, the illustrator may wish to make an exact line drawing from a photograph. He may either trace
the photograph or draw directly on it.

A tracing table will greatly facilitate the task of tracing a photograph (vid. p. 60). Good quality tracing paper or tracing linen is used. The tracing should be done lightly with a hard pencil, with all the ink lines carefully planned in pencil. The inking should be done using the photograph as a reference, not with the tracing still over the photograph.

A second method of making an accurate line drawing from a photograph involves drawing directly on the photograph and then bleaching it. The illustrator uses a waterproof ink such as Higgins American India Ink or an ink made especially for this purpose and obtainable from a photographic supply store, and draws his lines and stipple directly on the photograph. He should have at least two prints, on mat surface paper, printed rather pale so the drawn lines will show clearly. After the ink has dried, the illustrator bleaches out the photograph. The bleach is made of sodium hyposulphite and potassium ferricyanide which can be obtained from a photographic supply store. These powders should be mixed separately, about a teaspoonful of powder to one or two tablespoons of water. The solutions are poured together and painted over the photograph. The yellow deposit left by the bleach must be washed off with clear water.

These "photo sketches" will be reduced for publication as line cuts like any other pen drawing; the illustrator therefore, must use photographs enlarged accordingly.

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1. J. L. Ridgway, Scientific Illustration (Stanford University, 1938), pp 54-61.
XIII

PRESERVATION OF ILLUSTRATIONS

WHICH ILLUSTRATIONS TO PRESERVE

Some illustrations, because of the nature of the media, must be protected from smearing and smudging and other disfigurements as soon as they are done. Charcoal, pastel and pencil drawings are in this category. Other illustrations may be protected for only a short time or permanently, depending on how long they must last.

Most biological illustrations are used soon after they are completed and may then be discarded. These are protected only temporarily, from the illustrator to the printer. If the artist or author wishes to keep an illustration after it has been published, either in his file or to hang, he will want to use a means of protection that will preserve the picture for a long time. Oil paintings, water colors, gouache paintings, and occasionally pencil and ink drawings are preserved permanently.

PRESERVATIVES

Pastel and pencil illustrations are protected by means of a fine spary of shellac or plastic, or by glass, or by both. A shellac fixative is made by letting stand for a day or two a saturated solution of white shellac in alcohol, then diluting this

solution by one-half with water and filtering off the liquid. Sprays can also be bought from art supply dealers. Charcoal fixative, which may be used on pencil renderings, may change the colors in pastel drawings; the special pastel fixative is recommended in this case. After the pastel or pencil illustration has been returned from the printer and if it is to be kept any longer, it should be mounted permanently by the tissue mounting process (vid. p. 107), covered with a transparent acetate or a paper protector, and put in a safe place (or it may be framed and hung).

Ink renderings need not be sprayed with fixitive. When these are returned from the printer they usually contain some blue pencil marks (directions for reduction, engraving, etc.). These marks may be erased or left in place, depending on any further use of the picture. After permanent mounting, the illustrations should be protected with clear acetate or strong paper before they are filed away.

Water color illustrations should be treated as ink illustrations are, or framed and hung. Oil paintings should be varnished in order to prevent certain pigments from changing color. Glass is rarely used over oil paintings.

If a color illustration is not to be kept after it is once published, the artist may use any pigment he desires. On the other hand, if he wishes the picture to last more than a few months, he must use only permanent colors. Any painting which will fade,

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bleed, crawl or otherwise change within forty or so years can hardly be called permanent, and cannot be sold as such.

METHODS OF PRESERVATION

Sprays should be blown from a distance of about two feet onto the upright picture, sweeping lightly over the surface with several light applications in order not to blot or run the medium or spot the picture with fixative. Atomizers, insect sprayers and mouth blowers are used to spray fixative. Plastic fixative comes in an automatic spray can.

Transparent acetate sheets are fixed to mounted illustrations with drafting tape around the edge (the acetate should be cut to the size of the illustration). Paper or saran wrap protection is applied by taping one edge of the protector to the back of the mounted illustration, folding the protector over the front of the picture and taping the opposite edge at the bottom of the illustration or again on the back. The sides of the protector are cut flush with the picture or may be folded to the back and taped.

Glass is not ordinarily used unless the illustration is to be framed, in which case the framer will do the matting and framing with much less trouble than the illustrator is likely to have.
There are many last-minute items to be checked before the illustrations are ready to be sent to the publisher. If the author has an artist do his illustrations, he should check them before they reach the final draft. All numbering and lettering must be double-checked; misspelling is not uncommon among illustrators intent on the formation of letters and not the spelling of words.

CHECKING ILLUSTRATION PROPORTIONS

In order to check the proportions of the completed illustration, the artist should draw or trace a rectangle to the dimensions of the final reproduction (vid. fig. 16, rectangle ABCD). This rectangle is placed in a lower corner of the drawing. If the proportions of the drawing are correct, a rule laid diagonally across rectangle ABCD should also be diagonally across the drawing. The rectangle representing the final reproduction size (ABCD) should be measured minus the legend.

TITLES AND LEGENDS

Some scientific journals require the titles and legends to be set in type by the printer, while others prefer the illustrator to do the lettering. The artist should check the journal which will publish his paper for such points as required lettering, size of plates, and use of text figures.

The illustrations should be numbered on the back in pencil,
as "Fig. 1", "Plate 1", with the name of the author and title of the paper also written in pencil. Plate legends are listed on a sheet of paper enclosed behind the bibliography of the work; figure legends are listed on a sheet behind the plate legends. The figures and plates are placed behind everything else, and the whole work is sent to the publisher arranged in this manner.

Separate Figures

If at all possible, the method of reproduction as well as the kind of paper on which the illustration will be printed should be determined before the drawing is begun in order to know which techniques may be employed and how finely the drawing may be done. Line cuts may be reproduced on coarser paper than will take half-tone reproductions, but rough paper will not take fine lines or
close work well. Glossy surfaced paper will show minute details and fine line better than any mat surface.

Drawings and photographs should be shipped flat, not rolled or folded, whenever possible. The illustrator should pack the illustrations in such a way as to prevent crumpling edges in the mail. (Wide margins may help save an illustration from being crumpled.) The author's name, title of the paper, figure number and reduction directions should be plainly written on the back of each illustration. Corrections on the illustration to be made by the photoengraver are indicated by drawing a loop around the area in light blue pencil, extending a line from the loop to the margin, and writing the directions in the margin. Some simple directions such as "remove" or "delete" may be written on the drawing itself in light blue pencil.

All illustrations should have the edges trimmed neatly before being sent to the photoengraver, and should be mounted firmly and smoothly on white mounting cardboard (\textit{vid., p. 9}). They should be protected by paper covers held in place with drafting tape.

Text figures may not extend beyond the type matter of the text page when the figures are reduced.

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1. "Reduce one-half" means the same as "one-half off"; the final size would be one-fourth the area of the original drawing. "Reduce one-third" and "one-third off" do not mean the same as "reduce to one-third"; a drawing measuring three by six inches would measure two by four inches if the reduction directions read "reduce one-third" or "one-third off"; the same drawing would measure only one by two inches if the directions had read "reduce to one-third." The terminology of the reduction directions must therefore be carefully checked.
PLATES

Unless text figures are necessary for clarity, the illustrator may wish to group several figures on one plate, which is less expensive to reproduce than scattering them throughout the text. All the figures to appear on one plate must be reproduced by the same process, and most journals require that they all undergo the same amount of reduction.

The illustrations should be mounted on white mounting cardboard (posterboard) on which the plate dimensions have been drawn in proportion in light pencil. The darker and larger illustrations should be placed in the lower part of the plate so it will not appear top-heavy. Rubber cement should be used to mount photographs and drawings so that the photoengraver may, if necessary, remove them without tearing.

When grouping several figures on one plate, drawings to be reproduced by line cut (etching) may be mounted a short distance apart because the cut edges of the separate drawings will not show in the reproduction. Illustrations to be reproduced by half-tone, however, should be mounted so that the edges touch since their cut edges will show and must be tooled out by the photoengraver, adding to the cost of reproduction. When separate illustrations lie absolutely flat on the mounting board, the illustrator may be able to obliterate the cut edges by covering them with thick, pure white gouache paint.

2. Wistar Institute Style Brief (Philadelphia, Pa., Wistar Institute Press, 1934), p 44.
If the figures on a plate are to undergo different reductions, the illustrator will have to make a dummy plate. The true plate dimensions are drawn on a white cardboard and rectangles, representing the final, reduced figures are drawn in place. The rectangles must be carefully numbered, corresponding to the separate figures which are likewise numbered on the back. The numbers, titles and so forth are written in place on the dummy. Reduction directions, plate and figure numbers, author's name and title of the paper or book should be written on the back of each illustration, all of which are then put in an envelope attached to the dummy plate.

MOUNTING ILLUSTRATIONS

Mounting Board

The board on which the illustrations are mounted must be stiff and photographically white (vid. p.93). White posterboard is suitable; illustration board is also good, but expensive.

Adhesives

Temporary. Rubber cement is an excellent temporary adhesive to use in mounting illustrations. Too thick an application of the rubber cement, which is not allowed to "set" before the illustration is pasted into place, may cause a spot on the surface of the illustration which will be apparent in the reproduction. The proper way to use rubber cement is to apply an even, thin coat to the back of the drawing and another thin coat to the mounting board. These coats of cement should be allowed to dry for a minute before
the illustration is pressed gently and smoothly into place. Any excess cement may be rubbed off the board with a clean cloth and light pressure. An illustration mounted in this manner will lie flat for reproduction and yet will be removable from the mount if necessary. Mounting to last for a number of years must be done with a more permanent adhesive.

Permanent. Wilhold glue or Elmer's glue is a permanent adhesive; the illustration will tear if an attempt is made to remove it from its mount. The illustration should be smeared with a thin coat of the glue and applied to the mounting board with firm pressure. If the glue is applied to the entire back of a piece of thin paper, the paper may buckle, which will not happen with rubber cement.

The most permanent and smooth mounting is achieved with dry mounting tissue, which can be bought in sheets and rolls from photographic supply stores. A special dry mounting press is made, but an ordinary electric flatiron may be used.

A sheet of tissue is cut to fit the copy to be mounted. The copy is "tacked" to the tissue at two corners with a warm tacking iron (or the tip of the flatiron). The iron is touched to the tissue which is placed over the face-down copy. The tacked illustration is placed in position on the mount and the same two corners are tacked again, this time to the mount (the iron is touched to a sheet of paper placed over the face-up copy). Then the copy and mount are placed, copy up, on the felt bed of the press (or a piece of felt or on a piece of blanket on a flat surface), with a clean blotter covering the copy, as protection. The press (or flatiron), heated
to 175°F, is held down on the blotter for one minute.

It is easy to use dry mounting tissue, and the results are clean, absolutely smooth, and permanent.

USING OTHER ILLUSTRATIONS

Photographs

In order to use copyrighted photographs, the written consent of the owner of the photograph must be obtained and credit given in the publication. Credit is sometimes indicated by the symbol \( ^3 \) and the author's name printed in the lower margin of the photograph. "Photograph courtesy of ..." may also be used to indicate credit.

When using an illustration which has already been published, written permission of the publisher and sometimes also of the artist must be obtained and credit given to both. Credit may be indicated in one corner immediately beneath the illustration or in the legend accompanying the illustration.

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3. J. L. Ridgway, Scientific Illustrations (Stanford University, 1938), p 129.
Occasionally the illustrator must draw from live animal models, because a natural position must be depicted, or the specimen must be saved for further use, there are no other available illustrations of the particular animal or problem, and so forth. Live models present many difficulties, among which is the problem of motion. As in any drawing from nature, the artist must spend at least as much time observing his model as he will spend in drawing it. Sitting quietly near the animal for half an hour or so will enable the artist to learn its fundamental form, how this changes when the animal moves, how it moves; it will also give the animal a chance to become adjusted to the unfamiliar presence of the illustrator.

IMMOBILIZATION AND SPECIAL LIGHTING

An animal may have to be anesthetized before it will remain still enough to be drawn. In the case of reptiles and amphibians, this can be accomplished by lowering the animal's body temperature by placing it in the refrigerator for a few hours. A small amount of chloroform will make some animals drowsy; simply feeding others will keep them calmed. Birds may be kept in the dark until they are needed for actual drawing; usually the sudden light will serve to keep them quiet for a while.

Special pens and cages may be built or improvised for
immobilization of live animals. The cage should be made of material that will not obscure the animal; one side made of glass or lucite may be sufficient. If one-way glass is used, the illustrator will be able to observe the animal without himself being seen, which will tend to lessen nervousness in the subject and lead to more natural actions and poses. Small aquaria and flat-bottomed, wide-topped glass jars may be used successfully when covered with hardware cloth. Long, narrow, shallow boxes may be topped with screen or glass and used to hold snakes and lizards unless these must be depicted in a natural setting. Generally speaking, the animal should have enough room to turn around and assume a comfortable position without being cramped or allowed to roam.

The possibilities of subdued or colored light should not be overlooked when nocturnal animals are to be illustrated. The artist must be willing to work at any hour if he wishes to observe the secretive habits of shy, night animals.

TECHNIQUES

In order to obtain the character of the animal to be illustrated, the artist should make many sketches from all possible angles.

1. Vid. Robert C. Stebbins, "Courtship of the Plethodontid Salamander, Ensatina eschscholtzii," Copeia, 1949(4): 274-281, in which Dr. Stebbins gives an account of the courtship behavior of this salamander as observed during several nights by means of a dim red lightbulb. Illustrations accompany the text.
In this way he will gain knowledge of his subject; he will be able to "feel" the contours of the animal. These sketches should be quick line drawings, "gesture" drawings, a particular curve of the body in action, a foot, an expression, and so on. Only after a great deal of sketching will the illustrator know his model well enough to do a creditable drawing. He may base his final picture on a sketch he has made already or he may make a new sketch. It is usually not necessary or desirable to complete the picture in absolute detail; a suggested line may show a characteristic gesture which will make the picture "live."

Precise details may be studied while the animal is more closely confined; lizards and snakes have been held in one hand while drawn with the other, but small mammals are apt to bite unless held in a manner that prevents close scrutiny. Wide mouth quart and gallon jars will hold these animals for precise observation and drawing of details.

The usual tendency is to draw what one knows about a subject, not what is observed. Fur resembles masses with soft outlines and should not be drawn as a confusion of lines. Occasional hairs may be suggested (vid. plate 7), but the illustrator may become so involved in representing individual hairs that he will lose the form and character. (Coquille board and Ross stipple board may be used to advantage to draw fur; individual hairs may be suggested on the Ross board by scratching with a knife.) Only the outlines of feathers are seen from a short distance; even these disappear as the bird recedes from the observer. Scales may be suggested in medium value.
areas and not drawn at all in highlight and shadow areas unless the scale pattern is the important part of the illustration. The illustrator should not depict minute details and large features in the same drawing, for this would be incongruous.

DRAWING UNSEEN ANIMALS

If the illustrator is required to draw an animal which he has never seen, of which he is unable to obtain a live model, he will have to make use of other illustrations. One photograph or drawing will not give him sufficient information about the subject; he should study as many pictures as he can find in order to see the animal in different poses and from all angles. (A book or illustrated paper on the particular subject should be sought for this will contain many illustrations for study.) If a certain species of bat is to be illustrated, for example, and the artist has never seen one of these, he should obtain photographs of different species of bats as well as the desired species so that he will obtain a knowledge of the essential characteristics, the "batness" of the animal in general and of his bat in particular. If photographs are not available, one will have to resort to drawings and paintings. These may prove unsatisfactory because the artist's conception of the animal is faulty and he may have projected his misconception into his picture; drawings by several different artists, therefore, should be studied, and unless one is known to be particularly accurate, a compromise is made which is based on several drawings. (Straight copying is neither ethical nor artistic.) Stuffed and mounted models as well as sculpture should be studied when possible.
The illustrator should read carefully any accompanying descriptive literature when studying pictures since this may alert him to points obscured in the illustrations.

A list of references to illustrations is given on page . Some of these are useful for feeling, some for studying detail, drawing techniques, and so forth.
LINEAR PERSPECTIVE

It is not expected that the biological illustrator will be required to produce an elaborate picture based on exact linear perspective; for that reason, only a few basic rules and constructions are offered here. For a more detailed discussion, the illustrator should refer to textbooks on perspective.

Objects in space appear to change in size as they recede, parallel lines seem to converge, and horizontal lines do not remain horizontal. Drawings, to be convincing to the viewer, must at least approximate these conditions. To do this, the artist applies linear perspective.

This problem is to give, in the two dimensions of the drawing paper (the picture plane), an impression of the three dimensions of the object in space. The illustrator bases his drawing on a plan. If the picture is drawn exactly to this plan, it may, in some instances, appear disproportionate. The idea is to learn the laws of perspective well enough to supply them without having to measure mathematically every line and angle; the artist usually deviates somewhat from exact, correct perspective, but this

deviation is effective only when it is done with a knowledge of the underlying plan. The laws of linear perspective should be understood so that only a mental plan is needed.

One-Point Perspective

The simplest method of representing a three-dimensional figure in a two-dimensional space (i.e., the picture plane) is to draw it in one-point perspective, in which only one vanishing point is used (all parallel lines converge to a point on the horizon called the vanishing point). Line AB in fig. 17 is the horizon line, called HL in subsequent figures. (The horizon is always at the eye level of the observer, whether it is placed high or low in the picture.) Fig. 17 shows the objects below the horizon; fig. 18 shows the object on the level of the horizon (i.e., on the level of the observer’s line of sight).

![Fig. 17](image1)

![Fig. 18](image2)
A row of equally-spaced figures can be drawn in proper recession by using one-point perspective. Fig. 19 demonstrates this problem. The vanishing point is located (A), and the base line of the receding objects is drawn from it (AB). The first object (DB) is located on the base line, and the height of the following objects is determined by drawing from the top of the first object to the vanishing point (line DA). The base of the second object is located (Point F) on the base line; the top of this object will be at the point where EF intersects DA. A line (AC) is drawn parallel to the base line, which will also disappear into the vanishing point. If a line is drawn from the top of the first object through the base of the second object to intersect line AC (at c), and if this connecting line is extended in the other direction to the horizon line, a measuring point (MP) is established. By drawing a horizontal line from
Point F to intersect line AC (at point G), and drawing from this point to MP, the position of the third object is located on A B. Successive objects are located by this method.

Two-Point Perspective

When a side of a figure is not parallel to the picture plane, two-point perspective must be employed. Two vanishing points are found on the horizon, one for each visible side of the figure. See figs. 20 and 21 for examples of two-point perspective.

It will be noticed that the center of a plane in perspective can be found by drawing diagonals through the plane (fig. 21).
Three-Point Perspective

This system is rarely used in biological illustrating. It is needed to represent an object viewed from above or below, in which case three sides of the figure are seen.

Circles and Curves in Perspective

A circle in perspective is drawn by enclosing it within a straight-sided figure (vid. fig. 22). The figure enclosing the circle is drawn in correct perspective, and the circle is inscribed freehand. A cylinder may be drawn by inscribing circles in the top and bottom of a box drawn in perspective.

Curved figures with more complex outlines are drawn in correct perspective by means of coordinate squares (vid. fig. 23).

Fig. 22
Reflections

Reflections are drawn as demonstrated in figs. 24 and 25. In Fig. 24 the object is directly in front of the observer. Its highest point (A) is reflected directly below as A', and is the same distance down from the base (B) as A is above.
In fig. 25, the object is tilted obliquely towards the observer, and the reflection falls as in the preceding example, except that the direction and angle of tilt change the position of Point A over the reflector, and the reflection appears to fall farther forward. Actually, distance $AE$ equals $\frac{1}{2}$. The line from the figure to the vanishing point is decided by the angle of the object over the reflector.

**AERIAL PERSPECTIVE**

By aerial perspective is meant the artistic expression of space by loss of definition, value range, and color warmth, which is due in nature to intervening atmosphere between the observer and the object. The greater the distance between, the more obvious these effects will become.

As a figure recedes, detail is gradually lost. In walking away from a tree, for instance, the viewer will notice the individual
leaves being lost into leaf masses, and then these will fade into the whole tree until it is just a shape without form.

The warm hues seen in a close-by mountain will change to purple as the mountains recede, until finally the color is a cool, pale blue.

Objects close to the observer have a greater range of values than objects farther away. Thus, the deepest shadows and lightest lights are closest, while background figures tend to appear grey (vid. fig. 26).
Aerial perspective may be shown in black and white illustrations by using sharper lines and greater range of values in the foreground figures than in supposedly distant objects. Color change from warm to cool, as well as loss of detail and values, will denote aerial perspective in colored illustrations.
SUPERFLOUS DRAWING

There are occasions when elaborate illustrations are not in order. The illustrator must decide what are the important points and how to illustrate them to the best advantage of the reader. The purpose the illustration is to serve must also be considered.

Often a simple line drawing will be adequate, whereas a carefully wrought, detailed rendering may scatter a beginning student's attention and thus serve only to confuse. A drawing more detailed than the purpose warrants does not add to the usefulness of the work in which it appears.

An illustration should not require more work to make than its purpose warrants. Using an elaborate drawing where a simple one would suffice is a waste of time and labor. In plate 10, A is intended for the use of the beginning science student, and required thirty minutes to complete. B, which took fifty minutes to draw, might serve the same purpose as A, but C, which took over an hour and a half to complete, would tend to confuse the student.

The illustrator may have trouble deciding when to stop working on a drawing; overworking can become a habit. Generally speaking, the illustration is finished when a viewer can understand it clearly, when the subject is depicted adequately without superfluous detail. Further working over the drawing may destroy its liveliness and obscure the point.
Plate 2. Microscope camera lucida

Photograph courtesy of American Optical Co.
Plate 3: Speedmatic microprojector

Photograph courtesy of Bausch & Lomb Optical Co.
Plate 4. Triple-Purpose microprojector

Photograph courtesy of Bausch & Lomb Optical Co.
Plate 5. Balopticon projector

Photograph courtesy of Bausch & Lomb Optical Co.
Plate 6. Arizona Oak Leaves, genus Quercus. Stipple with outline, shading indicated by stipple and by heavier line on shadowed side.

The outlines were traced around the pressed leaves, the details being added later.
Plate 8a. Conventional signs used on maps.
CONVENTIONAL SIGNS USED ON MAPS

STREAM (PERENNIAL)
STREAM (INTERMITTENT)
LAKES AND PONDS
(PERMANENT)
(INTERRMITTENT)
(DRY BED)

MINE OR QUARRY

BRIDGE

RAILROAD (SINGLE TRACK)
(DOUBLE TRACK)

BUILDINGS

TOWN ••••
CITY

TANKS

FENCE (IN GENERAL) -------
(STONE) -------------
(BARBED WIRE) *****
(WORM) -----------

U.S. MILITARY MAPS:
BLUE = WATER, GREEN = WOODS,
BROWN = CONTOURS, BLACK =
WORKS OF MAN, THE GRID.

ROCKY LAND

WOODLAND

GRASSLAND

TRIANGULATION POINT

BENCH MARK

HIGHWAY

SECONDARY HWY.

SURFaced ROAD

DIRT ROAD

TRAIL

PROSPECT
Plate 9. Subspecies of the Desert Iguana, Dipsosaurus dorsalis, Demonstration of the use of a duplicated basic design.
Plate 10: Amoeba proteus. Three renderings demonstrating degrees of detail.
Literature Cited


LIST OF ILLUSTRATION REFERENCES

(Ink sketches good for feeling and movement but not for detail; color plates poor.)

(Black and white mammal illustrations by C. E. Schafer in a variety of techniques, some very good.)

(Excellent color plates and ink drawings; text gives distinguishing characteristics.)

(Black and white drawings, some very good.)

(Some ink drawings and many photographs.)

(Excellent pen and ink drawings by Lucretia Breazeale Hamilton.)

(Illustrated by T. M. Shortt, excellent line drawings and color plates.)

(Very good scratchboard illustrations, the animals done by Walter Weber.)

(Superior black and white illustrations using several techniques, by the author; with descriptive literature.)