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Scientific illustration

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SCIENTIFIC ILLUSTRATION

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by

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"Art hath an enemy called ignorance."

-Jonson

yet,

"Wherever art is too conspicuous
truth seems to be wanting."

-Proverb

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INTRODUCTION

It may be somewhat difficult at first glance to understand the essential character of the relationship of art to science, and especially to the natural sciences. Without illustration it would be impossible either to learn or to teach these sciences. Drawings are needed in the classroom and in the laboratory to aid the teacher, and they are perhaps even more important in individual research where there is no teacher present to guide and to instruct the student.

Scientific illustration is not only an aid to teaching, it teaches by itself when properly executed. In cases where verbal description is at best vague or clumsy, a good illustration explains with clarity and precision difficult points in question. Since in the great majority of cases specimens to be studied have many individual differences, an illustration of the average is not only an aid in identifying a specimen, but it is an excellent means, and, indeed perhaps the only one by which variations may be determined.

It is the purpose of this paper to discuss biological and related scientific illustration in both its aesthetic and practical aspects, with emphasis on the execution of such works. This discussion is in the light of its

relationship to college instruction and study. It is impossible to compose a concise yet inclusive definition of scientific illustration, or of illustration in general or indeed of Art itself, from which these other two have sprung. Therefore, in this case an aesthetic and functional comparison must suffice.

The field of illustration may be fixed by contrasting it with that of art, and, following this, by dissociating its component types. Such a task is not accomplished without the use of somewhat dogmatic statements, the opinions of the writer. The major part of the paper is concerned with the efficient production of scientific illustrations and with the techniques involved.

I

Aesthetic Analysis

There is no sharp line of demarcation between the realm of Art - the Art of Phidias, Michaelangelo and Leonardo - and the realm of Illustration. Phidias actually illustrated Greek legends in the Parthenon friezes, and Michaelangelo interpreted Biblical and mythological tales, and Leonardo's famous anatomical sketches were the basis for the perfect draughtsmanship to be found in his masterpieces. However, a rough differentiation may be made on the basis of relative emphasis placed on the qualities common to Art and Illustration.

Illustration, just as Art, involves dominant concept, expression, significant form, and technique, the last two of which are often combined as "style".

Dominant concept in a painting entails obviously the combination of a primary emotion felt by the artist, the meaning he attaches to it, and the central theme which he has molded from it. In the case of illustration, however, the term "dominant concept" can mean but the most important object in the drawing, and its use.

Expression is manifestation of emotion and eloquence in Art. The term is applied to the subjective sensations of the painter. In illustration expression holds a subordinate position. Here it denotes interpretation,

and then only when in reference to the more expressive types - fictional illustrations and poster work. Art stresses expression; illustration minimizes it.

Perhaps the prime quality to be found in a successful work of art is its power of communication of a sensed emotion through concrete and formal embodiment. There can be no Art without some order and significant form. Form involves first, composition, the spatial arrangement not only of the parts in relation to the whole, but of the whole in relation to the environment, be it a frame or a room. Harmony, balance, and symmetry, also components of form, indicate a certain reciprocal dependence among parts. These qualities require a fourth, continuity. Apparent in all generally accepted masterpieces of painting is a smoothness of plan and a flow of mass and shape which lend the impression of finish. Without the element of continuity, composition remains disjointed and erratic, often to the point of discomfort on the part of the observer. On the other hand, in order to avoid too much sameness in form, an interesting amount of contrast is needed. Illustrational construction is of great importance, since this is one of the few methods allowable for the draughtsman to show any appreciable creative effort. In arrangement and composition of the drawing he must call upon his senses of balance, harmony, symmetry,

continuity, and contrast. There is, however, one further factor, technique, which is important to both artist and illustrator, but for differing reasons.

With the artist a composite of characteristic form and of individualized technique results in style. The value of technique in illustration is only as great as its clarity and its usefulness in depicting the object. The regulative force behind art is emotion, for the manifestation of which style is essential. The regulative forces behind illustration, on the other hand, are precision and planning. They are directed toward the observer and toward the object, not to the draughtsman. Art is primarily subjective, then objective. The process of illustration is purely one of externalism. It is representational truth, as contrasted to the formally expressed emotion of art.

Illustration is pragmatism applied to art. We can enjoy art without connecting or correlating it with our practical needs, and its function is to satisfy. The creator, whose impulse arises from an excess of emotion, expresses himself by clarification and form, obtaining relief. The observer finds in a work of art an oasis where he is able to quench his intellectual and aesthetic thirst. Art engages the whole man - his senses, his mood, and his understanding. Illustration attacks his interest and his reason.

"While the arts of the community, great sculpture, architecture, and painting, embodying ideals of social unity,

are calculated to induce respect and contemplation", (1) the arts of commerce and instruction must be so self-evident that little searching for substance is required. In these arts of commerce and instruction are found the two major classes of illustration. Among the former are all types of industrial advertisement, newspaper photographs, billboards, posters, and magazine illustrations. The obvious common characteristic is attraction of the observer. These are psychological works, whose aim is to arrest the immediate and undivided attention of all viewing them. So forcibly must this be done that the interest will carry on into the printed matter. In many cases it is necessary to tell the complete story clearly in the short interval during which interest has been captured. Such illustrations involve conception, imagination, and originality, but little pure expression, since they are so influenced by the purpose of selling and distribution.

The instructive illustrations are of two categories: those which are purely formal, and those which represent fact. Graphs, maps, and charts, although now often rendered attractive by the use of color and stimulating symbols, are nevertheless formal expositions of plain fact. There is no expression, no interpretation present. Illustrational graphs

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(1) Henry Rankin Poore, Art Principles in Practice. p. 135

may be compared in this respect to pure design in the field of art. The only creative element involved in the former is ingenuity of arrangement, and often the planning is predetermined by the statistics themselves, if not by the statistician.

The "representing" scientific illustrations, as the name implies, re-present, or present facts again, and it is with the latter that we are most concerned.

II

Functional Analysis

The scientific illustration has a single purpose. It must teach. This entails not only the elucidation of written material, but even a replacement of text. (2) The scientist demands simple, direct exactitude, and it is the function of such a drawing to stimulate and to satisfy his intellect. Only a combination of the inseparable qualities of precision and clarity can accomplish this. The artist needs far more than a facility of technique to execute successful illustrations. In each case he is required to clarify the material to be presented, and often to amplify the presentation with necessary elements not actually found in the specimen before him. He must emphasize relevant matter, without resorting to distortion. The proper amount of information should be concentrated into each drawing - an excess would cause confusion, and an insufficiency would cause misunderstanding. Often series of drawings are essential in picturing facts not logically included in one.

The standards of these illustrations are directly correlated with their function, and all are interdependent.

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(2) Max Brodel, "Medical Illustration," in the Journal of the American Medical Association, p. 668.

Significance must be apparent in a scientific drawing. With or without title, the meaning should be self-evident to anyone acquainted with the general field represented. An illustration which teaches needs directness, almost obviousness, a quality accomplished by the use of simplicity of presentation and correct selection of detail.

The good scientific drawing is exact. All facts shown must be true, and there can be no falsification, however minute, of any detail involved even if it be done merely for the general effect of the work. The scientific illustrator is not an interpreter, and he may not exaggerate or distort the curve of a line, nor the value of a shadow because it might appear more "artistic". Indeed the term medical art, or scientific art is a misnomer. The process in this type of illustration is one of copying from nature, of synthesizing, and of delineating, but never one of expressing. Actually, many of the forms and contours of natural structures are inherently aesthetically pleasing. The illustrator should be wiser than to try to improve upon Nature.

The clarity essential to a successful drawing of this kind depends largely upon effective clearing away of extraneous material from the picture. Mere elimination of small detail is not enough, since a qualitative rather than a quantitative factor is involved. Here the artist must make good use of acquired judgment. The drawing is often

revised several times before only the correct elements have been incorporated in it. Abundance of detail in an illustration is easier for the artist to execute, and impresses the layman, but the difficult outline drawing is in many cases more efficient.

Plan and composition are indispensable to a scientific illustration. For each there is a separate and individual question of arrangement of material. The artist must solve the problem of representing the specimen, or its more distinctive features, to the best advantage, bearing in mind at all times the reaction of the observer, and the purpose of the drawing,

To the list of significance, exactitude, clarity, and planning we need to add technique, to complete the criteria of the approved illustration. This term indicates manner of presentation and is directly dependent upon the medium used. Since this is to be thoroughly discussed in Chapter VI it will be sufficient here to rectify an unfortunate misconception concerning it. Technique is not the result of remarkable artistic skill on the part of the draughtsman. It results from a great deal of practice and drudgery, and can be acquired by any normally coordinated individual. The ability to reproduce with proficiency and ease in several media is, however, compensation in itself.

III

Qualifications

The scientific illustrator must possess above all other qualifications training in science, practice in technique, and boundless curiosity. A background knowledge of the scientific field most closely allied with his specialized illustrating, plus a good foundation in the other sciences is indispensable. The medical delineator must have studied certainly Comparative and Gross Human Anatomy, Physiology, and Histology. Courses in Osteology and Pathology have also been found to be of great value. For the Botanical draughtsman, a knowledge of general Botany, Plant Anatomy, Systematic Botany, Mycology, and the like, are essential. To these rather general courses should be added as often as possible any further work of a related nature. These studies must be supplemented with continuous practice in sketching directly from specimens observed, and for the most successful results to the future illustrator, a thorough ground work in drawing, natural and mechanical, should be laid at this time. A great deal more than either an adeptness at drawing, or an interest in science is required to make a competent scientific illustrator. The man or woman who has a fine appreciation for art and a flair for drawing may very possibly have no such flair for scientific learning. Just so an excellent student of Zoology may find a prohibitive clumsiness when he attempts a drawing. Of these two the more fortunate is the latter.

Constant practice and application to technique would in all probability, overcome stiffness of finger. Obviously the person most suited for the work is one with capabilities in both fields.

The paramount requisite for the artist is basic scientific knowledge. It enables him to understand the specimen to be drawn. He is informed as to its salient parts, its function, and its gross departures from the average in respect to morphology, color, position and other subtler variances. Of more importance than this, however, is his conception of the necessary and relevant, a quality acquired by a study. He develops a sense of judgment and discrimination and is enabled to eliminate almost subconsciously, the details which have no value to the drawing, and which might confuse the observer. Thus he achieves not only simplicity, but clarity of technique and orderliness of presentation. It is not enough to have certain knowledge. The knowledge must be used to advantage. Even in the field of scientific drawing active observation supplements mere information.

Not only must the artist observe carefully all pertinent details of his own specimen, but he must assume the responsibility of finding other similar specimens, if they be available, to compare and contrast them with the one he is to draw. Thus if he illustrates an abnormality he can ascertain clearly just where differences occur. If the draw-

ing is to be of a characteristic structure, the average is more apparent. His observation cannot stop here, however.

The draughtsman needs to form the habit of text research. New and sometimes radical changes are continually being made in all realms of science, and he is expected to keep up with the major innovations in his field. Then too, he must learn to refer to works dealing with the specimen he is planning to illustrate. Very often older drawings are found to be helpful.

As in any other endeavor there is here a code of ethics, and the so-called illustrator who copies directly and deliberately another drawing, calling it his own is not only breaking faith, but what is perhaps worse in view of the consequences, he is quite possibly perpetuating mistakes which should have been corrected. Within the scope of the various medical illustrations--surgical, anatomical, and the many others--the artist's responsibility to the doctor and to society is especially significant. For this reason, if not for one of an ethical nature, there must be a firm maintenance of intellectual integrity in all works of this type.

Nevertheless, a certain amount of synthesis is necessary to the greater number of drawings. Seldom is a person in this profession so self-sufficient that he need take no advice from the works of others as to arrangement and presentation; and often he is fortunate enough to find

in another's drawing some detail which is not apparent in his specimen. When the artist is given the assignment to execute a picture for which he can find no specimen, he must resort to gleaning from what literature and illustrations he is able to find on the subject all pertinent facts available. From these he can synthesize his own work. This process of selection and combination is far removed from one of plagiarism, and requires an active sense of judgment on the part of the illustrator.

Judgment, in this case, the ability to distinguish between the relevant and the unnecessary, is an indispensable attribute of the scientific illustrator. As has previously been mentioned, in order to achieve the clarity of exposition required of a scientific picture, the artist needs know which particulars to omit. This responsibility is frequently taken over by the author or scientist who commissioned the work, to the extent of pointing out what structures are necessary to the purpose of drawing. It is up to the artist to decide which elements of line, of shading, and of fact are demanded to indicate form. This obviously involves technique.

Technique is a matter of practice, and can be perfected only by patient application. It must be mastered before the student can hope to produce a satisfactory piece of work, but once mastered it becomes an automatic

process, and the artist may be totally unaware of any great importance attached to it. Since this is true, the following remarks dealing with the topic of technique will be addressed to the student who wishes to improve his drawing assignments in the sciences, and to the beginning illustrator who desires some preliminary guidance to his chosen field.

The ability to sketch accurately and rapidly from nature is the principal prerequisite to technique. It makes no difference whether or not the beginner knows precisely how to make a neat brush stroke, if he has not learned to copy exactly the structures and details of any specimen before him. Although some instruction is certainly needed for this, with initiative the student is able to accomplish a good deal for himself. He can cultivate the habit of sketching rapidly and as accurately as possible at odd moments during the day. When not actually drawing he should notice carefully the form of everything around him - the angle of an open door, the highlight on his neighbor's jawline, the tones of shading on a cloud. Then he can notice how otherartistsand illustrators indicate these things in their own pictures. Such exercises are of great practical value, but only when the lessons learned are made to apply to actual presentation.

All study and practicing should be directed toward

understanding of perspective, form, color, shading, and outline drawing.

A thorough training in the use of perspective is absolutely essential, and should include a course in mechanical drawing. At any time the artist may be called upon to draw various types of equipment and apparatus. It is well within the province of medical illustration to require this, since in almost all surgical pictures are found retractors, probes, and scalpels,

By way of digression it should be here pointed out that in all types of scientific illustration there is sooner or later a need for the sketching of hands, in every conceivable position - holding instruments, pointing to details, or pulling back tissues, for example. Therefore the student would do well to practice drawing his own hands in as many attitudes as possible. This fulfills the double function of learing the hand, and also, because the fingers are such long narrow structures, it is one of the best exercises in foreshortening,the bugaboo of the beginner, and a problem even for the more advanced student.

IV

Execution

Once the student has become adept in accurate sketching, he must learn to execute a finished drawing. This involves elements of arrangement, actual technique, and attention to refinements which lend excellence to the final product.

By arrangement is meant composition, and organization of material. These are preliminaries. There must be a systematic relationship between parts and the whole design. The student needs ingenuity and discrimination to obtain unity in his drawing; it is accomplished primarily by practice, but it has been proven that some individuals have a better sense of composition and distribution than do others. To develop this latent sense the initiate must learn to consider each projected drawing as a separate and distinct problem, to be solved first by studying and observing, then by planning with purpose in mind, and finally by actual drawing.

There are two main steps in the technical execution of a scientific picture. The first of these is the preparatory sketch. It is ordinarily done in pencil, or, if the undertaking be large, in charcoal. In any case the medium must be adaptable, quick to work with, and easily corrected. In the initial sketch the object is draughted in masses and gross structure, rather than in outline. The

artist now determines the axes and directions of the components of the whole. At this time he plans the arrangement of the drawing on paper; then he places the written matter--descriptions or labels--to be included in the completed project. Each illustrator develops his own method of procedure from here. The following method is offered as suggestion, not as absolute direction.

The rough draught is corrected as to outline and more important details. A copy is made, usually by tracing lightly and precisely in pencil. The next step is one of determining the proportion and position of other details. When these have been fixed, the artist is ready to determine the range of values, that is the regions of greatest and least darkness, with all points of gradation between. This is done in the medium of the drawing; that is, if it is to be a black and white wash, the tones are filled in lightly at first with brush and very dilute ink. The entire picture is developed evenly, one part is not finished before another. Gradually the drawing is evolved by going over each part, each detail, and by bringing out its form and characteristics. This is a slow process. Oftentimes in the case of absolute outline drawings, a rough position of parts and structures is necessary in order to reproduce an exact outline. (Plate 1 figs. 1-5)

This process is substantially the same for any of the accepted techniques.

The technique used in a scientific illustration is dependent upon reproduction facilities, the type of illustration, and the purpose of the drawing, respectively. The easiest to reproduce are pen and ink drawings, be they plain outline, stippled, or cross hatched. Since these are all in absolute black and white, the process of printing is simplified. It is more complex in the case of wash drawings and other tone pictures such as dust and airbrush, and consequently more expensive. Color illustrations require an entirely different process, and they cost the most to reproduce. When many exact small details are to be presented, the tone drawings are most successful. Those pictures which may be of a more diagramatic nature are very well done in the black and white techniques. The more finished illustration is the tone drawing. It is used almost exclusively in illustrating medical and anatomical work, whereas stippled pictures are fully adequate for elementary textbook purposes. Color has many uses. In microscopic drawings where stain differentiations must be shown, in anatomical drawings where there must be distinction between arteries (red) and veins (blue), and in the paintings from nature where many color variations are important to classification, paint is indispensable. Tone drawings are best adapted to cytological and histological work. Pen techniques are too definite for this; under the microscope no line appears so positive.

Pencil, in reproduction, appears light and vague, and it is rarely used in books.

In all cases it must be emphasized that the technique used is of secondary importance. The research and planning which go before are of more importance.

V

Laboratory Drawings

In a discussion of scientific illustration, the work of the college science students cannot be ignored. In most of their classes and especially in the corresponding laboratory sessions, much drawing is done. These sketches are simple in the extreme, and often seemingly primitive in presentation, not only because of lack of practice, but also because of a basis difference of function as compared to the regulation scientific illustration. In the first place they are done solely for the benefit of the student himself. He is indicating a required minimum number of facts for which he is responsible. The student is not concerned with teaching someone else; drawings are to him merely a concise method of demonstrating and of storing learning. Laboratory drawings, after having been corrected and returned by the instructor, are kept in series by the student, and thus form and excellent method for review.

Since general college laboratory drawings are to be executed quickly and clearly, the medium must be both familiar and easily corrected. The obvious choice is, therefore, pencil.

Such drawings must be neat, and this necessity eliminates the use of any pencil soft enough to "smudge" after a normal amount of handling. The most successful

lead has been found to be medium hard. Too hard a lead gouges the paper, unless used expertly, and it is impossible to erase lines of this type.

The neatness of the drawing depends largely upon the grade of paper used. It must be durable and not too expensive. It should not become rough and wrinkled from erasure and constant use. For this purpose a good grade of bond paper is suggested. The dimensions of the sheet can best be determined by the individual instructor, since they are regulated by the size of notebooks, folders, or manuals used. Often manuals are arranged with blank pages at each lesson for drawings. Unless these pages are detachable, this is not always successful. The student is not free to manipulate the page to his liking, and may not be able to draw to his best ability.

Without a concept of preliminary arrangement, the use of proper medium is not sufficient to give an appearance of all-over neatness to the work. Drawings of only one type of an organism should be permitted on the page, yet this does not suggest that each page must contain but a single sketch. Such a requirement is beneficial to the student. Quite apparently, a page containing a melange of several types of organisms would only serve to confuse him at the time, and would be far more difficult to remember later on.

Placing of the drawing is also of prime importance.

The first consideration here is margin but this again depends upon the system practiced in the individual laboratory. The following format is suggested because of its convenience. (Plate II)

In the upper righthand corner is printed the classification of the specimen or specimens drawn, a separate line being used for each. This should occupy, on the average, a space of approximately two and one half inches square. Such an arrangement helps when reviewing. The printing need not be of any special kind unless so indicated by the instructor. The main consideration in this, as in all printing, is uniformity of size, of case, and of slant of the letters on the page.

For the donvenience of the instructor, and to balance the page, the student's name, that of the course, and the date are printed in the lower righthand corner of the page.

The drawing is so planned that approximately the same amount of space is left at top and bottom of the sheet after allowing room for the title. This should appear directly beneath the drawing proper. Then, centering from the other direction, the student arranges for side margins. Here space must be sufficient on the right to accommodate all labels. In all events, at least an inch of free space ought to appear around the sketch, with the possible ex-

ception of the right side, and even here labels should never "run over" to the edge.

The correct labelling of a drawing is not an easy task. There are often a large number of labels, and little room for them. The printing is necessarily small. Then, too, all lines from details on the drawing must be paralled, and should go directly from structure to label. Never is it permissible to cross lines. A right angle in the line above the detail to be labelled, (raising the line from its normal position, although maintaining its parrallel plane) is allowed only when there are too many labels assigned to one small structure. In this case it would be impossible to have all parallel lines arise from such a limited area. Since it is necessary for the sake of a neat and easily understood arrangement that all printed labels start one directly above the other, a perpendicular guide line, either in light pencil or with the fingernail, should be drawn at the appropriate position on the page. Thus label lines lead uniformly from structures to an even front.

Printing is difficult for many students. This can be corrected in almost all cases by the constant application of the two principles of simplification and uniformity. Individual letters are most successful when composed of combinations of straight lines and circles or ovals. There is no need for any other lines or curly-queqes; individuality of

this sort is ridiculous here. Letters should be uniform in size, height, spacing, and slant. Naturally all lines of printing are to be horizontal on the page. It is advantageous to rule lines for printing.

The drawing itself is the next consideration. The instructor will do well to remember that each student draws best and with most assurance when he is allowed to draw in the size which occurs naturally to him. It has been found that in general the variation of drawing size in an average class is small indeed. However, if a student habitually turns in sketches which are obviously too large or too small, a certain amount of guidance and of practice brings him closer to the normal.

The student must be impressed with the great logical value of making these drawings in his laboratory courses. It is actually impossible to learn thoroughly any of the biological sciences without drawing the specimens under examination. Exceptions are made, however, as for such subjects as Comparative Anatomy, where the structures and systems are complicated, and require of the students an undue amount of time to draw. The next best method is that of equipping each student with printed drawings without labels, or with semicompleted printed drawings, to be finished and labeled during the laboratory period.

By putting down in visual form facts learned and ob-

served, the student clarifies them, and emphasises them in his own mind. A detail, once drawn, is easily remembered; it has become the draughtsman's property, mentally and actually. If forgotten, it is always available for reference. When an entire course is to be reviewed, the sketches offer a concise method of doing so. It is possible that many facts might be overlooked if drawings were not a requisite of the course. Drawing is thus another aid to the student.

The drawing by each student is definitely indicative of that student's abilities in learning and of his thoroughness. He should realize just how much and how fair a basis for grading are these pictures.

A sure line cannot be drawn unless the artist knows exactly the position and direction of that line. It is impossible to determine this position and direction without first knowing the relationship of the structure which the line is to represent to the whole. It is, therefore, to put it dogmatically, not possible for the student to draw a true and sure line if he has not studied the specimen in question. A sketch indicates immediately to the trained observer any lack of investigation of subject matter on the student's part. Constant erasures and short, hesitant lines are signs of ignorance. Although a drawing copied from another may seem excellent, it usually is detectable through an indifinable lack of spontaneity and

freedom of execution.

The student who firmly declares that he possesses no artistic ability, and for that reason cannot do laboratory drawings, has either never tried to make any, or has not yet learned to study.

VI

Techniques

Pen and ink drawings all require the same preliminaries and the same care of equipment. It is advisable to make a pencil sketch of the specimen first, and to transfer it lightly in pencil to the final paper. For best results, this last should be rather heavy and smooth. There should be no chance of loosening fibers with the pen, an occurence which invariably leads to uneven lines and blots. To maintain even lines the pen, of no matter what kind or size, must at all times be kept clean and free from particles of dried ink. Even while in use the pen should be wiped at frequent intervals. The ink used may be any good brand of India ink; the only kind to make really black lines. The bottle must never be left open because of evaporation and sedimentation both of which change the composition of the ink, and thus eventually affect the picture. Handling of the paper before and during the process of drawing should be avoided, since ink does not adhere evenly to the paper where minute droplets of oils from fingerprints are present. The foregoing suggestions, learned from experience, are all made in the interest of the successful finished product. In the completed drawing all lines must be of equal width and should be as continuous as possible. Broken lines, unless purposely so executed, are indicative of carelessness on the part of the artist.

In stippled drawings the values of light and dark are reproduced by varying densities of the "dots". These are properly made only after some practice. They must be uniform in diameter, and perfectly round. For this a clean pen, lightly dipped in ink, and held nearly vertical, is essential. It is often easier to stipple correctly by resting the wrist on the drawing board. Such directions are, however, only suggestive, since everything depends on the individual artist, and the only consideration should be the quality of the finished drawing. (plates III, IV, V).

Cross hatching is another pen and ink method. It involves the use of short lines to indicate form. Whereas stippling reproduces morphology through simple shading, this technique demonstrates form by use of shading, and the direction of planes of structure. The artist has the feeling of molding each shape. The lines are either straight or curved according to the surface involved, and go in the plane of that surface.

These drawings are made on any of the smooth heavy papers, and are especially successful on scratch-board, for mistakes are easily scratched out, and highlights are formed in the same manner.

Tone drawings are made in varying values of one primary tone, which is most often black. There are two techniques in general use to execute these. The first is the dilute ink method; the second, the carbon dust technique.

For dilute ink work the implements needed are several fine to medium sable brushes, India ink, at least three small glasses or beakers, and smooth, heavy two-ply paper. This is a process closely allied to water-color work. It is best to make three dilutions of the ink, very faint in the first glass, deeper in the next, and rather dark in the last. It is dangerous to work with the undiluted ink; only in drastic accentuation of structure should the artist resort to it. If the drawing be started and developed gradually and evenly, as suggested on page 18 , it will be seen distinctly that none of the values to be presented are actually dead black, except perhaps when the lighting of the specimen is extremely strong, and the shadows appear relatively dark. (Plates VI, VII, VIII).

The paper on which the finished painting is to appear should be taped absolutely flat, preferably with scotch tape, to a conveniently sized heavy cardboard or wooden plank. This is to avoid the buckling of the paper when it has finally dried. It is sometimes necessary to pass a brush moistened in clear water over the surface of the paper, of course letting it dry before using it. Such a "bath" tends to remove infinitely small oil and dirt deposits left by fingers.

As a word of precaution to the beginner in this technique, it should be pointed out that his most dangerous tendency will be to use dark tones immediately which causes

the final product to be overdone. (Plate IX). It is advisable to decide first the positions and depths of darker spots on the specimen, but it is more successful to use the lightest tones in rounding out the forms initially, although dark tones cannot be omitted. (Plate X).

Near the completion of the drawing the finer brush is used to make the accents of dark which give finish. At this time the highlights are also fixed. Although these are usually left white throughout the whole process, there are often instances where they must be applied with Chinese White water color. Few highlights are far more successful than many. Too many accents of black, especially on outline, lend artificiality to the whole, and remove any feeling of vitality.

The carbon dust technique is used interchangeably with the dilute ink method. In this case the paper is heavy, but with a pebbled surface of the artist's choice. A soft carbon pencil is rubbed on sandpaper, and the dust seived through cloth, and collected. The dust is applied with brush, and rubbed onto the surface of the paper with a pointed paper applicator. A small cork placed in a holder, and pointed, accomplishes the same result. Highlights are removed with a medium eraser, or with sharpened bits of art gum. The general process is similar to that of the ink wash method.

The air brush is used to some extent in this

work. Here the color is blown onto the paper by means of air pressure. Details cannot be reproduced by this method. It isused mainly for retouching and for smoothing out a relatively large area of the drawing. An air brush is a good piece of equipment to have, but it is not essential.

Microscopic drawings are usually executed in wash, either ink or water color. No line is absolute under the microscope, and the pen methods can only indicate definite lines. These drawings are of two sorts; the representative, and the reconstructive. The former are not difficult to do, and problems encountered, as is so often the case in any art process, can only be solved with practice and further experience. (Plate XI).

Reconstructive microscopic drawing is possibly one of the more fascinating processes. Here the artist needs to know the field in question especially well. He must understand the function and the structure of the organisms in question. By focusing up and down on the organism he forms in his mind the three-dimensional reconstruction of the external morphology of it, and, still referring to the microscope, he draws what he has imagined. (Plates XII, XIII).

There is a definite place in scientific illustration for photography. It is an excellent and fast method for the recording of fact which is apparent to the eye, and which needs no simplification or clarification. In those cases where underlying structures are not to be

shown, and where the structure may be represented exactly as is, this method is valuable. It is especially so in microscopic illustration, although such photographs are more difficult to make. However, it is impractical to use this medium in a great many instances, since obstructions such as blood, which in a picture covers structures with an undifferentiaed mass of black, or movement of some live specimens, are insurmountable difficulties. It is almost impossible to indicate the differentiations between adjacent muscles in a photograph. The camera may be used to advantage, however, in the reproduction of external morphology.

Photography is an aid to the illustrator in the preservation of the appearance of a specimen which might deteriorate quickly, or which he might have difficulty in obtaining later for reference. This is often the case, since many illustrations are not completed at the time of sketching.

At present a great deal of work has been done with moving pictures in this field. Among the interesting phenomena thus recorded, most of which obviously entail movement, either of locomotion or of growth, are microscopic views of protozoa, bacteria, and other similar structures. It is used extensively in the registering of the actions of animals in their natural habitats. A newer application of this medium is found in surgery. Colored

motion pictures of operations are now being perfected and are becoming valuable for teaching purposes.

Since a comfortable and convenient environment is necessary for satisfactory accomplishment in this, as in all work, it is recommended that the artist arrange that his drawing quarters be well lighted and large enough. A daylight lamp is the best solution to the lighting problem. Drawings done in artificial light do not have the same appearance when brought into natural light.

An adjustable drawing table is preferred by most illustrators. As to the rest of the equipment the choice remains as always with the individual. A small cabinet at his left hand, and at the height best suited to him, is suggested to store the smaller and repeatedly used objects, such as pens, pencils, brushes, paints, and erasers. A larger cabinet with at least one large flat drawer in which to keep paper in good shape, and several shelves for completed drawings should be near at hand.

VII

Suggestions

To anyone interested in illustrating and most particularly to those desirous of making scientific drawings, I should like to recommend the study of the works of two masters. The first of these is the great Leonardo da Vinci, whose brilliant example of research and of execution humbles, yet challenges the modern worker in this field. Leonardo, however, possessed one further quality so needed in any field of scientific endeaver. He possessed a probing and a constructive mind. His interests lay first in the investigation of detail and of cause, and it should be remembered that there were in his day no correct scientific treatises to which he might turn. Then too, he had the valuable habit of recording, by sketches and by words, all facts observed, in his famous Notebooks. The scientist of today may recognise several errors therein, but the surprising fact is that there should be present such an abundance of verities.

Of the modern scientific illustrators, the best known is probably the late Max Brodel of Johns Hopkins. It was he who is credited with the establishment of medical illustrations in this country. It is also suggested that the student read the article written by Brodel, referred to in this paper, published in the

Journal of the American Medical Association, August 1, 1941.

The constant examination of methods used in texts and on canvas in all forms of art is of great value. This should be done with especial notice of clarity and representational ease of technique, and arrangement. Even the accomplished draughtsman can find examples somewhere which offer suggestions for the improvement of his own methods.

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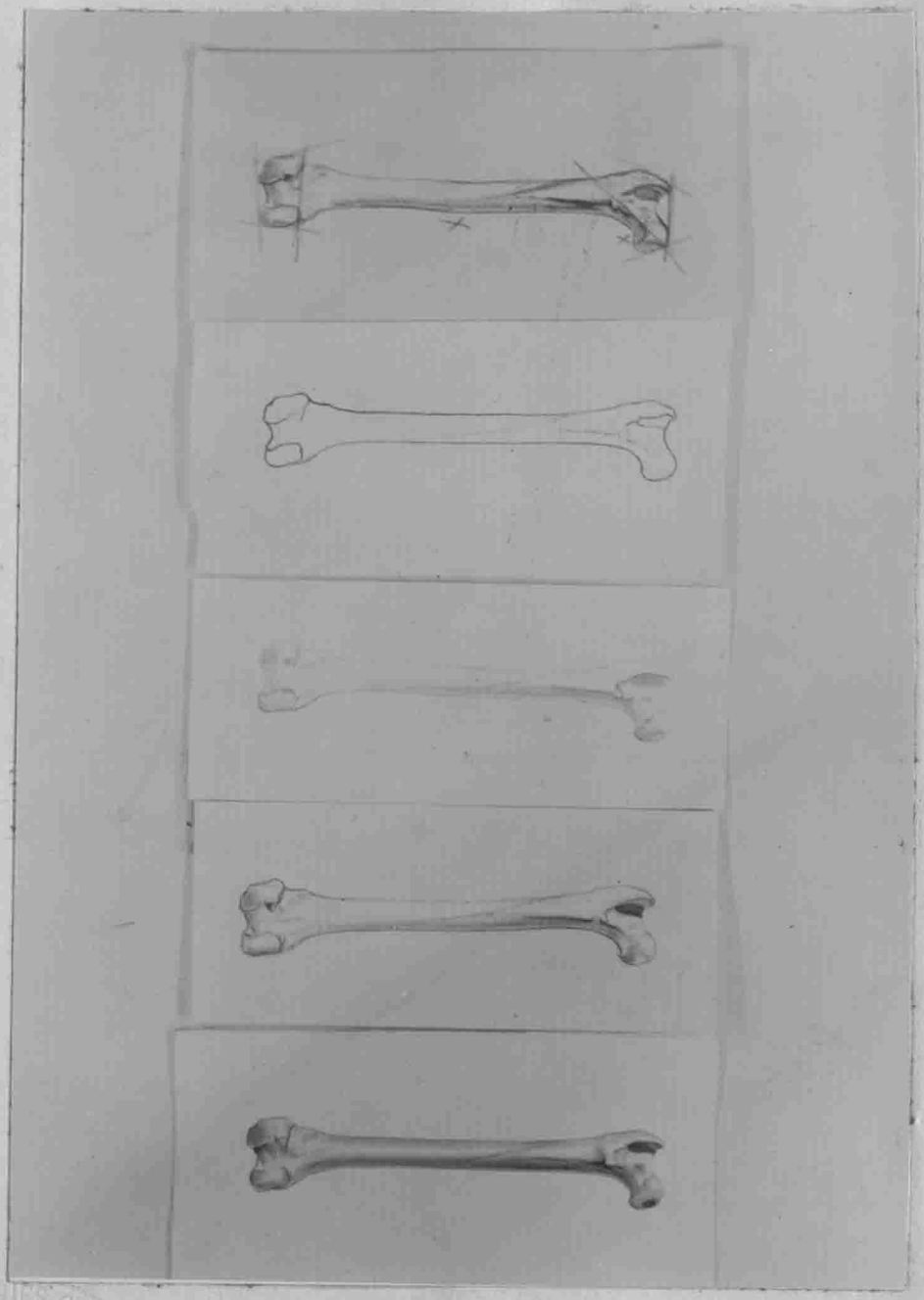

Plate I

"Gradually the drawing is evolved by going over each part, each detail, and by bringing out its form and characteristics."

-page 18

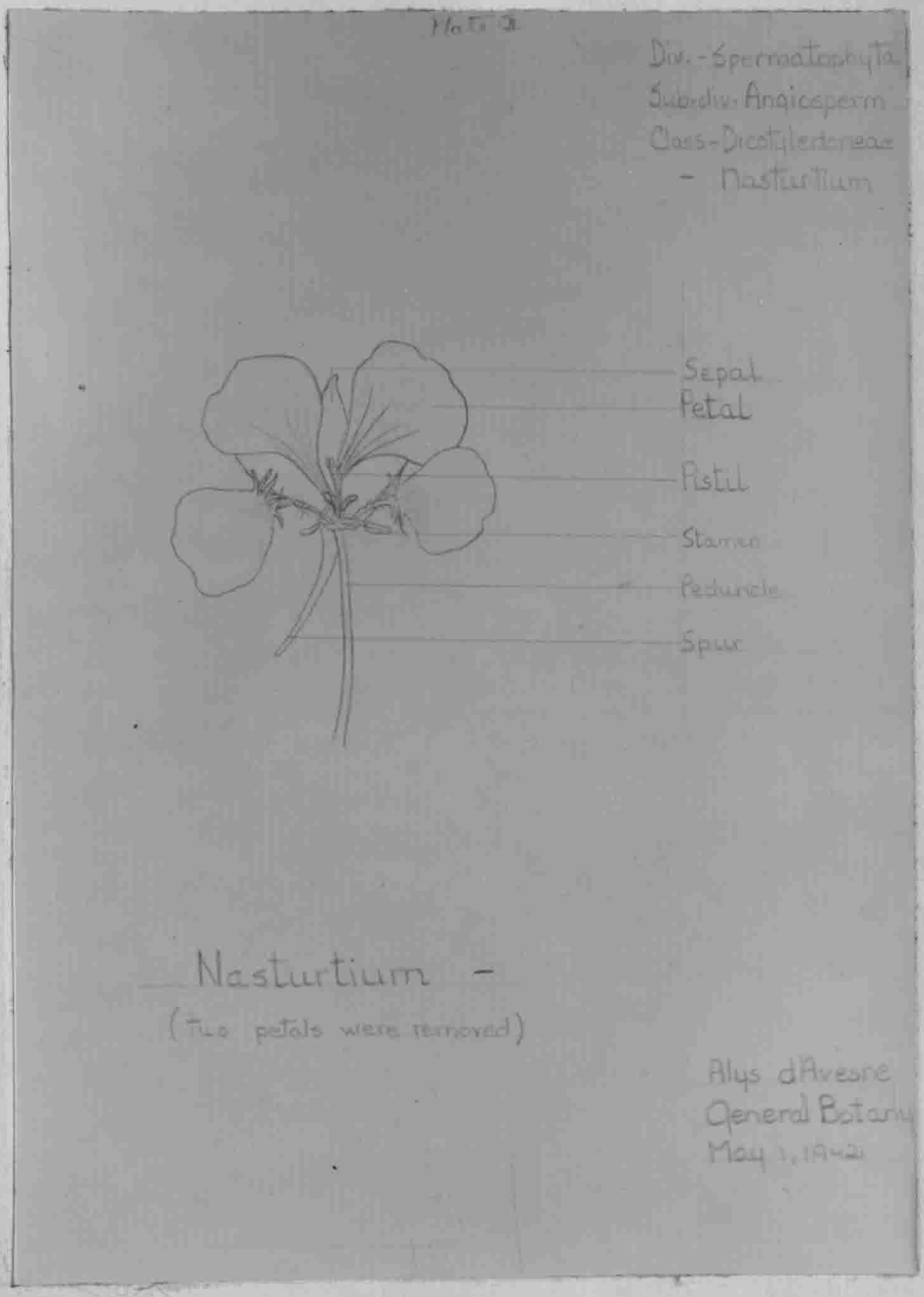

Plate II

" . . . (this) format is suggested because of its convenience and clear organization."

- page 24

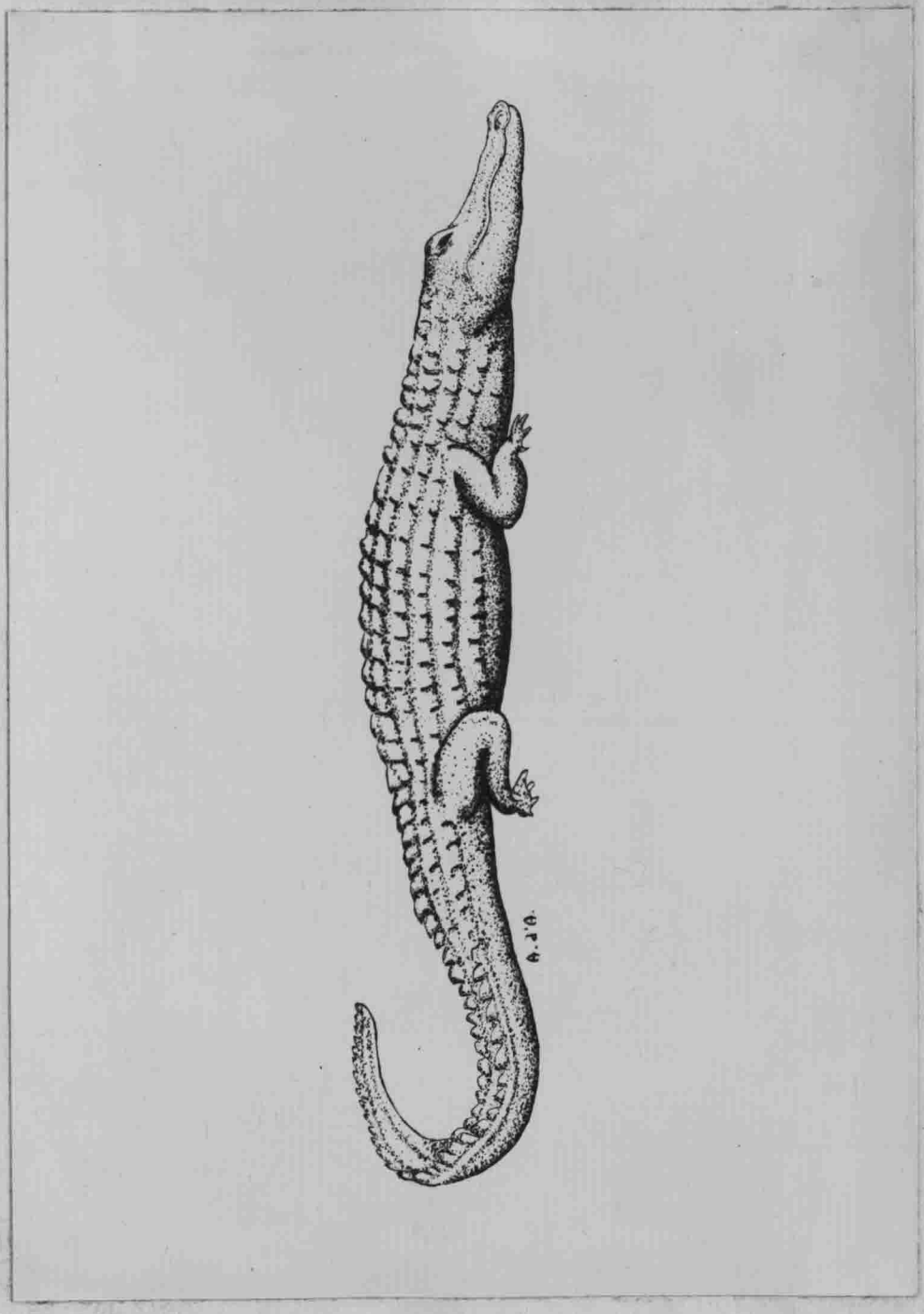

Plate III

"In stippled drawings the values of light and dark are reproduced by varying densities of the 'dots'".

- page 30

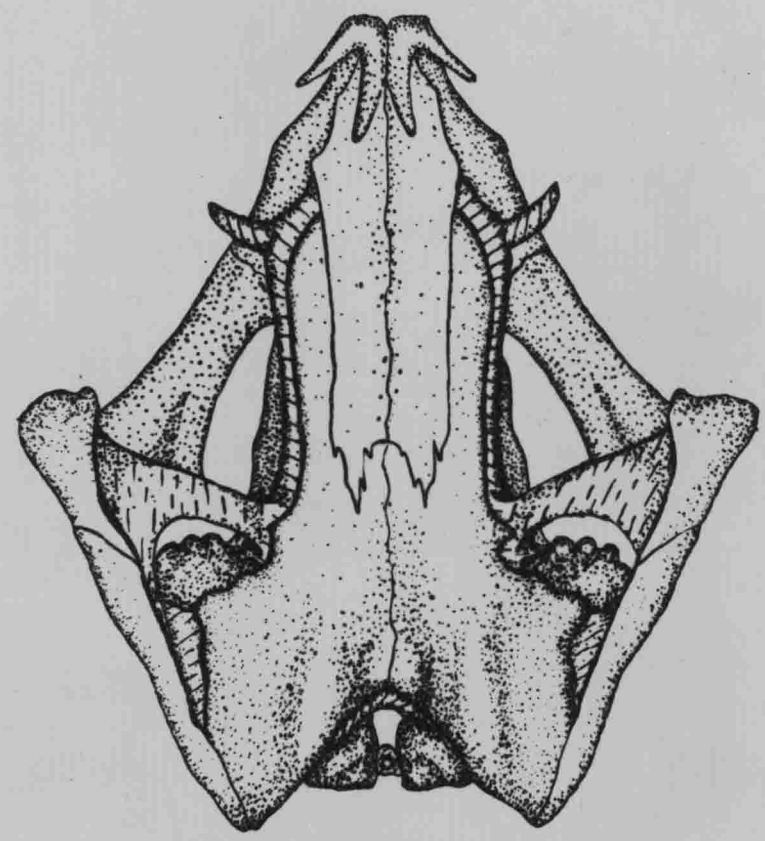

Plate IV

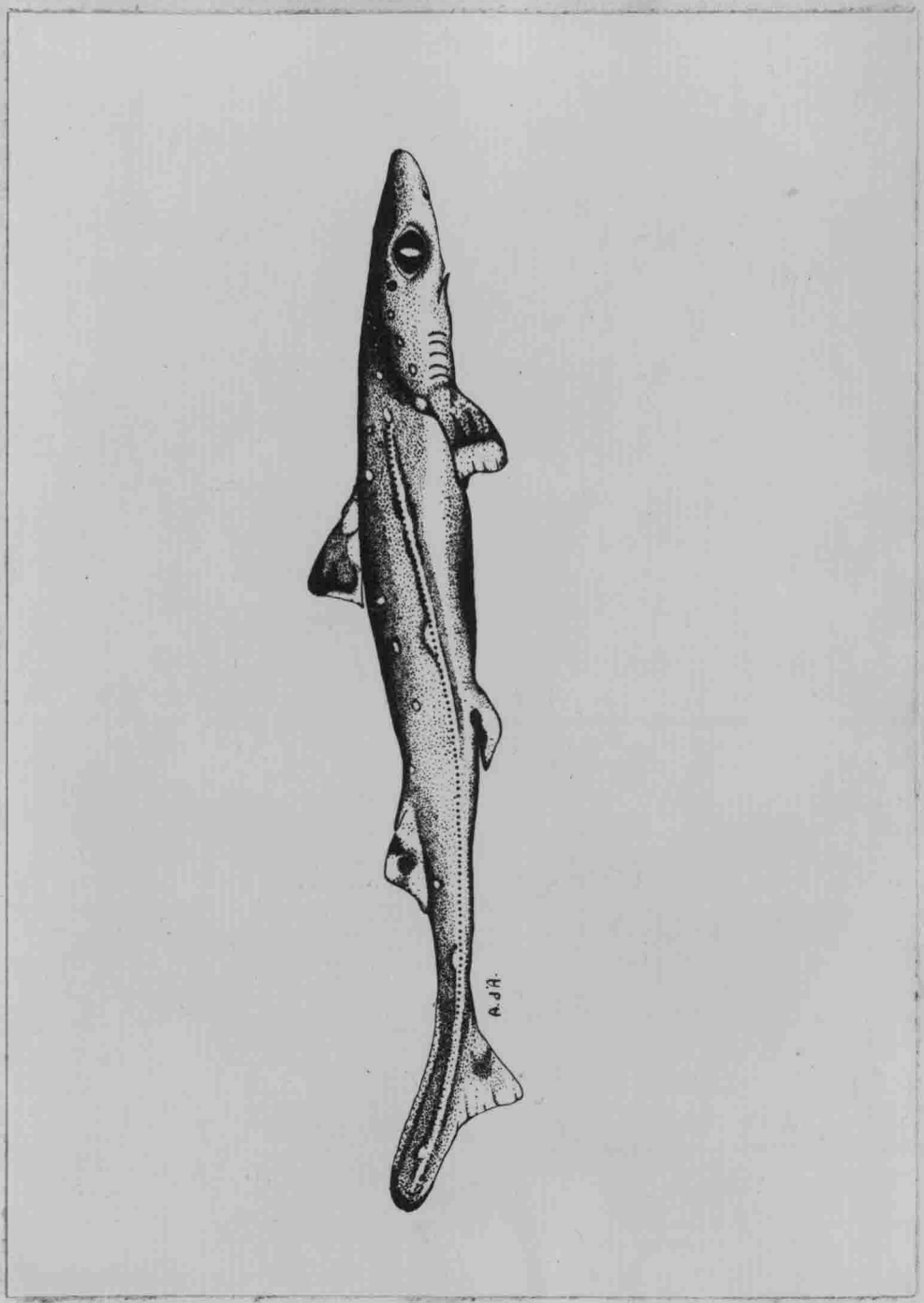

Plate V

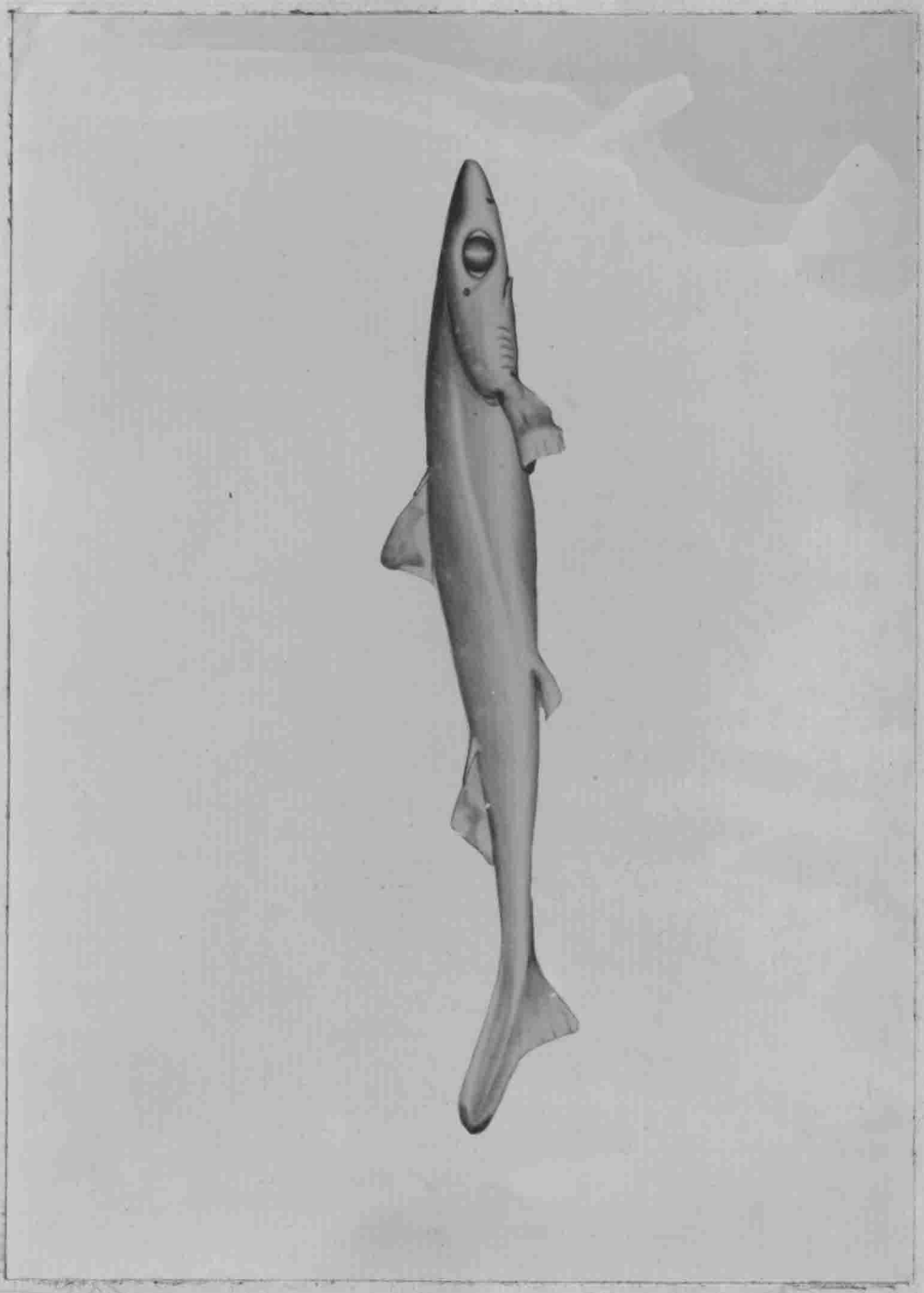

Plate VI

" . . . it will be seen distinctly that none of the values to be presented are actually dead black".

- page 31

Plate VII

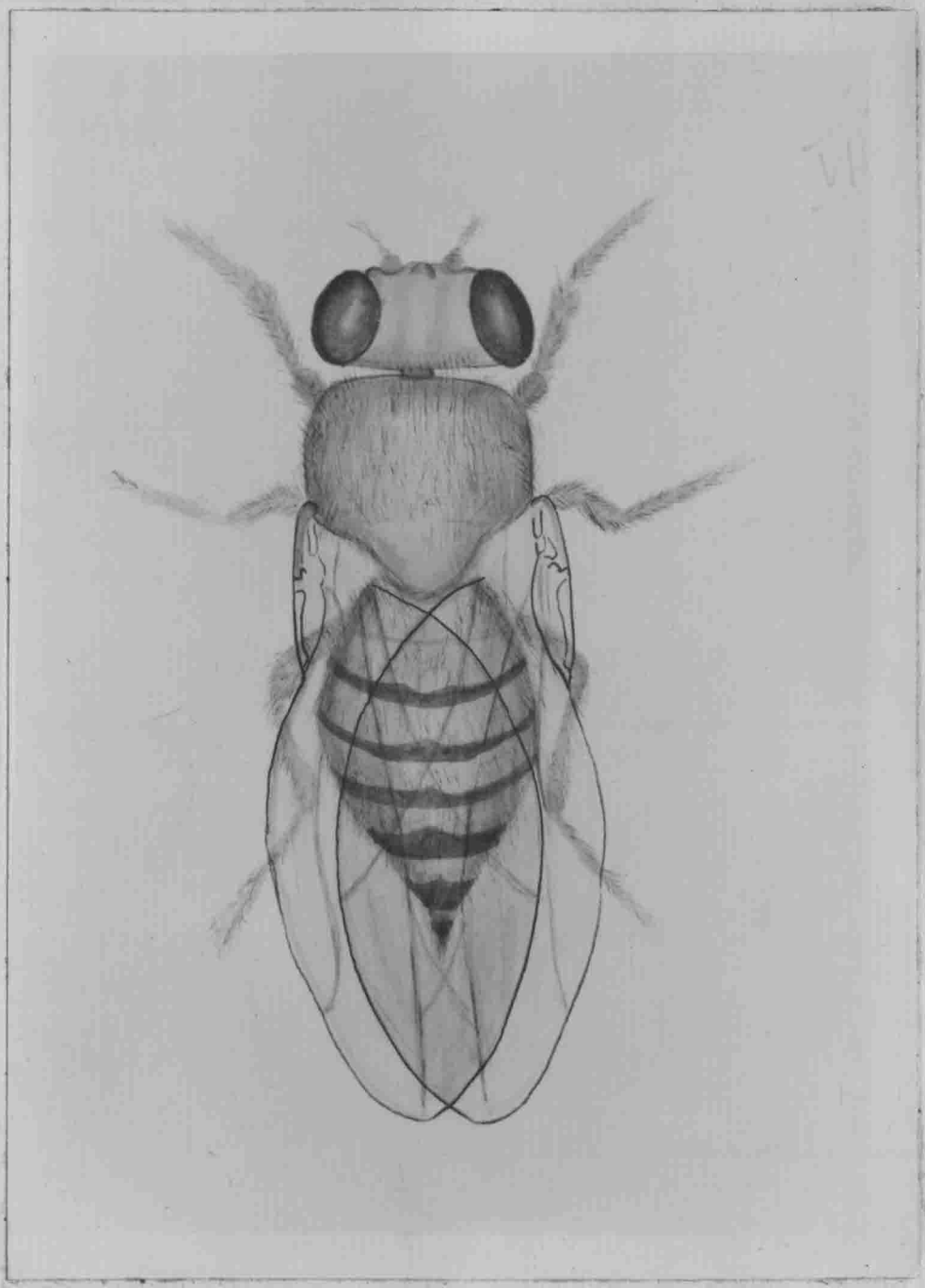

Plate VIII

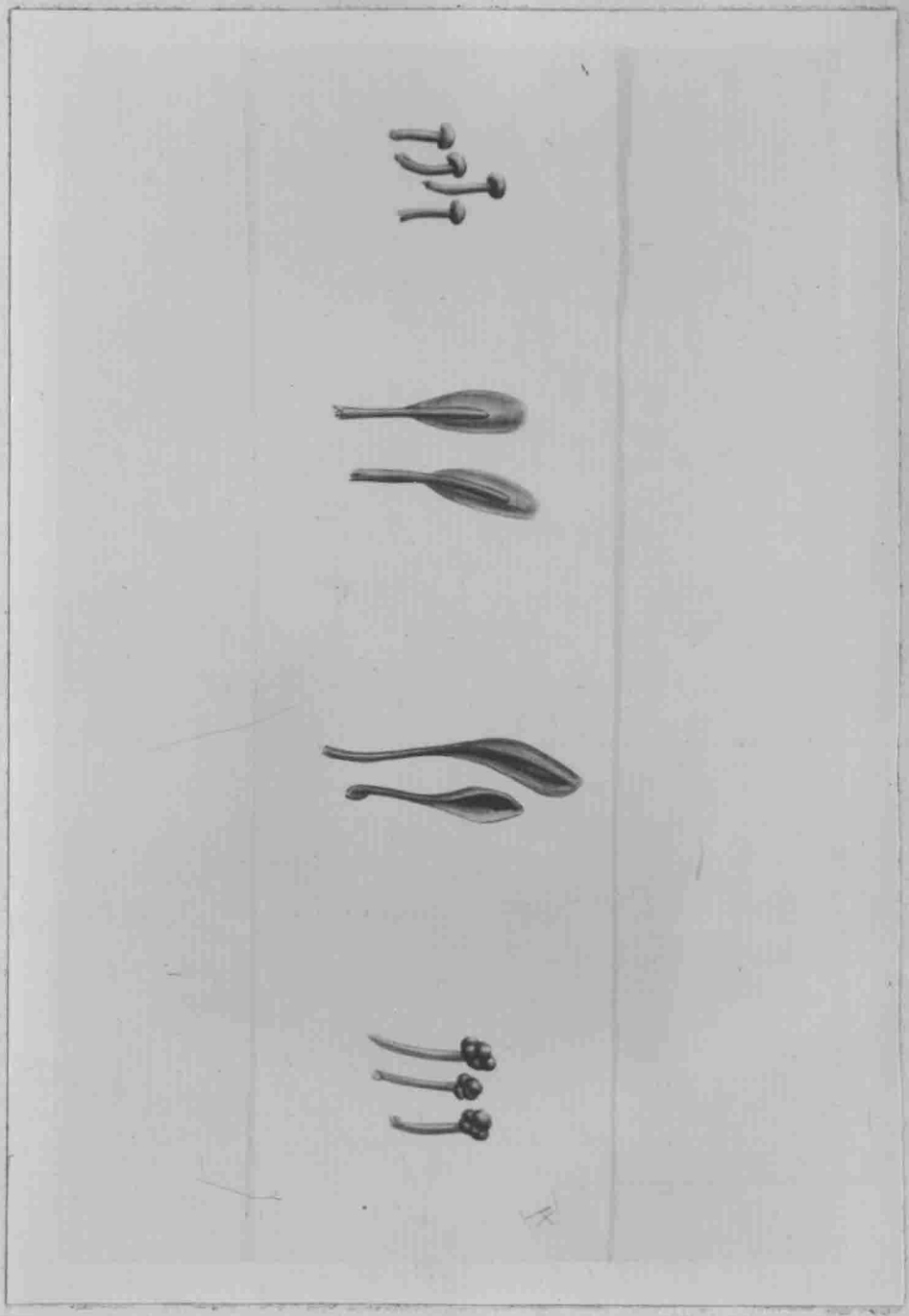

Plate IX

" . . . the most dangerous tendency will be to use the dark tones immediately, which causes the final product to be overdone". -page 32

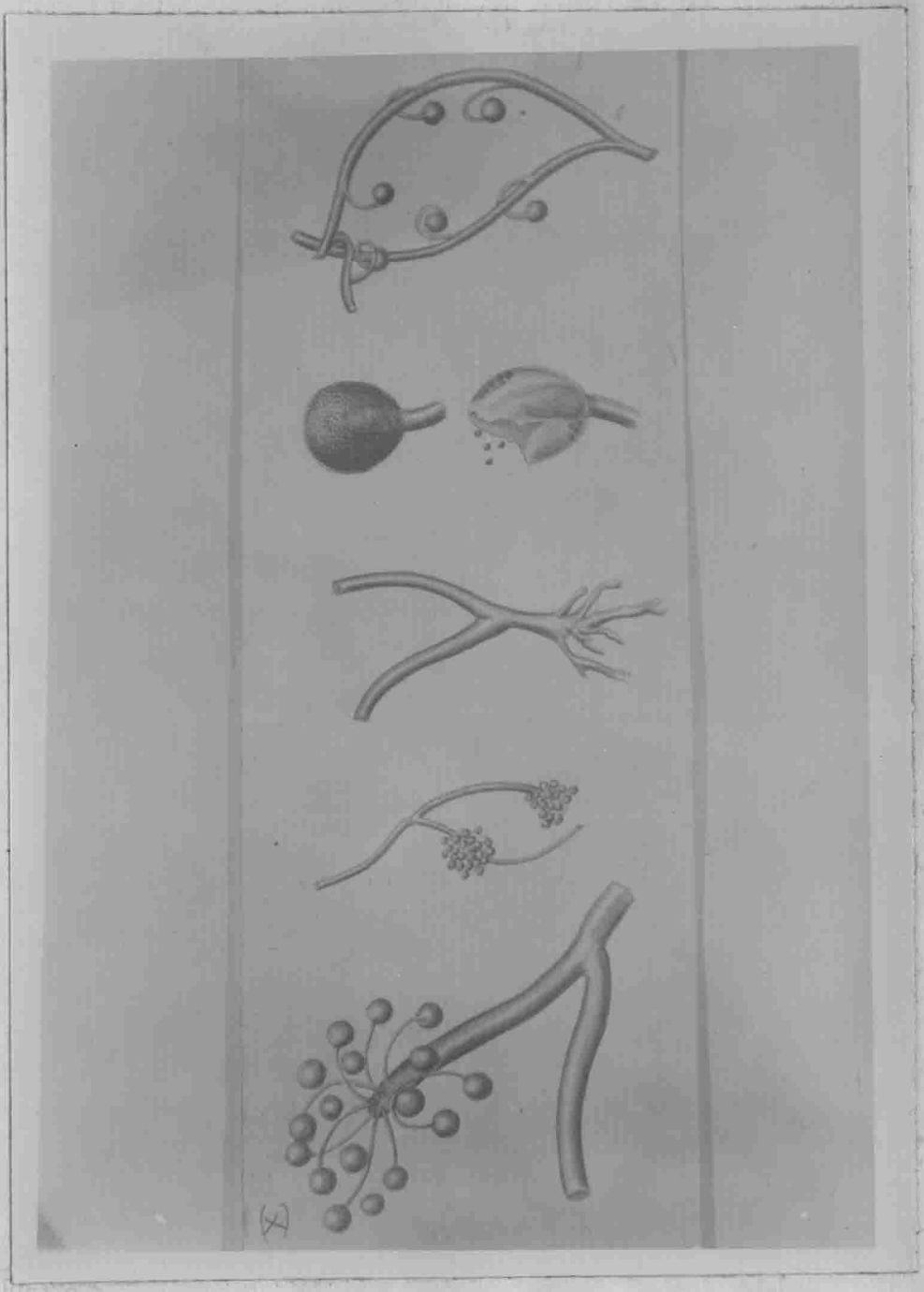

Plate X

" . . . dark tones cannot be omitted".

- page 32

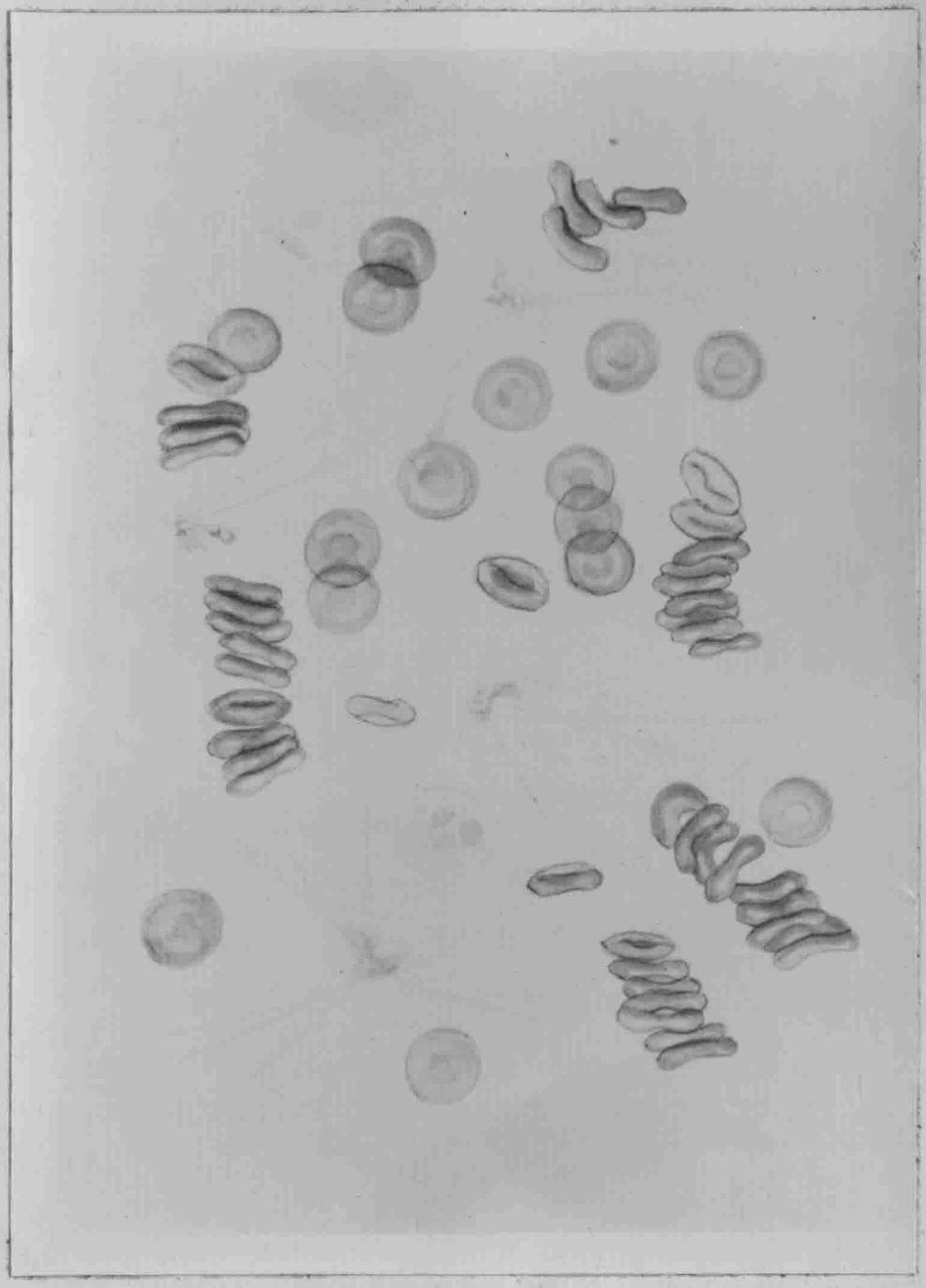

Plate XI

"Microscopic drawings are usually executed in wash".

- page 33

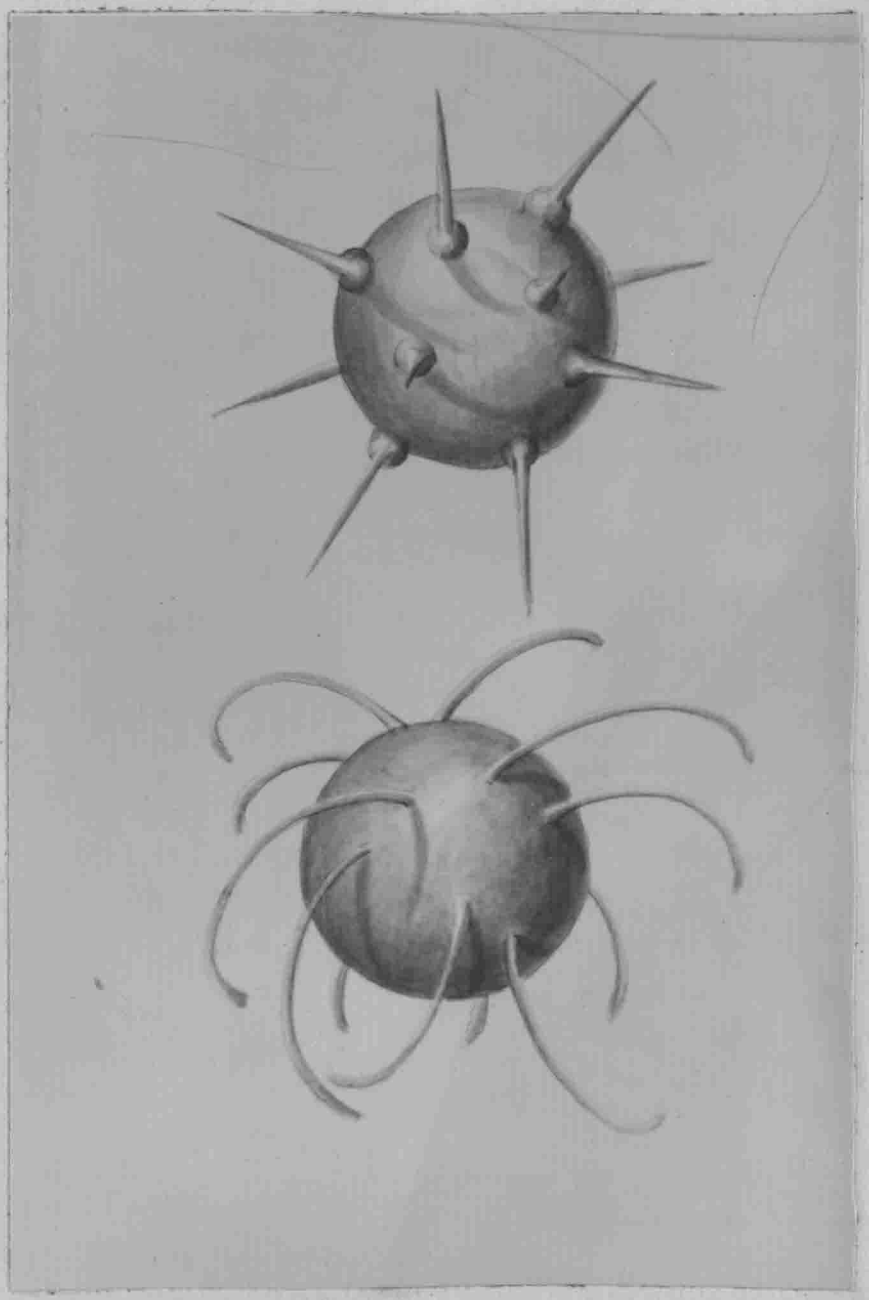

Plate XII

" . . . the artist . . . . draws what he has imagined".

- page 33

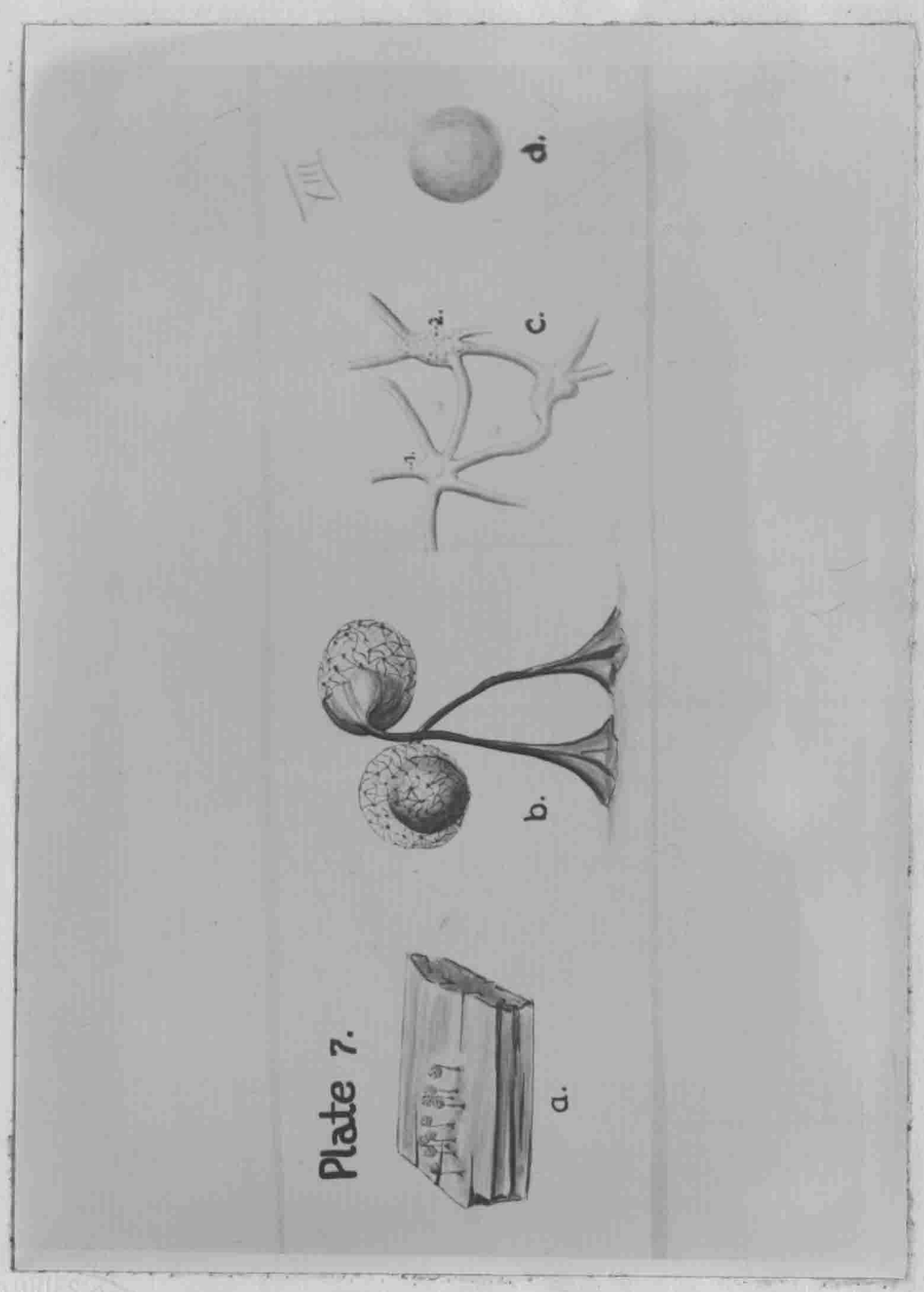

Plate XIII

Acknowledgement

For the genesis of opinions presented herein, I can but thank my professors who have encouraged and guided me so strongly in this field. Professor H. I. Myers initiated my interest in scientific illustration, and advised me during my graduate studies. To Professors J. W. Bailey and R. F. Smart, also of the biology department at the University of Richmond, I offer genuine gratitude for their patience and many suggestions.

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V I T A

I was born in Boston, Massachusetts, on May 19, 1918. My elementary schooling was accomplished in and around that city until, in 1931, we moved to Richmond, Virginia. I attended St. Catherine's School, and went from there to Westhampton College, graduating in the spring of 1940, with a B. A. in Biology.

Entering the Graduate division of the University of Richmond the following autumn, I continued studies in Biology and in Chemistry. At this time I also worked in the capacity of student apprentice with Mr. Hans Jelinek, Medical Illustrator for the Medical College of Virginia. During these past two terms I have served as laboratory instructor in histology and embryology, and I hope to complete successfully my work for a Master of Arts degree in Biology this year.