A METHOD OF ILLUSTRATION FOR ZOOLOGICAL PAPERS

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By
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"Is not the answer that Demos has all along preferred pictures to print, and only read books and newspapers because he could not get pictures readily and cheaply enough? The pen is a parvenu compared with the brush and the chisel—or their progenitors."

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PREFACE

I HAVE been asked to publish an account of a lecture which I delivered to the Association of British Zoologists in January, 1934, at a symposium on "Apparatus for Illustration." As I explained at the time, the only apparatus I used was pens, ink and paper. My excuse for speaking was that I had standardized a method of illustration in black and white which has been of use not only to myself but to my students and colleagues. I claim no originality for the method—in fact it all arose from help given to me by that most meticulous of workers, the late W. G. Ridewood—but I do claim that any zoologist, as long as he can draw a reasonably straight line, by following my method can turn out drawings that are really convincing. This is no mere conjecture; it is based on my experience during the last ten years or so, during which I have had the pleasure of helping a variety of workers, some of whom scarcely knew one end of a pencil from the other, but all, without exception, have found my method easy to follow, and have produced really good illustrations for their papers.

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INTRODUCTION

THE modern scientific paper is a product of intense specialization, and this applies to zoological papers perhaps even more so than to other sciences. The days when it was possible to be a real zoologist—those happy days when every one worthy of the name knew more or less the anatomy of all classes of animals—are gone and we are left with a plethora of subjects for research; subjects which in the light of the researches of the end of last century may be regarded as the minutiæ of detail. We deal with the kidneys of water-fleas, the profundities of the Golgi Apparatus, or with abstruse chondrocrania. The fact that emerges from this, and it is a fact that must be faced, is that very few people read our papers. We should, all of us, like to read any good zoological paper, but as often as not our own specialization makes it extremely difficult to understand clearly the results of some piece of research not directly in a line with our own. This is of little importance to those who are in the position that they need not worry about what their colleagues think of their papers. But to most of us, and especially to the beginner at research, this is, as it should be, something of great importance. Apart from the natural desire to spread the knowledge of results arrived at after the expenditure of so much energy, it must be remembered that promotion comes largely by research. Therefore, to make one's papers readable, and by this I also mean understandable, should be one of the main objects of all researches. Most of us can write papers that can be read, but it is quite a different matter to present our results in such a form that they are *easily* grasped by our colleagues.

Now children learn readily from pictures—and so do zoologists. A good picture is often worth pages of writing, for zoologists on the whole are busy people, and have not time to wade through pages of description without explanatory illustrations. There are many papers I am certain which, either through lack of illustration or from faulty illustration, have missed the mark. It is therefore to the advantage of every one concerned if the author will put as much energy into the illustrating of his paper as into its writing.

To illustrate a zoological paper is neither an art nor a science, it is an exercise in common sense; and it is something all workers can do well if only they will spend sufficient time considering what illustrations to publish and how to publish them. I feel that the fault of many papers is that they are illustrated entirely from the point of view of the author. Now this should not be—the illustrations should be for the other man. For example, so often some complicated section is figured, and of course the author understands it; but then he knows the whole anatomy of the animal. The important point is

whether or not zoologists generally will understand it. The object of the worker should be to devise figures which represent his main results at a glance—diagrammatic if necessary or, as is usually the case, semi-diagrammatic. Figure sections by all means if they help, but make certain that other figures are published which it is reasonable to suppose are understandable to your fellow-workers without too much effort. The figures should, in a sense, represent the summary of all the main points obtained, and this is a good rule on which to work. Having finished the piece of work, make certain that each important point in the summary has at least one illustration which explains it.

When you have settled what is to be figured, the next question to decide is what form the illustrations shall take, and where they shall be placed. Some workers appear to believe that plates at the end of the paper give it an air of distinction, and are thus to be preferred to figures in the text. This is an entirely misconceived idea, for they fail to realize that text-figures are by far the most convenient to the reader. After all, zoologists are only human, and the effort of turning to the end of the paper to search among the plates for the relevant figure is sometimes too great, and the figure is not referred to, or else is merely glanced at when the paper has been read. Where possible use simple text-figures, and place them as near as can be to the text describing them. Of course this is not always possible, as a figure may be referred to in numerous places in the text. In this case place it at the first important reference to it, for it is easier to carry a picture of the figure in the mind than to turn over pages and search for it.

The method of making text-figures that I describe in this book, allows them to be produced by the cheapest printing method. This question of the cost of reproduction is of importance to all of us, but it is often overlooked. Some workers will produce very beautiful and elaborate plates at the expense of a great amount of trouble, and are then disappointed that the additional cost of the plates may lead to the rejection of their paper. I do not want it to be thought that I am suggesting that plates at the end of a paper should never be published. Sometimes they are necessary, but unless they are really essential it must be remembered that they are a luxury. Wash drawings, photo-micrographs, coloured plates can all be used with great advantage, but it is always as well for the author to satisfy himself beforehand that the extra money is available for their publication.

One of the chief drawbacks that I find among research workers, whom I have been able to help in the production of their papers, is their lack of knowledge of the elementary methods of printing, and the possibilities that are open to them in their methods of illustration. I have therefore devoted a section to an explanation of how a simple "line block" is made, and then, after describing the method I use for my text-figures, I describe various processes that may come in useful, and certain rules which I think it advisable to follow in order to obtain the most satisfying results.

PRINTING

METHODS of illustration may be roughly divided for our purpose into two groups. The first is that used for what I call the "line" drawing, that is a drawing in pure black ink on a white ground, which may consist of lines or dots, or a combination of both. It is this type of drawing, with its various modifications, that I deal with in this book. The second group includes pencil sketches, black-and-white paintings, or photographs.

The cost of making a printer's block of a line drawing is sixpence a square inch, with a minimum charge of about seven shillings. All other types of drawing have to be reproduced by some more elaborate and costly method. There are many such processes, and it is of course impossible to detail them here, but the point to bear in mind is that they are all relatively expensive. As an example, one of the most usual is known as the "half-tone process." This is the process used in reproducing photographs in newspapers; and the same method, but with a more delicate "screen," is often used for scientific illustration. For the making of such a half-tone block the charge would be about elevenpence a square inch at least, again with a minimum charge for fourteen square inches.

This minimum charge must not be overlooked. You may produce a drawing which when reduced to an appropriate size for printing occupies, say, 6 square inches. The charge for this will be the same as if it covered 14 square inches. By grouping together small figures which are all to be reduced to the same degree, it is sometimes possible to produce a block covering more than the minimum area. In this case an economy is made, as the charge is for the combined area. Thus, when several small figures of related or comparable parts are required, it is best not to scatter them piecemeal throughout the text; it is more economical, as well as more convenient, to group them together in a single block occupying the full width of the letterpress. Individual figures in such a composite block may be lettered *a*, *b*, *c*. . . .

Thus the line drawing has the great advantage that it can be reproduced by the cheapest method—the "line process"—but also it has further advantages. The line block can be set up with the type of the letterpress and printed on the same paper, which means that drawings reproduced by the line process can be reproduced as text-figures. Until recently half-tone blocks could only be printed on a smooth surface paper, and hence all drawings reproduced by this method had to be printed on a plate separate from the letterpress. Nowadays, with the development of the "offset" process it is possible to print half-tone blocks, or at least to produce a half-tone effect, on a paper with a relatively rough texture—that is of the type used for the ordinary

letterpress of any scientific journal—so that we can now illustrate our papers with half-tone text-figures. Offset printing on to rough paper produces a very beautiful effect, but this is because the microscopic dots, of which the half-tone print consists, become slightly blurred during the printing process. In other words, the final print, compared with a print on smooth paper, is slightly out of focus. Now while this may be advantageous in the illustration of some scenic effect, it is just what we do not want in illustration of scientific papers.

The first step in the making of a line block is to photograph the original drawing so as to obtain a negative of the size at which the figure will be finally printed. The negative is then used to obtain a positive picture, in the same way that one would proceed in printing an ordinary photograph, but instead of using a sensitized paper, a sensitized metal plate is used. This is made by coating a sheet of metal—zinc is almost invariably used except where extremely delicate detail is required, when it is replaced by copper—with an aqueous emulsion of albumen containing ammonium bichromate, a mixture which has the property of becoming insoluble when exposed to light. Now where the negative is pale, that is in the black areas of the original, the light passes through on to the plate and renders the emulsion insoluble. On the other hand, black areas on the negative, corresponding to the white of the original, will prevent the light passing, so that the emulsion covered by these areas remains unaffected, and hence soluble. After exposure the metal plate is covered all over with a specially prepared ink and then washed with water. The still soluble emulsion washes away or is gently rubbed off, while the emulsion which has come under the influence of light, being now insoluble, remains and, because of the ink, stands out as a black positive of the original. The plate is now dried and slightly warmed until the ink becomes tacky. It is then dusted with a resinous powder called "Dragon's Blood," or ordinary fine bitumen powder, which sticks to the ink but not to the clean surface of the metal. The plate is then thoroughly washed and heated until the resin melts, and, together with the insoluble emulsion and the ink, forms an acid resisting coat or enamel.

We now have a plate corresponding, line for line and dot for dot, to the original, but in which the lines and dots, instead of consisting of ink on paper, consist of an acid-resisting enamel on zinc. This plate, called the enamel print, is now ready for etching.

The principle of the etching process is that acid is allowed to act on the surface of the plate, with the result that it eats into the unprotected surface while all the lines and dots of enamel protect the underlying metal from its action. The picture is thus made to stand up from the metal plate. A dot will appear as a squat pillar—a line as a flat-topped ridge. If such a plate is now rolled with a roller covered with ink only those parts which stand up will be inked, the valleys in between which have been etched away will remain clean. An impression of this on paper will clearly give a permanent reproduction of the original.

In this short account I have only given the outline of the process. My

object has been to give the ordinary zoologist some idea as to how his black-and-white figures are dealt with, so that with this knowledge he will be able to appreciate the points that I consider of extreme importance in preparing the drawing for reproduction.

I have referred above to the final size of the picture as opposed to its original size. Now this is a point which is not always sufficiently considered. To begin with, all figures should be drawn larger than they are required as final prints. Reduction—within limits—sharpens up a black-and-white drawing, as you will find if you look at one of your drawings through a reduction lens—a solid watch-glass is excellent for this purpose. Now you may find it necessary to produce some extensive drawing in which it is impossible to get all the detail you require in a small picture. In this case you must draw your picture large and then submit it for publication to some journal that is published with a large page—say quarto size. Do not think that your figure, however large, can be reduced to fit into an octavo page. It certainly can be reduced, but over-reduction, even with a good drawing, may spoil your effect. On the other hand, do not assume that in a small journal large figures can be produced on folded plates or on double pages. This is an expensive process, and, besides, a picture across a double page is usually spoiled along the fold when the volume is bound.

Assuming that you have decided on the journal to which you intend to submit your paper, now study recent numbers of that journal and obtain an accurate measure of the largest possible size for a text-figure. It is roughly equal to the width times the height of the letterpress, but often you will find that figures slightly larger than this are published. Now utilise this space to its maximum. Thus you may have a column of letterpress $4\frac{1}{2}$ inches wide and your original may be 6 inches wide. Now do not say as usual "reduce to two-thirds this size"—which would be to 4 inches wide—but say definitely "reduce figure so that width equals $4\frac{1}{2}$ inches". Do not despise the extra half-inch available.

Another point which is not sufficiently known is that if one of your figures is drawn so that on the usual reduction it almost fills a page from top to bottom, but leaves an ample margin at the sides, then alter the directions for reduction so that it completely fills the length of the page. Editors prefer it, as it is an expensive process to include a few lines of letterpress underneath a figure just to fill up the page.

When giving instructions for the reductions of your figures always state exactly the reduction you require—do not leave it to the editors—it may lead to disappointment, as I know to my cost. And when quoting the reduction state this in some definite manner—do not say "reduce two-thirds"—this may mean anything. Calculate the actual size of the final figure and quote this both as regards width and height—or else draw a line in ink of definite length just below the figure, and then state what length this should be when reduced to the size you require.

The most convenient size to draw your originals is about 1½ times the size at which they are to be printed. Thus a final figure 6 inches by 4 inches should be drawn 9 inches by 6 inches. Now this is one of the most important points which must be continually borne in mind, not only when planning out the figure but during the actual drawing in ink—and for this reason—there must be no line or dot in your figure which, when reduced to two-thirds its linear dimensions, will be so thin or small that it will not print. In a black-and-white drawing which is to be used as an individual picture you may put as much excessively fine detail as you like—but not if it is to be reproduced and printed by the line process. I know of many figures in which the originals in themselves have been as near perfect as can be, but on printing, just the fine detail which made them appear so good has either disappeared or appears as a blotched effect. Printers and block-makers can do most things with the modern development of printing—there is scarcely anything that they cannot reproduce accurately *if they are given a free hand.* But for scientific publication this is not the case. There are two main factors—the surface of the paper used by the journal, and the cost. While a block-maker will guarantee to reproduce accurately some detailed drawing if he can choose his own fine surface paper, this may become an impossibility on the paper which the printer of the journal is obliged to use. In fact, the proofs which you receive of your line drawings are pulled by the block-maker and, naturally, he uses a fine surface paper. On this every detail that you wish for may appear, but do not be too hopeful—compare the paper of the proof with the paper of the journal before finally passing them as satisfactory. You can correct a block by having a new one made, say, on a larger scale; but you cannot alter the paper of the journal—at least not easily. And then as regards cost; the block-maker, by interesting refinements, can sometimes protect the finest details of a drawing so that they do not disappear from the block, but this is very skilled work and takes time—hence it has to be paid for as an extra.

I will now try to explain why it is that fine details are apt to be lost in printing. In figure 1*a* I have drawn an imaginary section through an enamel print—that is the plate as it goes into the etching-bath. On its surface there are four dots, *a*, *b*, *c*, and *d*, of different sizes. Immediately the acid commences to eat downwards into the metal, depressions or valleys are naturally formed in between the dots. Now valleys have walls as well as floors and the acid works in all directions: that is, it will proceed to act on the walls of the depressions and so undercut the protective layers of enamel.

Actually the etching process is carried out as a series of etches. During the first etch the acid is only allowed to act for about 30 seconds. The plate is now washed and, by a simple method, the walls, and walls only, of the depressions eaten out by the acid are covered with "Dragon's Blood," and so protected from the further etching. The plate is then passed through more etching-baths, and between each etch the walls are again protected. But it is during the first etch that the damage is done. The amount of undercutting

will naturally depend on the strength of the acid and the duration of the etch; but clearly it will be the same for all dots and lines whatever their size. The effect of this is shown in figure 1*a*. Around each dot the acid has undercut and left a projecting ridge of enamel. Now the enamel is not very strong and so breaks off, and this reduces the size of the dot left standing up on the plate. In the case of dot *a* the diminution compared with the original size of the dot

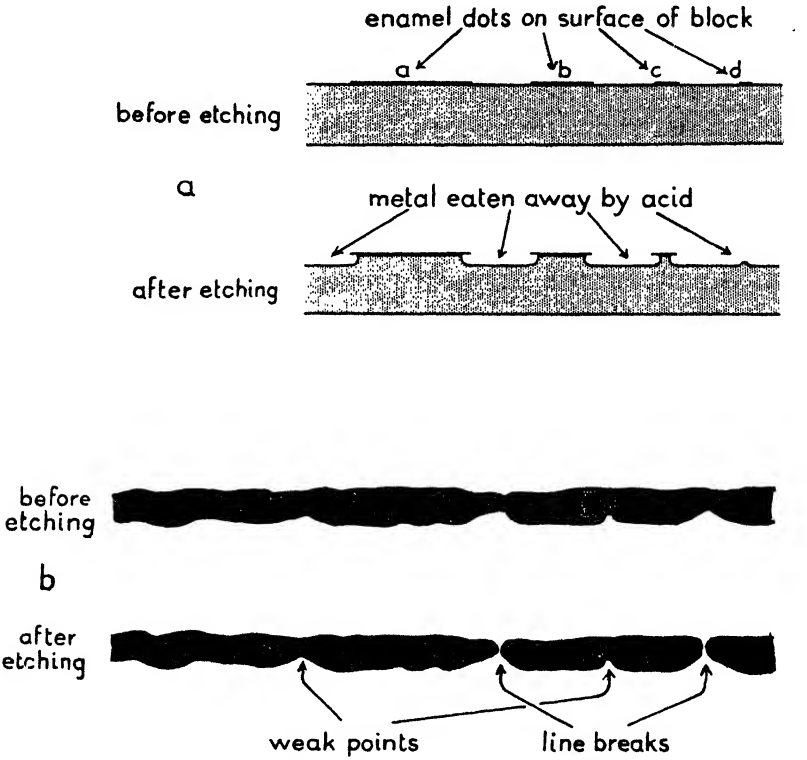


FIGURE 1

(*a*) Section of block before and after etching to show undercutting of enamel by acid and consequent diminution in the size of dots—or their complete disappearance.

(*b*) Magnified view of badly drawn line as it would appear on the surface of the block before and after etching to show how the narrow parts of the line break down owing to the undercutting by the acid.

is negligible. In dot *b* the final dot is definitely smaller than the original. Dot *c* is left as a thin pillar which will, in fact, become more and more of a pillar with subsequent etches; while dot *d* has been etched away and so will not come out on the print.

Thus in your original you may have produced a beautiful shaded effect by innumerable minute dots or, as more often happens, by a graded mixture of large and small dots. Now in the production of the block the smallest of these

dots will be etched away completely, while those a little larger will be too unstable on the block to print off more than a few copies. The result is that where your shading merges into a high-light—and it is here that the mistake is usually made of placing extremely small dots—the dots do not print at all, and hence your shading instead of merging gradually into the high-light does so abruptly.

The effect of undercutting is naturally produced on lines as well as dots. In figure 1*b* I have drawn a magnified picture of a badly drawn line—the type produced by drawing across the nib instead of drawing along the line (see later, p. 10). It will be seen that in places the line is thin. If these are thinner than a certain size, they will break down just as in the case of the dot, and gaps will appear.

While the trouble with isolated dots and lines is bad enough, it is not as bad as the effect of undercutting on deep shadows where the effect has been produced by dotting or shading with lines at random. It is a very common mistake, even among expert artists, to increase the intensity of a shadow simply by adding a few dots or strokes until dark enough. To begin with, if the dots are minute they will be etched away, as I have explained above, and leave white gaps on the print; but there is another important effect which comes in here. If dots, even respectable-sized dots, are placed at random, there is no control over the size of the gaps between them—some will be large but others excessively minute. Now it is on these gaps that the acid works during the etching process. During the first etch of 30 seconds the acid will eat into the metal however small the gap. But now the plate is washed and dried and dusted with "Dragon's Blood," as I have explained above, and nothing can prevent the resin getting into these minute gaps between the dots and filling them. In other words, after the first etch they are completely protected from the etching fluid. As a result they do not appear at all on the final print. An examination of the block under a lens will show them as extremely fine depressions, but they are so shallow that when the block is inked they too retain the ink and so print black instead of white.

An irregularly shaded area is thus apt to come out blotchy—white patches where the dots have been drawn too small, and black areas where the dots or lines have been drawn too close together.

The remedy is simple—when you are shading your drawing *never draw at random.* Always place each dot and line just where you want it. You will then have no difficulty over controlling the size of the gaps between the dots. Even more important, choose carefully the size of your dot. In the method I describe in this book I use a uniform size of dot, that is, whether I am shading a pale area or a deep shadow, I use the same size. There is no reason why larger dots should not be used, and in fact, I explain how I enlarge some of the dots to produce certain effects, but I never draw a dot below my standard size. As to what this size should be I can give no certain instructions. Figure 4 C represents a facsimile of one of my drawings—that is, it has not been

reduced in making the block—and from it some idea of the best size of dots can be obtained. Needless to say, it is impossible to draw the dots of exactly uniform size. When the nib is full of ink they tend to be large, and when it is running dry they are small and mis-shapen. It is the small dots which must be avoided; ink over them again so as to bring them up to standard size.

The best way, however, to learn the appropriate size of dots is to look through journals or, better still, books illustrated by professional artists, until you find a picture in black and white that is really good, and base your drawing on that. But my advice is always—be bold and choose a large dot. I know it comes as a shock when you start shading a pale area with big black dots, but if you carry on, and, when you have covered a considerable area with shading, half close your eyes and look at it, you will be surprised how smooth an effect you are producing. An additional advantage in a bold drawing with thick lines and large dots is that if by chance, as sometimes happens, you have to transfer your paper from a quarto publication to an octavo, your figure may still stand the extra reduction necessary.

PENS AND BRUSHES

For pens I have a collection of nibs, and am always on the look-out for nibs that may give a good round dot or a steady even line. I do not recommend any special brand, as most nibs come in useful at some time or other. The only make that I avoid is the J type, or any other square-pointed nib. These are useful for drawing broad straight lines, but are dangerous for curved lines and obviously do not produce a round dot. I find that old fountain-pen gold nibs are very useful—especially for large drawings where the lines and dots are bold. Old nibs I prefer, and use them until they actually fall to pieces. They are much smoother at the tip—in fact most new nibs are too sharp at first and take some working before it can be felt under the hand that they are giving a smooth steady line.

Keep the tips of the nibs clean, but only the tips. Leave the mass of dried ink on the base of the nib—it helps to support a well-seasoned nib when most of the temper of the steel has gone. In cleaning the nib, however, avoid touching the tip with the fingers or it will become greasy and the ink will not flow, except as a blot. While drawing, the ink is continually drying up on the point. This should be wiped off frequently and I find the cloth used by oculists for cleaning spectacle lenses useful for this purpose. Other types of cloth are apt to leave minute hairs gripped between the two halves of the nib. For the very fine work to be done under a lens, which I shall describe later, the finest nibs obtainable are necessary. Ordinary "mapping" pens are too coarse, and for the best work really fine nibs must be obtained at an artists' supply shop.

Paint brushes are of course useful for painting in large black areas, but cheap brushes are dangerous. Only use good brushes that taper to a perfect

point when moistened. For fine white lines drawn on a black surface I make my own brushes by cutting away the outer bristles of a medium-sized brush until only those at the centre are left. In this way the tapered point of the brush is retained supported by a column of bristle about the thickness of a medium-sized pin. This will hold sufficient white paint, but must be continually wiped and replenished. I have also used minute "pin" feathers of such a bird as a snipe mounted in pin vices as fine brushes. They give a good point and, at the same time, the brush is flat so that they are useful in drawing fine straight lines.

Indian ink may be made by grinding the solid form in water, but I prefer to buy a bottle of ready-made ink. This is naturally more constant in strength, and also it is waterproof—an important point when drawing white on black. With a non-waterproof ink this is, I believe, impossible.

The main fault with drawing inks is that they tend to dry up long before the supply on the nib has been used. This is important when dots are being drawn. When drawing lines it is obvious when the ink is running out or beginning to clot, but with dots it is not so. The ink clots suddenly between two dots and then the tip of the nib is coated with solid ink, which it is difficult to remove completely. This should be avoided, and as a precaution I always wipe the nib before dipping it into the bottle. This soon becomes a habit, but even so it is surprising how soon a thick clot is formed at the base of the nib.

Another trouble with inks is that they go bad without showing any obvious sign. A line drawn with such an ink appears normal, but under a lens it will be seen as a dark grey line covered with black specks. This is very important in any drawing that is going to be reproduced, as in the block-making process such lines are apt to break down. Ink that has not been used for some time should therefore be tested before any drawing for reproduction is made with it. The ink that I find best is "Stephen's Black Drawing Ink (Indian Ink) No. 191." This clots slowly and runs very evenly from the pen.

For white on black I have found no satisfactory white ink. I always use a good stiff white paint, of the consistency of cream, and paint it with the brush I have already described. It is necessary to go over each line or dot more than once to get a really good white. There are special white paints made for this purpose, the best of which is "Process white."

Always use Bristol board for drawing. It is expensive, but it is worth the money. It has a very fine surface for black-and-white drawing, but, what is more important, any mistake or blot can be scratched out again and again until the Bristol board becomes as thin as tissue paper and it still preserves a surface that will take the ink well—that is, if the scratching out has been done properly. The value of this property of Bristol board cannot be overstated. Most good drawings are altered time and time again before they are ready for reproducing, and blots and smudges cannot be avoided altogether. Never waste a drawing by doing it again; scratch out the mistakes, unless there are

too many. To do this use the curved edge of the blade of a very sharp scalpel, but never use the point. Hold it so that the blade is vertical to the paper and scratch lightly backwards and forwards in one direction. Then turn the paper at right-angles and go over the same area. This may have to be done several times before the scratched out area is perfectly clean. Never mind if you scratch out more than you intend—it can be drawn in again. When the patch is quite free from any mark, go over it with a clean indiarubber. This pulls off any minute pieces which have been scratched loose. Then finally polish the surface with something smooth, such as the bone handle of a scalpel or, better still, the smooth round top of a fountain-pen. You will then find that it will take the ink as well as the unscratched surface. It is slightly more absorbent, but this only means that the ink will dry more quickly.

It sometimes happens that it is decided to alter a drawing radically. In this case do not scratch out the area it is decided to alter, but cut it out and stick a window of fresh Bristol board in its place. This is a simple procedure: suppose it is decided to cut out a patch about three inches square, obtain a strip of the same Bristol board as has been used in the original drawing, about 5 inches wide, and pin it firmly down on to a wooden board across a strip of plate glass. Lay the drawing across this strip so that the area to be renewed lies entirely over the strip and also over the glass plate, and pin it down firmly. Now with the point of a heavy sharp scalpel cut hard round the area and through the underlying clean Bristol board. You will then obtain from the underneath strip a piece of Bristol board that fits closely the cut-out hole in the original drawing. By cutting on to plate glass a very clean edge is obtained to both the hole and the piece to be inserted. The drawing must now be stuck onto cardboard and the new piece stuck in place. The cut made by the scalpel is at first visible, but this can be obscured by smoothing it over with a fountain-pen top, as in scratching out. Even if it is visible in the final drawing it is of no consequence as it will not come out on the printers' blocks. After a little experience a part of a drawing of any shape can be replaced in this way, but until you have had practice it is best to cut out some straight-sided figure, e.g., a triangular piece, and use a steel ruler against which to cut.

Another very useful point about Bristol board is that it is "transparent". With an ordinary electric light bulb behind, it is possible to trace a pencil drawing through it, and this is a great advantage over those opaque prepared cardboards such as "Fashion boards," which are often used for illustrations. For tracing I possess a drawing-board of plate glass mounted so as to leave room underneath for a light, but in daylight an ordinary window-pane is just as efficient. I only use my drawing-board when it is dark, and also sometimes in the winter when the window-panes become unbearably cold. Obviously, if an alteration has been made in the drawing and the Bristol board has had to be pasted onto cardboard, it is impossible to trace direct through the board. It is as well, therefore, to do all the main tracing before beginning the drawing.

There are various thicknesses of Bristol board, the thinner sheets naturally being less expensive than the thicker. Thick sheets stand more scratching out and are easier to handle, but I always use thin sheets on account of their transparency. If the drawing to be traced on to them is complicated it is essential that they should be as transparent as possible, but even if the drawing is relatively bold and simple you never know when you may want to trace some addition on to it. Apart from this the cost is an important factor as Bristol board is not cheap.

DRAWING

BEFORE drawing anything for scientific illustration it is essential either that you should have the object to be drawn in front of you, or that you should be able to picture it as a solid object in your mind. *In either case rough pencil sketches are indispensable.* Never attempt to draw in ink direct from the object. Draw the picture first in pencil on ordinary smooth paper that will stand a fair amount of rubbing out. Make your pencil sketch as detailed as you like—incorporate all the hasty sketches from your rough notes—use coloured crayons if necessary to bring out separate structures and see that you have drawn in everything that you wish to show in your final figure. The importance of these preliminary sketches cannot be over-emphasized. It is in this process that you find out whether you really do know what it is that you want to illustrate. As often as not at the first attempt you find that you have no certain idea as to how some parts of your proposed figure should actually appear, and this means doing another rough sketch of this part. I have often worked for months before I have collected sufficient drawings to put them together into one pencil sketch for my final figure. The pencil drawing, once made, can very rapidly be translated into black and white, but when this has been done do not throw away the sketches—keep them, for they may mean more to you than do the final published figures.

ON DRAWING OUTLINES

THE final pencil sketch, having been completed, should be traced with a fairly blunt pencil of hardness H on to the Bristol board, but only trace the main outlines—do not trace the detail. This should be drawn in free hand afterwards with an HB pencil. Keep the pencil very sharp for the detailed work by rubbing it on a piece of fine glass paper. Now the outline may be inked in.

The pen should always be held in the position shown in figure 2 *a*. That is, it should be held symmetrically over the line, and this should be drawn from left to right away from you.

Always draw from the elbow. If possible, use a large flat table, not too high, over which you can sprawl. Then keep the elbow fixed and move the

whole forearm, using the wrist only slightly. In this way you will obtain an even line. This is important, not only from the mere look of the thing but also from the point of view of reduction in printing. If you draw across the point

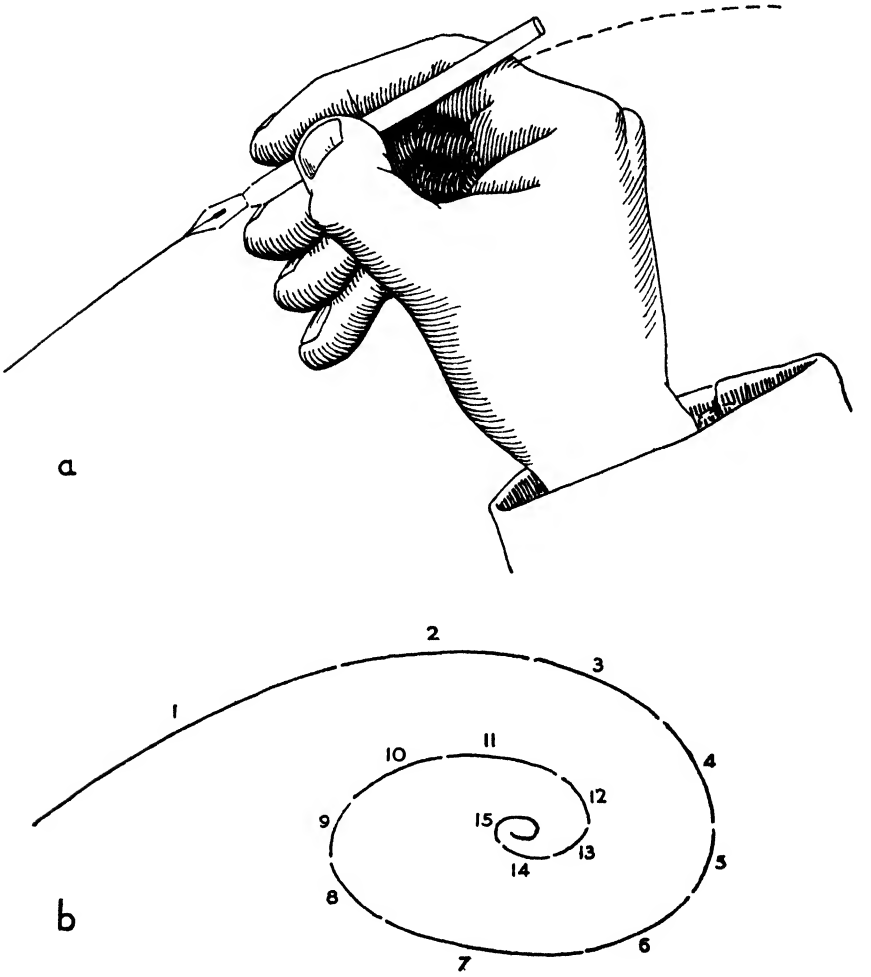


FIGURE 2

(*a*) Drawing showing the position in which the hand should be held in drawing outlines.
(*b*) Curved line showing the separate strokes required to produce it.

of the nib you will obtain the bad type of line which, as I have already explained (p. 6), will break down on reduction.

By this method long flat curves or straight lines can be drawn at one stroke, and the quicker you can draw them the more regular will they be. For this process *do not alter your own attitude* but continually alter the position of the Bristol board so that the line to be drawn—or rather, the piece of the line—forms the

arc of a circle with the right elbow at the centre and the forearm acting as the radius. In other words, draw from the elbow and never attempt to draw large curves from the wrist. If you do, unless you have an abnormally steady hand, you will start off all right, but the end of the curve will be unsteady and will have to be doctored later. You will usually have to shift the paper very frequently, every few seconds, but do not worry about this as it saves a lot of time in the end. In figure 2*b* I have drawn a curve and have indicated the 15 separate strokes which were required for the final curve. The last stroke—No. 15—since it is very small, requires different treatment. I draw it entirely from the wrist and draw it very slowly. This has two advantages, it enables one to follow closely the pencil line that is being inked in and it allows the ink time to flow off the pen and give a line of uniform width.

We will assume now that the main outlines have been completed. It is now necessary to consider the shading. At this stage it is best to clean up the drawing. It is surprising how dirty a drawing is apt to become in a laboratory. A piece of bread, not too stale, is an excellent material for cleaning the paper, and if a rubber is used, use a large soft piece. Whatever you use, always make certain that your background is really white before you attempt to put in the shading.

The first step in shading is to imagine, as best you can, what the object to be drawn would look like if it were opaque and lighted from one direction. Always choose that direction so that it is asymmetrical to the object. This ensures there being no uncertainty about the curved surfaces. If, on the other hand, you draw a symmetrical object as it would appear if it were lighted directly from above or in front, it is then often difficult to settle whether a curved surface is concave or convex.

Having chosen the source of light, the next step is to shade in your rough drawing or, better still, trace a new pencil outline on smooth paper from your inked-in outline and shade this with a medium pencil (fig. 4A). This is the second step in which your knowledge of the object is tested. You will find that you are uncertain as to how the shading should go, whether one part should be in deep shadow or only faint, or, as more often happens, whether an area should gradually darken or whether it should have a fairly sharp boundary between light and shade. This merely means that you do not know the shape of your object and you are forced to study your material again to make certain.

Your pencil-shaded rough drawing will look flat—the shadows will not appear dark enough. It is not possible to produce a good black with an ordinary pencil unless you use a very soft type. These, however, are to be avoided in any laboratory. Rough sketches have rough handling, and you will find that any drawing made with a B or any soft pencil becomes hopelessly smudged before you have finished with it. Use an ordinary HB pencil and make certain that you get degrees of shadow—actual depth of shadow will come soon enough when you start translating your pencil sketch into ink.

The illustration shown in figure 4 A represents fairly accurately a pencil shaded drawing, but is much more contrasting than a drawing on ordinary paper with the usual type of pencil. It is a carbon sketch on scraper board (see later, p. 27), and I have drawn it by this method in order that it can be reproduced by the line process.

Having produced your shaded drawing you now proceed to draw in the "light contours". That is, draw pencil lines around areas of equal light intensity. Choose arbitrarily four degrees of brightness, 1 to 4—number 1 representing the high-lights and number 4 the zones in the deepest shade. If you have shaded your pencil sketch fully, this is a very simple process. You have merely to draw a line around the areas which have not to be shaded at all, the high-lights, and this gives the contour between zones 1 and 2. Now draw a line which separates the palest shading from the darker shading you have chosen as shade No. 3, and this gives the contour between zones 2 and 3, and so on. It sounds a complicated business but you will find that it is really easy. For one thing, after putting in the boundaries of the high-lights, which must be a simple process, you find that the other lines run, on the whole, parallel and only diverge when the shape of the curved surface is altering. In the simple case of the cylinder which I have illustrated in figure 3 the light contours are naturally all parallel, but in the more complicated case in figure 4 B you will see how the lines run. This last figure also illustrates that if the object to be drawn is complicated it is sometimes advantageous to plot more contours than in a simple

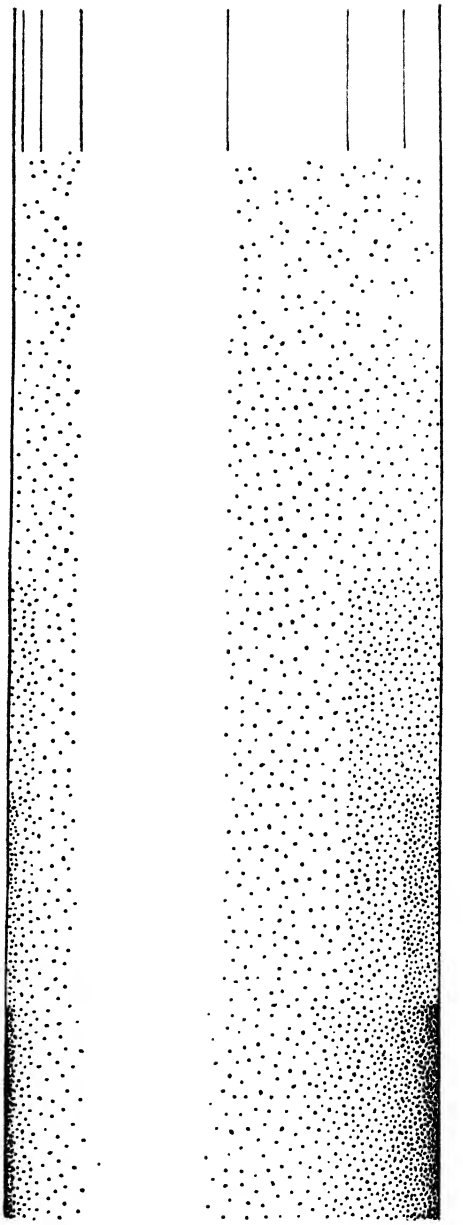


FIGURE 3

To show six stages in the drawing of a cylinder lighted from above and to the left.

case. In this figure I have divided the shading into five zones instead of my usual four.

Having zoned the pencil shaded drawing, trace the light contours on to your completed outline drawing and now commence to shade. The first thing is to select your nib. Choose a broad one which will give a uniform, fairly round dot with *light pressure*—in fact, with scarcely any pressure at all. Avoid any nib that will give a definitely shaped elongated dot or any nib that only marks on definite pressure. It is so easy to dot over an area if the nib hardly has to touch the paper, whereas if you have to press a certain degree to get the dots of a definite size you will find that your hand rapidly becomes fatigued. I often wash out my fountain-pen—all fountain-pens have a comparatively thick point—and use it as an ordinary nib. It does no harm to the pen.

Leave the high-lights blank and cover the rest of the drawing—zones 2, 3, and 4—with uniform squares of dots, *making the axes of the squares vary at random*, and avoid drawing neighbouring squares with sides parallel. Now the length of the size of a square represents the average distance apart of the dots in the area of palest shading. Hence do not make the squares too small to begin with. Draw a test area around a high-light on your rough pencil outline and satisfy yourself that you are not making it too dark. If you are, then increase the size of your squares.

Having covered the whole area except the high-lights with squares of dots, now fill in the spaces between the squares as uniformly as possible. This will produce a uniform tint. I do not say that this is the only way to obtain an evenly shaded area by dotting, but I am simply describing a rule-of-thumb method which is, I think, easy to follow. If you follow my instructions accurately and draw your squares at random you will avoid regular triangles, or, worse still, rows of dots. These are abominations in any black-and-white drawing, unless, of course, they are wanted to show some particular structure or texture. If the shaded area represents a curved surface or a flat surface in the shade then rows of dots must be avoided. They always show up in the final reduced print as marked streaks. This not only breaks up the surface unwarrantably, but such streaks always catch the eye and indicate something which is, in fact, not there.

At this stage it is surprising how the drawing begins to stand out, and the subsequent stages become much simpler. Continue by leaving zones 1 *and* 2 alone and fill in zones 3 and 4, placing dots between the dots already there as uniformly as possible. This will make these two zones approximately twice as dark as zone 2. Now treat zone 4 alone in the same way and you will have zone 4 twice as dark as zone 3 and four times as dark as zone 2.

The figure is now in a sense finished, and you may begin with the process of touching up. But it is this part of the drawing that is so important. With a little practice a drawing along the lines I have described can be done easily and quickly, but it is the final touching up that should take time and transform

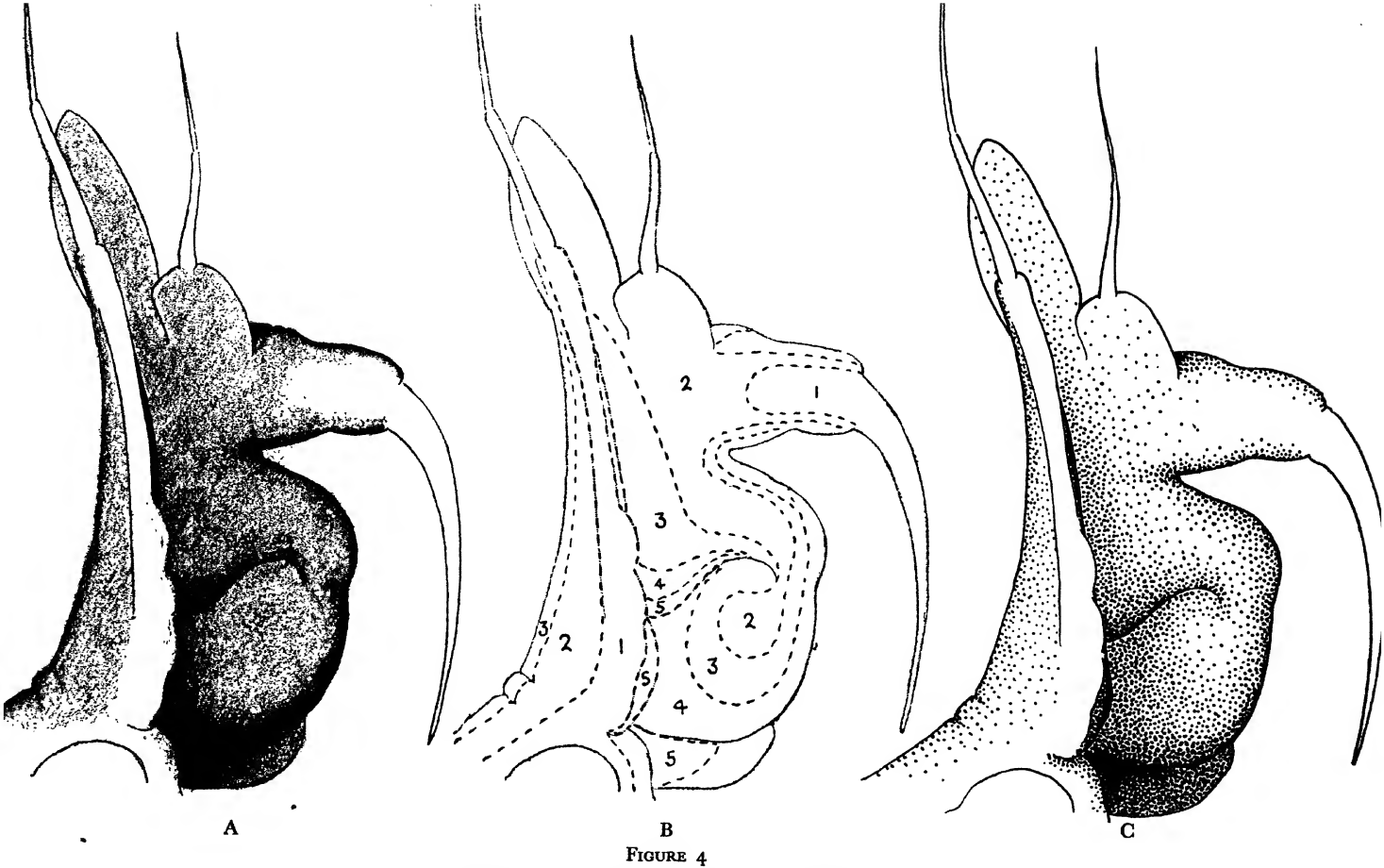


FIGURE 4

To show the three steps in producing the final drawing.

(A) The rough pencil-shaded sketch—in this case drawn on scraper board (p. 27). (B) Outline of sketch with light contours.

(C) Final drawing—in this case reproduced facsimile.

an ordinary figure, which merely indicates the solidity of the object, into a finished drawing that is really satisfying.

The first touching-up is to mask the boundary lines between the zones of shading, which at this stage are very obvious. Do this by putting in extra dots just sufficient to make one light zone merge into its neighbour. Thus along the first contour which marks the edge of the high-lights, always place a few dots at random in the high-light zone itself, but here, of all places, avoid lines of dots. Treat the other separations between the light zones in the same way and then rub out the pencilled-in light contours. Now half-close your eyes—this brings out the contrast between the light zones—and you will soon see if there are any boundaries that you have left unmasked. You will now have a drawing that looks good but yet it lacks something, and that is that the darkest zones are not dark enough. Hence you proceed to darken all the outer edges of the darkest zones, but this work is done under a lens with your finest nib.

First of all see that some of the dots alongside the outline are half on and half off the line. If by chance, as usually happens, they all fall completely inside the outline then, under a lens, dot *irregularly* over the inner edge of this line, placing your dots wherever there is an obvious gap. This can be done with your dotting pen, but it is sometimes easier to draw them with your fine pen, making the dots approximately the same shape as the remainder.

Now with your fine pen make the marginal dots fit into each other *without touching*. Up to now, if you have followed my instructions, you will have unconsciously avoided allowing dots to overlap, and it is very important in this final stage only to allow adjacent dots to touch—or rather, be joined—just in those places where you want them to do so. If you do this, then your final drawing can be reduced in printing considerably. In fact, the possible reduction is only limited by the size of the dot.

In this filling in by enlarging the marginal dots, the dots should be made to approach closer to each other the nearer they are to the margin. In figure 5 I have illustrated this; at the left of the figure the dots are as they would appear before the final shading. You will notice that the four dots at the bottom are irregularly half on and half off the boundary line. The shaded areas around the dots represent the areas drawn in under a lens with the fine nib. You will also see that the dots farther away from the actual margin are scarcely touched, while those at the margin are transformed into polygons fitting in approximately with their fellows.

You will often find that shading to this degree of intensity gives you a sufficient depth of tone and contrast with your high-lights. If so, then stop—but if you still want a darker edge then join the outermost dots by bridges, as I have illustrated in figure 5.

Do not make the dots fit closer and closer together or you will produce just as bad an effect as is obtained by irregular dotting. Remember always that there is a limit to the narrowness of the channel between the dots. I have seen

a drawing which represented many hours of hard work under a lens where the dots in the darkest zones were so close together that it was difficult to see the white lines between them. As a drawing it was magnificent—but it was energy wasted as it would not reduce for printing.

You have now reached the limit of your shading. Only one more thing remains to be done to your drawing and this is to search with a lens for any

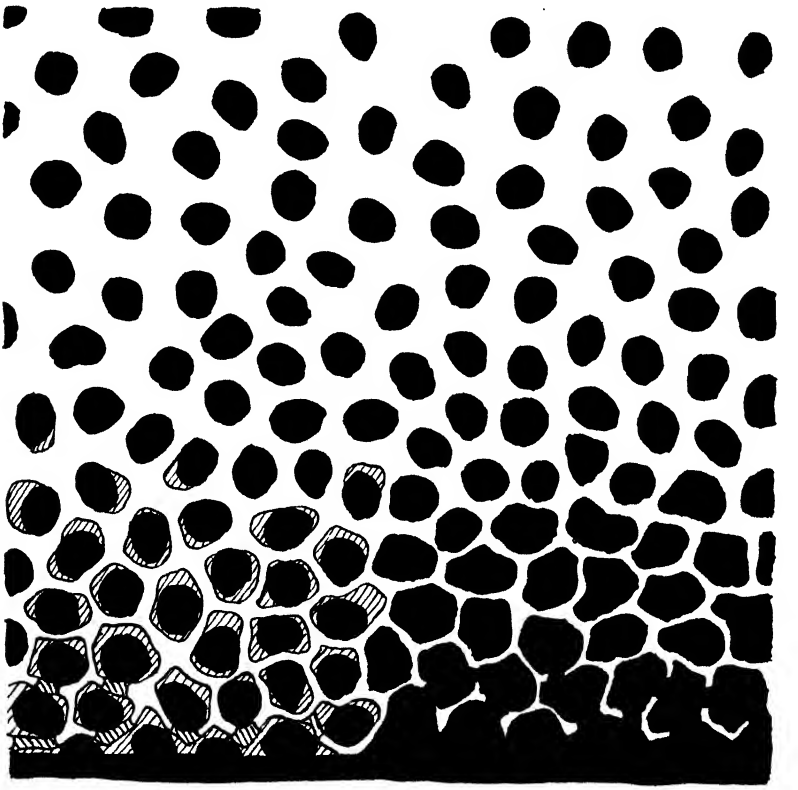


FIGURE 5

Enlarged drawing of dotting at the edge of a figure representing deep shadow—to show the method of increasing the marginal dots so that they fit into each other. On the left the cross-hatching indicates the areas to be filled in with a fine nib to produce the effect on the right.

weak lines. The dots will all be bold enough if you have followed my instructions, but also, in filling in the final shadows you must of necessity search the dotted areas with a lens and naturally will enlarge any dot that happens to be undersized. The lines, however, especially those unsupported by dots, may have irregular margins. Any serrations or gaps should be filled in so as to give a uniform thickness to the lines.

A CRITICISM OF THE SHADING EFFECT

It has been suggested to me by an eminent zoologist, who is also a great artist, that my method is not strictly correct in that when you look at a surface curving away from you into the shadow, the edge of the image that you see is not actually the darkest zone—this is just inside the margin.

Now this is correct if you are looking at the object against a light background. The lighter zone at the margin is due to the fact that this edge—which is a surface that you are looking at tangentially—as it curves away from you, is pointing towards the light and acting as a mirror reflecting light from the background. If, however, you are looking at an object against a black background, then this lighter margin is absent. You can see this very well in statuary; if, say, an arm carved in marble is viewed against the light, the bright zone at the edge of the statue is obvious, while if it is viewed against black velvet then it disappears.

This method of leaving the actual margin a shade paler than the zone immediately inside has its advantages and leads to a very beautiful effect as, for instance, in the case of skulls and bones generally. But it is very difficult, and I do not advise anybody except an expert to try it. It has another disadvantage—it always gives the impression of a shining surface, and this is often undesirable.

Normally, when we draw an object for scientific illustration, we omit any background, and in this sense our figures are all incorrect. According to my method, therefore, all the objects drawn (and in fact the vast majority of text-figures) represent what the objects would look like if they were on a black background and that background was removed. It may not be correct, but it is a convention—just as in fact all black-and-white drawings are conventional representations of what we actually see or imagine.

DETAILED WORK—HISTOLOGICAL AND CYTOLOGICAL EFFECTS

It is often necessary to draw histological preparations including a variety of tissues. It is impossible to give more than a few general hints as to how this should be done. It should be realized that by the black-and-white method only a semi-diagrammatic effect can be produced. If a more realistic picture is necessary, then a pencil and wash drawing is essential, and this, besides falling outside the scope of this book, should only be undertaken by those who know how to use a paint-brush. Good effects, however, can be produced if each tissue is drawn in a characteristic style in such a way that this style represents their texture or some other quality. Thus, in the figure illustrated

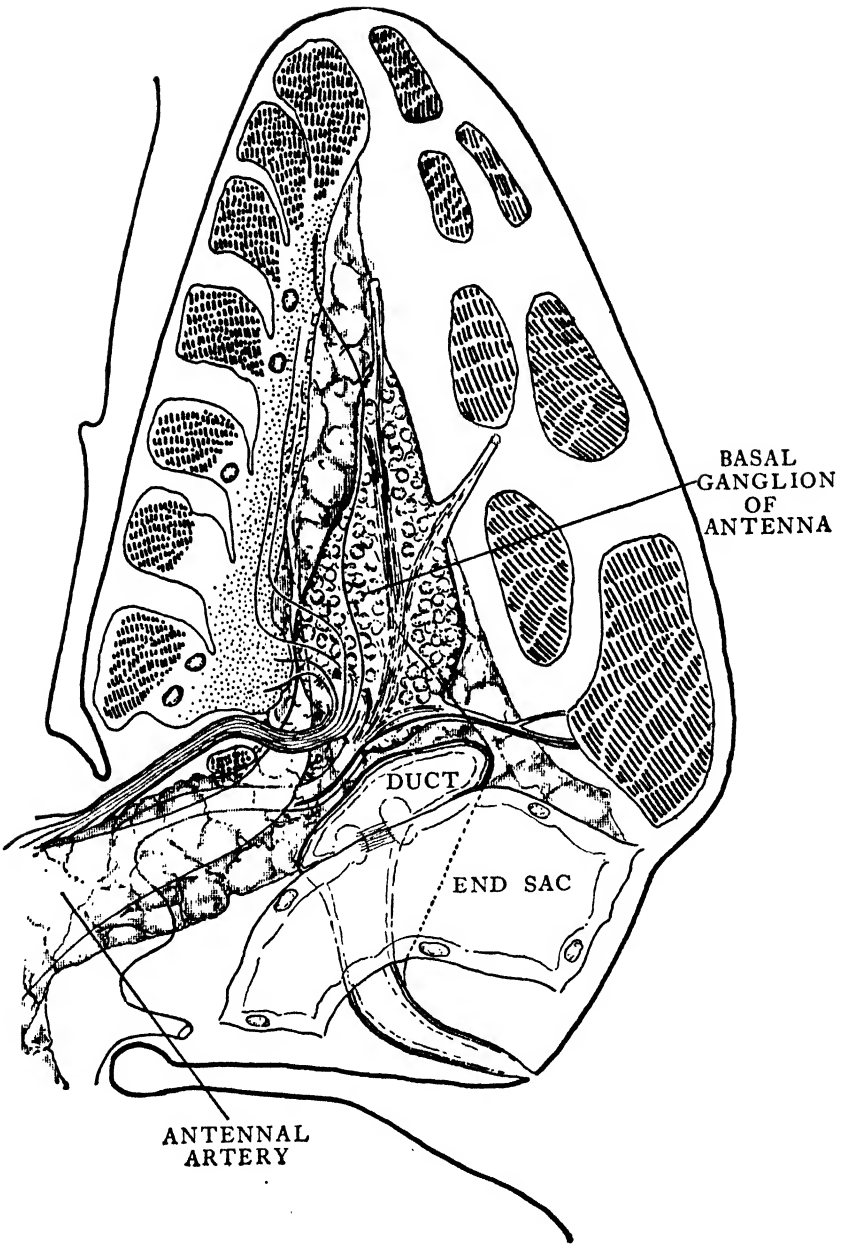


FIGURE 6

Drawing showing (*a*) conventional representation of tissues—muscles, nerves, etc.
(*b*) shaded effects produced by the use of scraper board.
(*c*) the use of two colours to bring out some particular structure.

(fig. 6) I have indicated muscles by short parallel bold strokes, nerve cells by small circles with a few dots round their margins, and so on. I shall refer to this figure later, but it is obvious that no precise instructions can be given. It is a case of learning to sketch with the pen and being bold. Try out patterns and styles on a rough drawing and you will soon discover a simple sketching method by which you can depict some idea of the tissue you wish to draw.

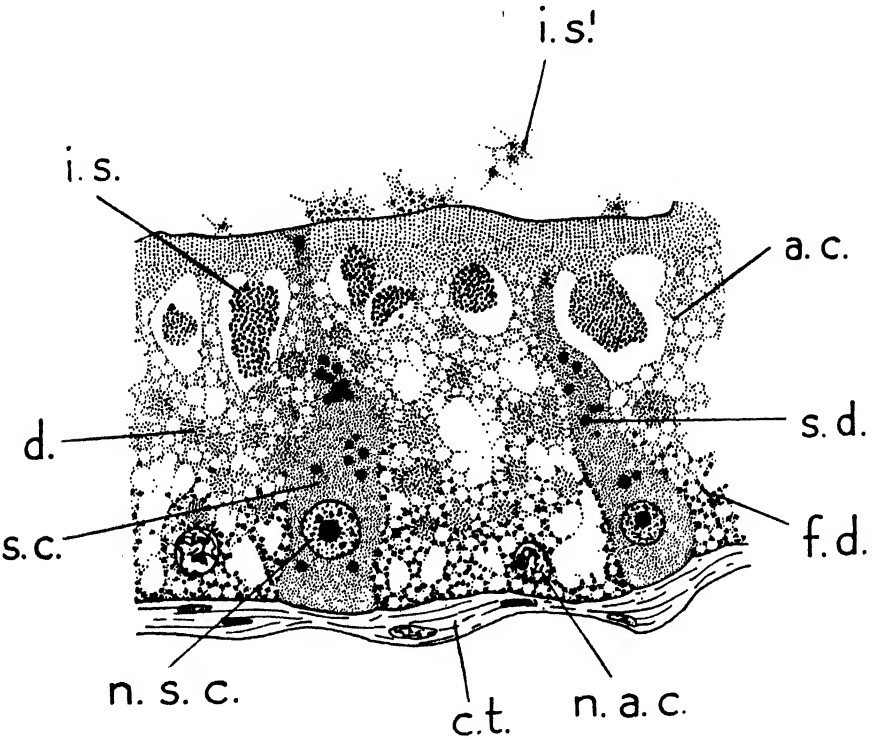


FIGURE 7

Facsimile of drawing by Mr. Alistair Graham to show cytological detail represented entirely by dots.

(*Trans. R. Soc. Edin. lvii*, p. 301, fig. 8.)

With cytological preparations much more realistic effects may be obtained, but again it is not possible to give precise instructions. All the details of the cell—the nuclei, the vacuoles and other cell inclusions—should be accurately drawn in pencil so that the extent of the ground cytoplasm is definitely marked out. This should then be uniformly shaded by accurately placed dots. It is a difficult process, but the method of starting with squares of dots which I have described (p. 14) should be used. The difficulty lies in the fact that there are no large areas over which the squares can be placed. However, this step should be carried out as far as possible, and then with a little practice it is

possible to fill in the gaps between the cell inclusions so as to get a uniform effect.

To figure vacuoles circular areas of appropriate size are left blank (fig. 7), but care must be taken to bring the dots of the surrounding cytoplasm accurately up to the circular margin. If the vacuoles appear to have a staining

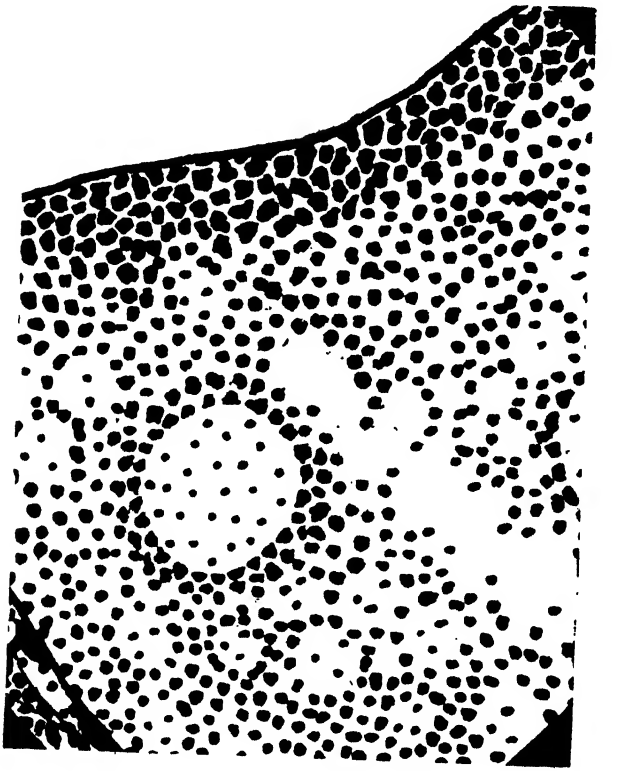


FIGURE 8

Photomicrograph of small portion of drawing to show method of using dots to depict cytological detail.

(*Q. J. Microsc. Sci.*, *66*, pl. 10.)

surface membrane this can be drawn by treating the dots that mark the circumference so that they fit together without touching (see p. 16), and at the same time the sides of the dots facing into the vacuole are flattened in such a way that the flattened parts together form the circumference. This is illustrated by the photomicrograph of part of a drawing shown in figure 8.

A darkly staining selvage can be produced by fitting the dots together (fig. 8). If, as so often happens, the surface layer of the cell shows striations normal to the surface these should be rarely, if ever, reproduced by lines, but

rather by rows of accurately placed dots. The beautiful effect that can be produced in this way is clearly seen in figure 7. To obtain this effect, however, the dots must be of uniform size; they must be equally spread along the rows, and the rows themselves must be equally spaced.

This figure is interesting in another way. As it is produced here it is a facsimile of the original. As it was published in the *Transactions of the Royal Society of Edinburgh*, vol. lvii, p. 301, it was reduced to about three-quarters the original size. By comparison of the original as seen here with the published figure it is obvious that this drawing has lost a lot of its beauty in reduction. The dots were of such a size that on reduction they fused together, and although the published figure was the best example I could find of cytological drawing by my technique, it was obviously not as good as the original.

Beyond these few instructions little can be said. The best rule is to work from the ground cytoplasm. Dot this in accurately and evenly and then add dots in one place, make the dots fit closer together in another, and so on, so as to represent the various structures it is desired to figure.

LINE SHADING

I HAVE now described the shading by dotting method. I do not wish it to be thought that I consider it of necessity the best black-and-white method. All styles of drawing based on line shading can yield results as good and even better. One has only to look at the illustrations of earlier biological monographs to realize this, for in many cases these were printed from steel or wood blocks, which owe their beautiful effect to the fineness of engraved lines. My reason for not advocating any such method as one for general use is that they require an artist's hand to yield good results. There are many zoologists who are fortunate in being able to shade by lines, and I reproduce a simple drawing to show the type of effect which may be produced (fig. 9). I do not think, however, that this style can be learned—or only in rare cases; either you can use the method or you cannot. It involves having a steady hand and being able quickly to sketch closely parallel lines all of equal intensity; and, more important, it necessitates knowing exactly the degree of shading you require before you start drawing. If a research worker feels he can do this, by all means let him use the method, but if not then I suggest trying the shading by dotting method.

The principle of shading by lines is simply that over dark areas thin parallel lines are drawn relatively close together and usually curved in some manner appropriate to the curvature of the surface which is being figured (fig. 2 *a*). In order to get a darker effect there are several methods; each line may be thickened over the dark area to an equal degree or extra lines parallel to the original may be inserted, or finally a second set of lines across the original may be drawn giving the effect known as cross-hatching. The last method is

the simplest, but here the difficulty from the point of view of reproduction is to keep the white squares between the lines which result from the cross-hatching, of sufficient size to allow the usual reduction on the block. The other methods are effective and yield beautiful results, but they are very difficult. Unless the worker is an expert the method is mainly undesirable because of its inflexibility.

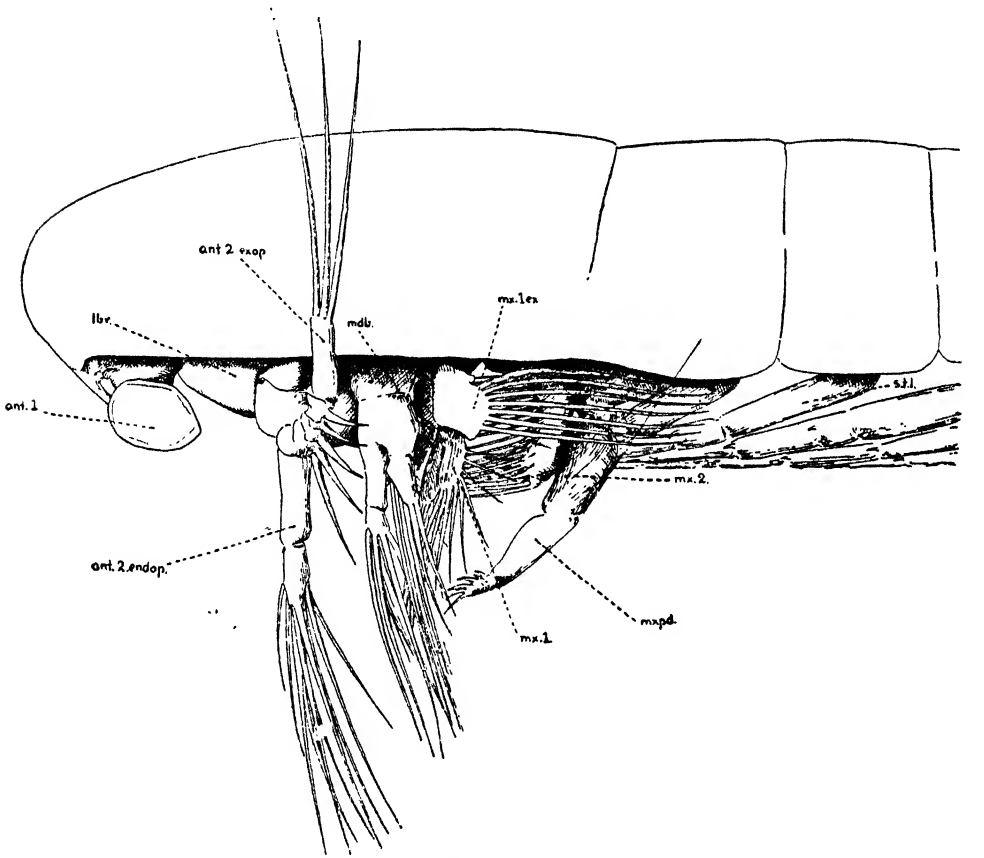


FIGURE 9

Drawing to illustrate line shading. This figure shows the sketching effect produced by cross-hatching, while figure 2 shows the more formal result obtained by thickening the lines to produce the shadows.

In all drawings it happens that, as the shading progresses, at first some effect will appear unsatisfactory—it may be too dark or too light. Now in a line-shaded drawing the area can be darkened by one of the methods I have mentioned, but once darkened it must remain so. If it is too dark then a large area must be scratched out and re-drawn. By the dotting method, on the other hand, it is easy to alter any effect either way—dots may be added or

removed. It is perfectly easy to scratch out individual dots with a fine scalpel and insert them again if it is found necessary. Thus there is a great latitude in the control of the shading. I find that in practice I am continually adding a few dots here, removing a few dots there on a drawing which I had considered finished. I think that unless you have the expert touch this control of the shadows is not possible in a line-shaded drawing—and it must always be remembered, as I have pointed out, that it is the final touches to the shading effect that produce the really satisfying results.

WHITE ON BLACK

It often happens that in a black-and-white drawing an effect has to be produced which can be done better by drawing white on black than vice versa. For example, in the drawing illustrated in figure 13 there are certain setae which at their tips lie over a highly lighted area and therefore can be represented by black lines, while at their base they lie across an area in deep shadow. Obviously in this region it would be of no use representing them as black lines as these would not be seen against the black background. In such a case they should be represented as white lines instead of black. It is surprising in effects of this sort how you may look at the drawing and appreciate all that the figure is meant to represent without realizing that maybe a group of setae start as black lines and abruptly change to white. It would seem at first sight that the method would lead to strange results, but actually it is difficult to see in the finished figure those places where the method has been employed. A photomicrograph of a drawing illustrating this method is shown in figure 10.

These white lines should be painted over the black with the special fine brush that I have already described (p. 8). The paint used should be process white. It is a tedious business; the brush will sometimes only do a stroke or two before the paint clogs. It must then be wiped and renewed with paint. The object should be to get a white line in position, however faint. This can then be reinforced under a lens by subsequent coats of paint.

Another place where it is essential to use white lines on black is where guide lines pass over a black area (fig. 10). It is of no use thinking that the eye can carry a black line across a black area—it cannot—it only leads to uncertainties and in any case it is unnecessary. These guide lines should not be painted in, they should be scratched out. The method is to rule the line in ink across the white area and continue it in pencil across the black zones. The pencil leaves a shiny line on the dull Indian ink. Then, with a sharp scalpel scratch out a strip over the pencil line. Of course one keeps this strip as narrow as possible, but there is no need to keep it particularly narrow. The main point is to scratch out a pure white avenue; then polish it well, as I have described, and fill in with black again, leaving only a narrow white strip in continuation at either end with the black guide lines. The easiest way to do

this is to rule with a fine pen two parallel lines so close as to leave a narrow white strip of the width of the black guide line and in continuation with it. The remaining scratched out area can easily be filled in.

FIGURE 10
Photomicrograph of portion of drawing to illustrate the use of white on black.
(*Discovery Reports*, III, p. 205, fig. 2.)

MECHANICAL STIPPLING

BY means of mechanical stipples it is possible to introduce into a black-and-white drawing areas of uniform shading of various degrees of darkness and texture, and, what is most important, these can be left to the block-maker. All that is necessary is that the area it is desired to shade shall be sharply marked out on the original drawing by a fine boundary line. It is often convenient that this should be in ink, but it is not necessary—a sharp pencil line is sufficient. The area itself is then lightly shaded with a blue pencil, but never with red. The area can cover lines already forming part of the drawing and it is possible to indicate lettering on top of the stipple.

The various patterns of mechanical stipples can be obtained in sample form from any block-maker, each with a characteristic number. The number of the stipple chosen should be quoted on the drawing. The patterns used most in scientific drawings are those based on dots or fine parallel lines or irregular grained surfaces. Examples of two different patterns are shown in figure 11.

The use of stipples can best be explained by an example or two. In a section of an arthropod embryo it may be of importance to figure the coelom standing out from the remaining body cavity. In the actual section drawn

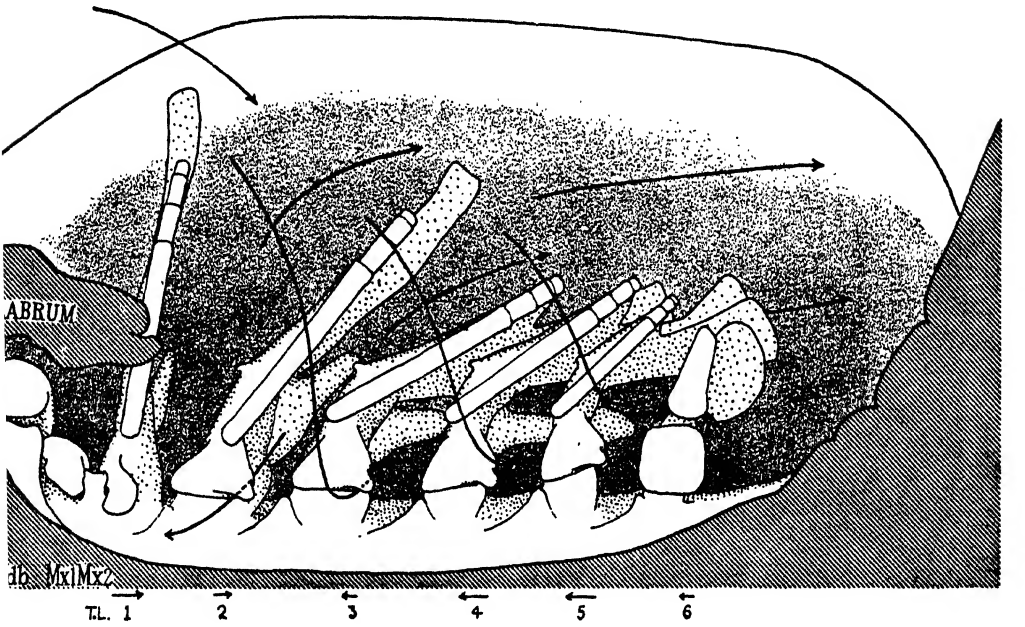


FIGURE 11

Drawing showing (*a*) a regular lined machine stipple below to represent a cut surface. (*b*) a graded machine stipple above to represent shadow.

both may appear as clear empty spaces, but the coelom can be marked out by a fine grey stipple. In drawing a solid reconstruction the cut ends of cartilages or bones may be conveniently illustrated by a stipple of fine parallel lines. In drawing one set of organs in detail in a solid reconstruction it may be of use to figure the extent, but not the detail, of some other organs. These can be outlined and figured by a fine grained stipple.

An important point in choosing a stipple is to remember that, while your drawing will be reduced in reproduction, the stipple will appear in the final print as in the sample. If then, in a dotted black-and-white drawing, you choose a dotted stipple you must make sure that your drawing, on reduction, will not be reduced to such an extent that its dots become of the same grain

as those of the stipple. Usually the stipple is much finer than dotting drawn by hand, but over-reduction has been known to occur in block-making on grounds of economy.

A final possibility with mechanical stipples is to produce a shaded effect. The area is shaded carefully by hand, using a blue pencil, and the block-maker does the rest. The stipple chosen should preferably be a grained or dotted effect (fig. 11).

SCRAPER BOARDS

SCRAPER boards are specially prepared drawing-cards, heavily impregnated with clay and with a roughened surface, with which it is possible to obtain complete gradations in shading—that is, a half-tone effect—and yet the drawing can be reproduced by the line process.

The simplest type is that in which the surface is irregularly broken up into a multitude of minute valleys and hillocks. An example can be seen in figure 4 A. Outlines may be drawn in Indian ink, but care must be taken not to make the lines too bold. Owing to the clayey nature of the surface, the ink is apt to flow too easily from the pen. Shading may then be put in with a carbon pencil. Light pressure blackens only the tops of the minute protuberances from the surface as small irregular dots while increasing pressure flattens them down and produces larger and closer dots, thus giving a darker shading. It is possible, by pressing hard enough, to produce a completely black area (fig. 12 A). If it is desired to produce a high-light in the middle of a deeply shaded area this is done by scraping it out with a scalpel. The surface comes off easily if the scalpel is sharp and held at right angles to the board but, of course, once the surface has been scratched away it cannot be used again.

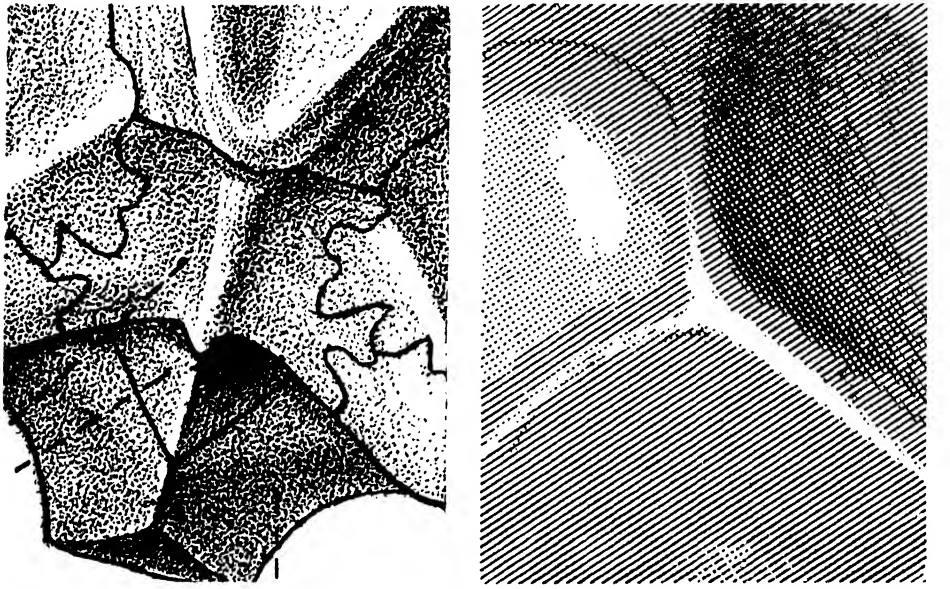
In another type the surface has been pressed with a fine grid so that it is broken up into a series of regularly arranged minute square dots (fig. 6). The effect produced is similar to that obtained with the irregular surface, but not so pleasing. It also has the disadvantage that, especially with a fine pen, it is difficult to get smooth curved lines. The point of the nib is apt to catch in the grooves of the surface and slide along them.

A modification of this type is the grey tinted scraper board (fig. 12 B). In its preparation, it is first printed with a series of fine black parallel lines, the distance between the lines being about twice the thickness of the lines. This gives the paper a uniform grey tint. Now at right angles to these lines the paper is pressed, but not printed, so as to produce a series of grooves of the same size and spacing as the black lines.

In using this type of paper it must be remembered that your are starting with a uniform grey. With a carbon pencil a darker grey is produced as it converts the parallel black lines into cross-hatching. Extra pressure will press down the surface and produce a deeper tint. A light grey can be produced

by gently scraping the surface which breaks the black lines into a series of dots. A pure white area is produced as before by scraping more heavily. This can be seen on the right of figure 12 B.

The types of scraper board I have described are those which appear to be most useful for scientific illustration, but there are, of course, other kinds, some coarser and some finer. Samples can be obtained from any dealer, and it is always advisable to obtain as many kinds as possible before settling on any one.



A FIGURE 12 B

Photomicrograph of two types of scraper board.

(A) White board with irregular grained surface. (*P.Z.S.*, 1904, ii, fig. 130, p. 469.)

(B) Grey board with regular grooved and ridged surface. The white areas have been produced by scraping.

There is one unusual type which is worth mentioning—the plain smooth black board. This is simply a card heavily coated with china clay and then printed black. Drawing on it is done entirely by scraping, but as only lines can be scraped and not dots it can only be used for special subjects.

Scraper boards are sometimes, but not always, so opaque that it is not possible to trace through them. The drawing should then be traced on to them with a greaseless re-tracing paper; a blue variety for tracing on to the white and grey boards, and a red variety for the black boards.

Alterations can be made in the pencilled areas, but any ink line or any scraped area cannot be changed. Skill is required to obtain a uniform shading with pencil, and a lot of practice is necessary before good effects can be consistently produced. On a small piece of the board, however, it is possible to

try out various effects. The surface will stand a moderate amount of rubbing so that pencil effects can be tried several times on the same piece. This is important as scraper boards are expensive. Despite their cost I feel that they are insufficiently known and should be used more extensively.

LINE PRINTING IN TWO COLOURS

An effect can sometimes be obtained in printing text-figures by using two colours, black and another colour, that it is difficult to obtain in any other way.

In drawing a solid reconstruction of some complicated organ, there may be parts, in fact there usually are, which are hidden by others in the aspect you have chosen and which may be important. Thus the duct of a gland may coil away behind the organ and yet the complete duct is essential to the figure. The parts thus hidden should be drawn in coloured ink—not red—and instructions marked on the drawing to the effect that these lines should be printed in grey ink. It is surprising how in such a print it is not obvious that two coloured inks have been used. The grey lines and dots give merely the impression that they represent structures behind the parts drawn in black.

In other cases it may be that the drawing is very complicated and you have used up all the different ways of representing various tissues or parts, and yet there are some structures which it is important should stand out clearly in the final picture (fig. 6). Thus in a complicated nervous system it may be essential that certain tracts or individual fibres should be emphasized. As before, these should be drawn in coloured ink, and an indication made that they should be printed in some special colour. Of course, there is no need for the colour used for drawing to correspond to the colour used in printing.

This method is useful and effective, but it must be remembered that it is a luxury. Do not, for instance, think that you can use more than two colours. An editor may be willing to allow two colours but will draw the line at a third, for each colour means a separate printing and a special type of printing at that. The black text-figure is printed with the text, but the second colour has to be printed separately in exact register with the block. Hence the cost is more than double that of an ordinary figure.

GUIDE LINES

It might seem at first sight superfluous to give instructions about guide lines, and yet I have seen more text-figures and, in fact, drawings generally, spoilt by bad guide lines than by anything else. There are only three rules to be learnt but they are important, and considerable time should be spent in inserting the lines. In nine cases out of ten it is just the reverse—the drawing is finished and maybe it is a very good effort—and then the guide lines are

scrawled across it hurriedly and without any order. The result is that some become unduly obvious, others inconspicuous and, the worst effect of all, the lines as a whole stand out at the expense of the drawing. Actually with little effort it is possible to make the lines so unobstrusive that you hardly notice them when looking at the figure and yet each one runs directly from a point where the lettering is printed to a definite point in the figure.

First, the lines should all be of uniform thickness and should bear a definite relation to the main outlines of the drawing. A little thinner than the thickest outlines and certainly no thicker is the best rule; by using the same nib and ruler in drawing all the lines this presents no difficulty. Both ends of the line should end sharply, and it is sometimes effective to enlarge the inner end by placing a small dot on it. There is then no question as to what part of the drawing it refers to. I have already mentioned that guide lines passing over black areas should never be left black but should be painted in white. If, as often happens, the end of the line falls on a black area then this must be white and should be enlarged by a white dot.

Then as to the number of guide lines; I maintain that there is a limit to the number of lines that should be inserted in any text-figure. One can only tell by the look of the thing—if you feel that you require a large number I think that is a sure sign that an extra drawing is required. I have seen excellent drawings of dissections published that have so many guide lines that you cannot see the wood for the trees. The lines themselves become confused and, in any case, obscure the figure.

The third rule, and the most important, is as to the arrangement of the lines. It is difficult to say more than that the lines should all radiate from some centre (fig. 13). This centre may be chosen variously; sometimes it may be the geometrical centre of the figure or it may be the most important part of the figure. In any case the lines must radiate, and radiate uniformly. If this is done then I maintain that they are as inconspicuous as possible. The effect can easily be tested by drawing an irregular outline. Then fix a point near the middle of this figure and from it draw a series of radiating lines starting from the edges of the figure and extending outwards. Do not space the lines regularly but make them subtend various angles with each other. You will then find that despite their irregular arrangement they are not conspicuous and fit in with the irregular outline you have drawn. Now draw one or two lines that do not pass through the central point you have chosen. These lines at once stand out from the rest and do not appear to fit in with the figure.

Considerable time should be spent in choosing the centre from which the lines are to radiate. They can be inserted with a soft black pencil or, better still, a rough tracing can be made and various centres tried.

It sometimes happens that a good centre is found for all the lines with the exception of two which clash. In this case one of these lines should be drawn normally. The other should be drawn near by and also radiating from the centre, and then, at its inner end, bent round to end on the appropriate part.

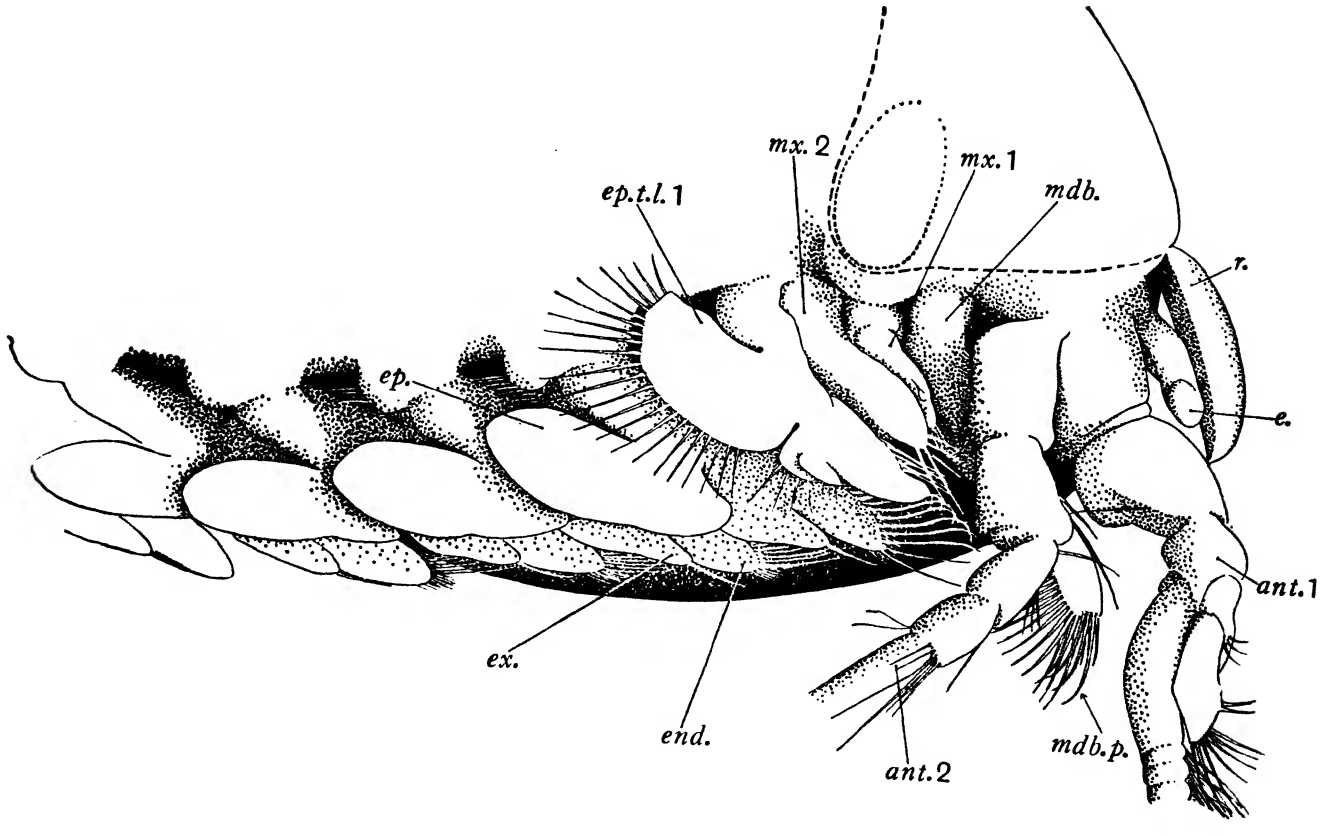


FIGURE 13
Drawing illustrating the use of white on black and the arrangement of guide lines.

This can be seen in figure 14. The lower guide line m. clashed with line mx.1., and so I drew it to one side and curved round its lower end. If I had drawn it in any other way it would have stood out from the rest of the lines.

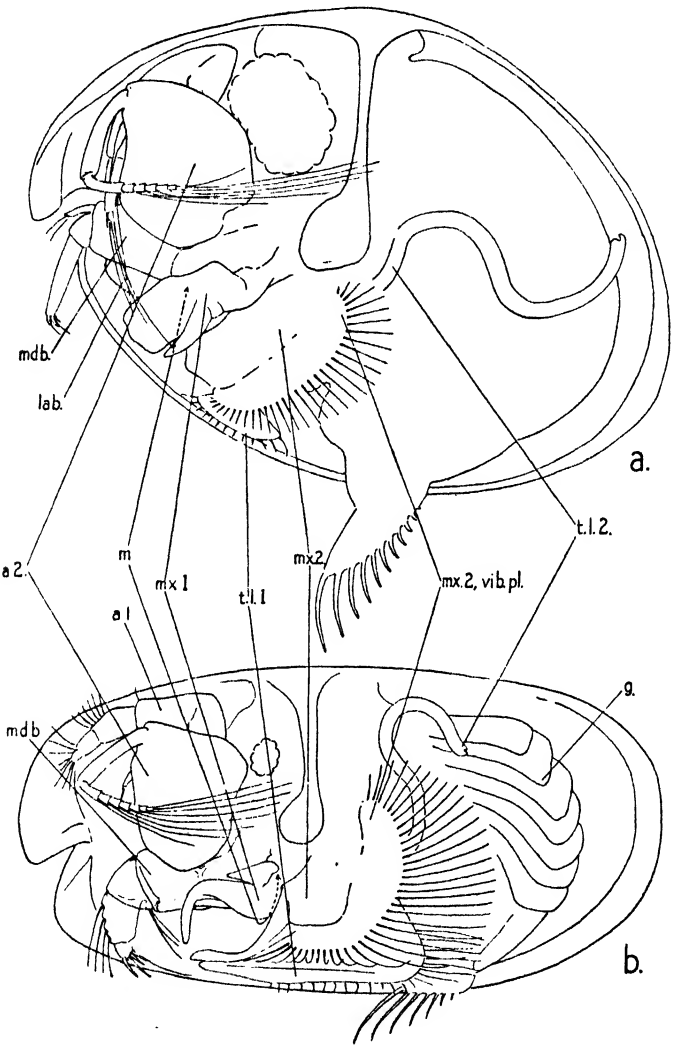


FIGURE 14
Drawing illustrating the arrangement of guide lines.

Another point can be seen in this figure. I have placed the guide letters in such positions that from each of them a pair of guide lines can be drawn, one to the figure above and one below. In the case of mdb., however, there is no suitable point which would not involve drawing guide lines out of harmony

with the rest, i.e. they could not be made to radiate from the two centres chosen. To avoid this I have duplicated the guide lines for mdb.

Figures are often seen in which all the guide lines are horizontal or vertical, but all parallel. Sometimes all the lines are like this, with the exception of one or two which run anywhere—this produces a dreadful effect. Horizontal lines I consider should, as a rule, be avoided. Text-figure drawings are not usually based on horizontal lines and rarely are they drawings of structures showing horizontal stratification; for this reason alone such an arrangement of lines produces a very conspicuous effect and something out of keeping with the drawing. The only case where I have found them useful is where two similar drawings are to be compared structure for structure. But even here, as figure 14 shows, a more pleasing effect can be produced by choosing two separate centres from which the lines are made to radiate.

LETTERING

I CAN say little about lettering as I rarely do it myself. Unless you happen to be an expert at printing I always advise leaving the lettering to the block-maker. It is a point, however, on which the editor should be consulted since it is naturally more expensive to have the printing inserted than to do it yourself.

If the lettering at the end of your guide lines consists of single letters, these can sometimes be inserted on your drawings from books of printed letters that are obtainable. Or, of course, letters can be cut out of any well-printed paper and pasted on. The difficulty here is to find letters of the appropriate size. Any letter pasted on the original will be reduced, and, since your text-figures will not all be reduced to the same extent, you will have to search for similar type but of various sizes to suit them individually. It is of course desirable to have the same-sized guide letters throughout the paper.

If the figures are to be inserted by the block-maker they must be very clearly marked on the originals. This may be done with a hard pencil at the end of each guide line. Sometimes the guide letter, or it may be a whole word, is typed and stuck on in position. In this case indicate on the drawing that this is for the convenience of the block-maker. Otherwise, you may find that the typing has been photographed on to the block, and a typed letter is, of course, not clear enough for good reproduction by the line process.

Another method of indicating the guide letters is to paste a piece of oiled tracing-paper along the top of the Bristol board above the drawing. The guide lines can easily be seen through the paper and the guide letters can be written in position in Indian ink. There can then be no question as to what those letters should be. The important point about this method is to paste the tracing-paper on firmly. If it can shift at all you are sure to find the wrong letters at the ends of the guide lines, and it is an expensive item to alter letters once they have appeared on the printer's block.

GRAPHS, MAPS, ETC.

THE drawing of graphs and maps is an aspect of illustration of which I have had little experience. The following remarks are mainly due to Dr. Stanley Kemp, F.R.S.

As in the case of all other illustrations, the most important consideration is to be certain that the diagrams represent *obviously* that which it is intended they shall represent. In the case of graphs this is not always easy. A worker on a problem gets into the habit of representing certain relationships—for that is the function of a graph—by a series of curves. In reproducing these for publication, however, considerable thought must be given to making them easily understandable to fellow-workers. Do not forget that biologists are not usually mathematicians.

As regards the actual drawing of graphs, these should be drawn on blue squared paper and not on any of the brown-red varieties. The blue lines do not reproduce, so that the block-maker can use a graph on blue paper direct.

It is of first importance that the meaning of the figures forming the scales on the ordinate and abscissa should be clearly stated on the graph. It is no good giving a string of figures and expecting the reader to dig their meaning out of the text.

Usually it is sufficient to draw a vertical line on the left for the ordinates and one across the bottom for the abscissae, with a comparatively open scale; but if it is important for the reader to be able to fix definite points on the graph with accuracy, a finer scale is required, and this should be repeated on the right-hand side and, if necessary, at the top also, thus giving a rectangular frame. By this means values can be determined by placing a ruler across the figure through corresponding points on the scales.

The size of the units on the scales is also a matter worth consideration. The units should always be chosen so as to use the maximum area allowed for the size of the figure. Thus, suppose the maximum height of the scale of the graph in the published figure is four inches, and suppose that the ordinates represent numbers: if the extreme numbers to be plotted are 0 and 400, clearly the scale should be drawn so that 1 inch represents 100. But if the lowest number to be recorded is about 200 and the highest, say, 280, then place the 200 mark at the base of the ordinate line and 280 at the top, thus using a scale where 1 inch represents 20. It must be remembered that the slope of the curve is the significant character, and by utilizing the maximum height of the curve this magnifies the slope.

It is often possible to combine a number of graphs in one figure. Thus the concentration of a number of different types of animals may be represented on the same frame by a corresponding number of curves. One animal can be

represented by a plain line, another by running dots, another by line-dot-line, etc. In this case, of course, the ordinate scale must be the same for each curve.

Two scales, however, may be represented on the same ordinate line—but not more than two. Thus in figure 15 the number of organisms scale is

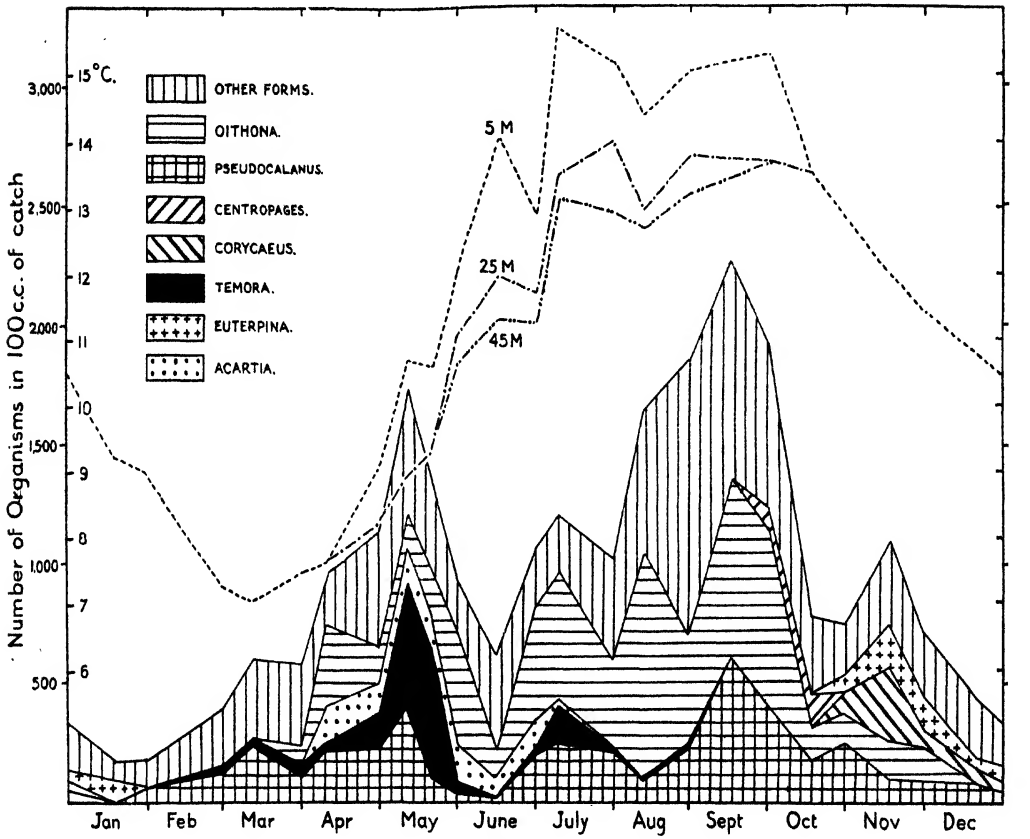


FIGURE 15

Graphs to illustrate (*a*) the use of different sorts of hatching for the production of multiple curves.

(*b*) the use of one frame for recording two different but related relationships, i.e., temperature and animal density.

(*Modified from F. S. Russell*).

indicated to the left of the ordinate line, while on the right of the same line the temperature scale is indicated. It will be noted here that the scale for temperature has been so chosen as to place the temperature curve as far as possible away from the number of organisms curves and at the same time allows for the largest possible scale of temperature.

This figure also shows the use of different sorts of hatching for the production

of multiple curves. Machine stipples may be used, but this is hardly necessary in the majority of cases. References to different types of hatching, or different types of line used, should always be inserted on the graph itself. They will usually fit comfortably into a vacant corner.

Maps and charts look best in a frame of ink lines. If latitude and longitude are not given, a scale of miles must be inserted, in fact, unless there is an obvious reason for doing otherwise, it is always best to insert a mileage scale so that an idea of the extent of the area represented may be obvious. If the latitude or longitude of particular places on the coast-line are of importance, it is sometimes useful to draw two short lines from the corresponding point on the map with figures representing the necessary details.

In charts, the land may be picked out by a fine dot stipple or, if there is very little of it, it may be black. In contours showing soundings it is well to adopt the Admiralty system: — · — · = 10 or 100 fathoms or metres; — ·· — ·· = 20 or 200 fathoms or metres, and so on.

In complicated charts representing, for instance, the abundance and centres of concentration of a particular animal, it is useful to use a series of graded tones, the darkest representing the maximum concentration. For this purpose, machine stipples may be used, but the greatest care must be taken to obtain a set which grades regularly in intensity and at the same time allows each tint to be identified without difficulty. All one family of stipples should be used; thus, do not use a dotted stipple for a light area and a lined stipple for a darker, for what may appear the lighter of the two to one person will appear the darker to another. It will be found generally that not more than eight tones, including white and black, can be used. In fact, it is inadvisable to aim at more than this, as a greater number would result in the differences between adjacent tones being too small, and the eye of the reader would become strained. This is a point on which it is advisable to consult the editor or the block-maker, who can always state what stipples are available.

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