

THE CONSTRUCTION AND USE OF STEREOGRAPHIC
TRANSPARENCIES IN HUMAN PHYSIOLOGY

by

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THE CONSTRUCTION AND USE OF STEREOGRAPHIC TRANSPARENCIES IN HUMAN PHYSIOLOGY

CHAPTER I INTRODUCTION

In the teaching of physiology as in other biological sciences there always arises the problem of adequate visual material. Many attempts have been made to use flat pictures, models, preserved specimens, fresh specimens, stereopticon slides, and moving pictures. These materials and devices are good as far as they go, but they all have their own peculiar limitations. Flat pictures often are misleading unless the student understands how form is represented by shadings and tones. Modern educators say this about flat pictures: "Flat pictures have but two dimensions. They lack depth, which sometimes gives the pupil wrong initial concepts."¹ Models are more realistic than flat pictures, but accurate models are expensive and usually are not available. And even the best models leave much to be desired in presenting absolute scientific accuracy. Good preserved material, in some respects, is more realistic than models. But many teachers have neither

1. Heiss, E. D. and Obourn, E. S. and Hoffman, C. W.,
Modern Methods and Materials for Teaching Science,
p. 161.

time nor patience to keep an adequate supply on hand. To expect the school board to buy a complete supply is out of the question because of the expense, since old material must be constantly replaced if this type of material is to be kept in first class condition. Fresh specimens would be excellent, but there the expense would be even a greater problem than in the case of preserved material. Stereopticon slides present much the same problem as flat pictures. Moving pictures are fine for presenting living material, such as the beating of the heart and peristalsis of the stomach and intestines. But for dead specimens the cinema film is no better than flat pictures, except that it can be shown to the whole class at the same time. This, however, is no advantage for individual study.

An encouraging possibility in visual aids, especially for the biological sciences, is the three dimensional pictures which approach the preserved and fresh specimens in being realistic. They have the added advantage of being cheap and easy to handle and file. They overcome the difficulties of flat pictures and make it easy for the student to get a correct impression of the actual appearance of the object represented. They can be used either as the main visual material supplemented by the more expensive fresh specimens and

models or they can be supplementary material in case the more expensive fresh specimens and models are available. In any case they are superb for individual study and as review material because of their realistic appearance and the ease with which they can be handled.

As was stated above, there is always the problem in the teaching of physiology of getting good laboratory specimens for study. The writer does not think that his problem in that respect has been particularly unique, but it is rather a common problem with all biology teachers. Even when funds are available for getting the material, it doesn't always arrive when it is needed. And in case of living material it sometimes arrives too soon and by the time the class is ready for it the specimens, for some reason or other, will all be dead or so reduced in number that their usefulness is practically eliminated. At best it is very uncertain to depend on living specimens. Because of expense the amount of material is very much limited. Not being supplied with the specimens needed, the class has to fall back on whatever visual material is on hand, which usually simmers down to a few inadequate models and the illustrations in textbooks. Also because of the limited supply most of the material has to be

used as exhibits and class demonstrations with little or no individual work to let the student discover facts for himself. Occasionally specimens of exceptional quality are available. By fixing such specimens on a series of stereopares (stereographic transparencies) showing the parts to be studied, such fine specimens can be preserved in a manner that will multiply their usefulness in a multitude of ways.

Statement of the Problem

To meet some of the needs of physiology teachers it will be shown how three dimensional pictures can be made of the excellent laboratory material gotten from time to time and thus literally to "freeze" it in a form that will be a good substitute for the real thing.

The suggested method will make this excellent material available for study by individual students just at a time when they need it. The problem is not only a matter of photographing the material properly to show every part correctly and clearly, but organization also presents difficulties which must be overcome if this method is to function smoothly and effectively. Details of instruction must also be worked out to show how this type of picture may be used in the best

way to supplement and reinforce other means for learning. This study will not present a complete course in physiology. However, an attempt is made to include enough material to make it clear how a complete course may be worked out on this basis.

Stereographic transparencies, which are called stereopares in this study, are proposed for this course. Their advantages will be explained fully in the pages to follow.

Location of Study

Most of the work of this study was done at Richmond Union High School, Richmond, California, where the writer is employed. Through the courtesy of the administration much of the necessary apparatus, specimens, and other facilities were generously provided.

The Method

The method presented in this study involves the construction and use of stereopares as an aid in the teaching of human physiology. The photographs used in the making of the stereopares were taken of instructional material in the class room. These stereopares are to be used to stimulate the students to greater

effort in studying the specimens they see in the stereopares. Students often question the practicality of studying physiology. This attitude, no doubt, is partly due to the fact that they have very little concrete experience on which to base their judgment of such a course. By presenting to the student a series of stereopares on a unit in physiology, they are given a basis for their judgment of its content and can more intelligently enter into the study of it. A class of students are to be given a chance to see a few well chosen stereopares from a unit. Then they will enter into a preliminary discussion of the unit in general. This is to give the instructor an opportunity with proper comments and suggestions to raise many interesting questions to be answered by further study of the stereopares and other material included in the course.

After the students have thus been given a proper introduction to the unit, they are to be given a set of study guides which give specific directions for further study. Then when sufficient time has been given for the completion of the unit, the stereopares are again to be used in review. They should be easily accessible in case questions might arise which will require further examination in order to insure a correct answer. Thus the very important educational prin-

ciple of repetition is employed to make the impressions more vivid and permanent.

This is not set forth as the only method nor even the best method for teaching physiology. But it is a method that does not violate accepted educational principles and it is hoped it will meet a need of many teachers who are looking for something to stimulate their students to greater effort and to enhance their own efficiency. The writer, having used it with good results, believes others can do the same.

Procedure in Making the Study

The foundation for this study is laid in the many years of experience of the writer in teaching physiology. More particularly, when this study was undertaken a careful survey was made of all the teaching units of the subject. From those units that showed possibilities of illustration with stereographic photography, a few were chosen at random and stereopares were made of illustrative material suitable to those units. These stereopares are used as exhibits with this study. Bones were selected because they lend themselves especially well to stereographic photography. However, other units, such as on the internal organs here represented by those of the frog, were

also included to show that they can be treated stereographically. To show further variety of uses of this method, a few stereopares were made of parts of the human skeleton comparing them with homologous parts of other animals.

The study involved not only a matter of selecting things to photograph, but also the securing of a suitable camera* and the making of equipment both for taking the pictures and afterwards assembling them into stereopares. A sliding board was made to which the camera was attached, so that when one picture was taken it was a simple matter to slide the board, with the camera attached, to the correct position for the second picture.**

The assembly of the stereopares required the construction and use of several gadgets. The one usually referred to as the adjusting frame*** was constructed with a frame to hold a piece of plate glass. This frame was used to adjust the pictures on the celluloid strip to which they were attached, so that when they were viewed in the stereoscope they would show depth or a third dimension.

* See page 9

** See page 44

*** See page 46

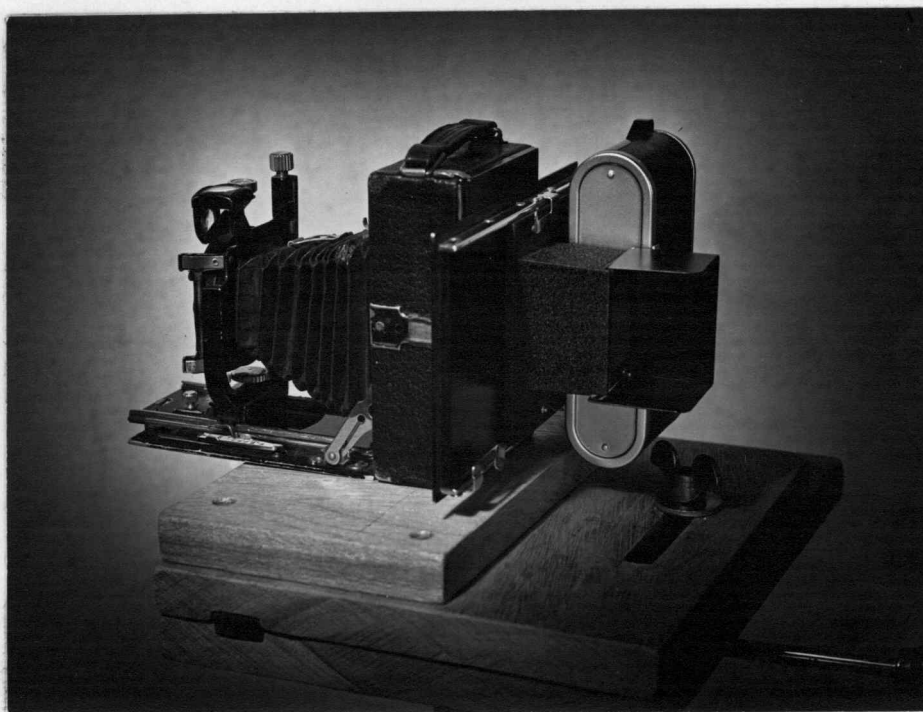


Figure 1. Camera shown with ground glass back open, and the attachment in position for focusing.

Another gadget made for assembling the stereopares is a clamping device.* It was made to hold the stereopares while their edges were bound with black tape.

The trimming apparatus shown in the pictures, Figures 2 and 3**, is made of a couple of iron strips with a thin strip of tin soldered to the side of each. The tin extends three-sixteenths of an inch out from the edge of the iron. The device was used for the purpose of trimming the black tape, making the border the same width all around the edges of the stereopare.

In looking over the various stereoscopes on the market, none could be found that would take the particular type of stereopares made for this study. One was found which with a little adjustment could be adapted for use. This stereoscope is the one called the Tru-vue viewer, which is originally made for a thirty-five millimeter film strip. The slot through which the film passes is not big enough to take the celluloid strips out of which the stereopares are made. Therefore, the slot had to be enlarged. This was accomplished by two narrow pieces of plastic one-sixteenth of an inch in thickness. By this little change it was possible to adapt it for use in this study.

* See page 50

** See page 12

The making of all the above given apparatus and gadgets was for the purpose of producing the stereopares. Another phase of the study was the planning and organizing instructional material for the use of the stereopares. The stereopares, being made, called for a guide sheet to show the student what stereopares to study for a certain unit as well as what to observe in each stereopare.

Labels of parts in the pictures have been omitted because of extra expense in making stereopares with labels and because there really is no need of it. The features to be studied in each stereopare usually are few and they stand out so clearly that it is not difficult to point them out by means of the instructional material in the guide sheets. And for review it is an advantage to have unlabelled stereopares. It challenges the student to remember what he has learned about the parts he sees.

Definition of Terms

The name stereographic transparency as used in the title of this thesis has reference to a transparent film which has on it two dissimilar pictures of the same scene or object. These two dissimilar pictures

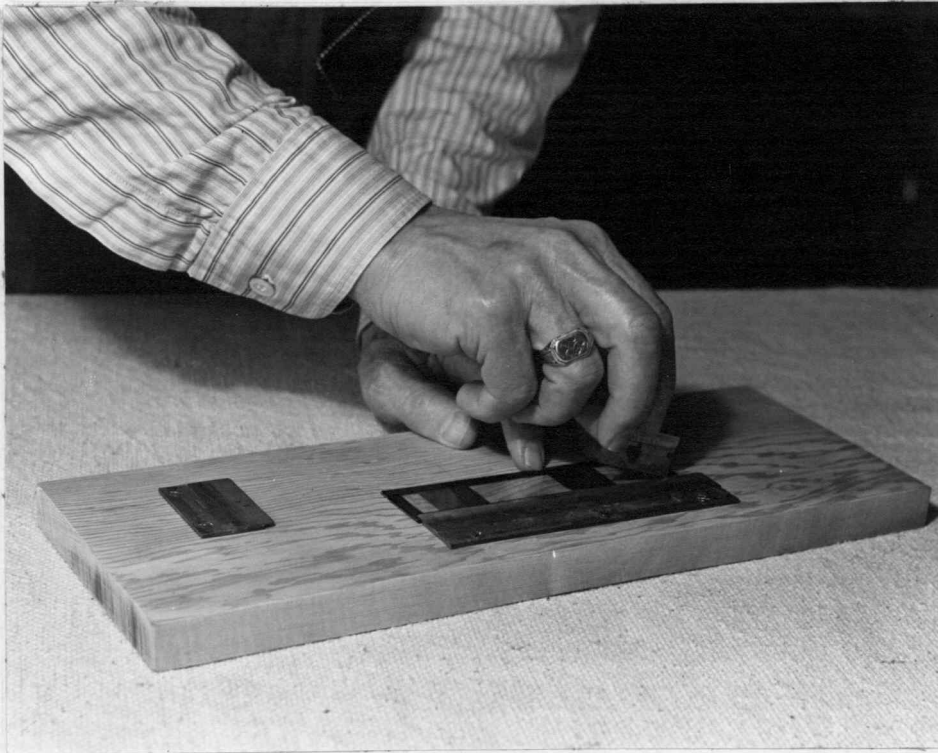


Figure 2. Trimming border on long edge of stereopare.



Figure 3. Trimming border on short edge of stereopare.

when placed at proper distances apart and viewed through an instrument with lenses which bring the two pictures together so they appear like one will produce an illusion of solidity or depth of the object or scene pictured on the film. Such an illusion of solidity or depth in a picture is said to be stereographic. "Stereo" is derived from a Greek word meaning solid. "Graphic" comes from a Greek word meaning to write. So the word "stereographic" literally means solidly written. The instrument through which the pictures are viewed is supplied with two prismatic lenses which cause the two pictures to appear superimposed on each other. Since this change is what causes the visual perception of solidity, the instrument is called a stereoscope, which literally means solid view.

The shorter and more convenient term stereopare is used instead of stereographic transparency in the body of this study. The derivation and meaning of the root "stereo" has already been given. The root word "pare" comes from a Latin word meaning to appear. Hence stereopare literally means to appear solid. "Pare" is also the root word of transparent and so the shorter name stereopare carries with it practically all the significant parts of the longer term, stereographic transparency.

For the smaller units of study the name "guide" has been applied. This word carries with it the idea of material that is intended to guide or direct the student in his particular assignment.

Limitations of This Study

The material and method of this study is not intended to apply to any other subject but human physiology as taught in the sophomore year in high school. The fact that some of the pictures are of other animals does not imply that they are intended for the study of those animals, except insofar as such a study will help understand the human body better.

There is no attempt in this study to elaborate on any other method than the one that makes use of stereopares as an aid to instruction. The fact that reference is made to reading matter and the study of charts, models, and other aids, is merely incidental to give a setting for the method of employing stereopares.

This study is not a guide to photography, though it does give some of the photography involved in taking and mounting the pictures on stereopares. There is no attempt to show how stereographs in general are made, though many of the general principles for making all kinds of stereographs are followed.

It would be a mistake to assume that this method is to supplant methods already worked out. Rather it is hoped that this method will stimulate other teachers to use and correlate it with their own methods to enrich them and make them more effective. It is presented to be used as a supplement to any course in human physiology. While the writer has had some very pleasant and encouraging experiences with this method in his own classes, he still has the happy anticipation before him of seeing it fully worked out.

CHAPTER II

HISTORICAL BACKGROUND

Greek and Roman Period

Over two thousand years ago the Greek mathematician Euclid knew that each of the human eyes has a different view point and therefore they see objects differently. In fact he showed by a mathematical theorem how to construct two spheres as seen separately by each of the two eyes. Then by looking at the two spheres with both eyes at once he tells how it is possible to bring the two spheres together into one which shows depth. He described this phenomenon in his treatise on Optics.

More than fifteen hundred years ago Galen, a Greek physician to a Roman emperor, treated the subject of binocular vision more fully than Euclid. In his book entitled "On the Use of the Different Parts of the Human Body" he tells how the eyes when looking at the same object do not both see the same thing. He calls attention to a familiar demonstration that anyone can make by looking at an object first with one eye and then the other and finally with both. All Galen needed was a camera to take two pictures of the object as seen by the two eyes and a stereoscope to join the two pictures into one.

The Medieval Period

K Many have studied binocular vision since Galen, of which Batista Porta is perhaps one of the most eminent. In his work "On Refraction" (1593) he reviews the discussion by Euclid on the sphere and cites from Galen the "familiar demonstration" mentioned above. But Batista believed that we see with one eye at a time and he tries to explain Galen's phenomenon of seeing objects in different phases with each eye on this basis.

Leonardo da Vinci in his discussion on painting brought out the fact that no matter how good an artist is in trying to depict depth by means of colors and shadows he cannot equal the real thing. Then he shows by a diagram how the eyes each see a different view of an object. What one eye cannot see back of the object the other eye can, except a small space which neither eye can see. He speaks of objects as taking on a certain transparent appearance because of the ability of the two eyes to see back of them. This he says cannot happen in a painting because both eyes are shut off from the back of the object in the painting. The above observations of da Vinci show that he knew that each eye separately gets a different image of each object

seen, but that these dissimilar images are somehow brought together in the brain to give the perception of depth.

Francis Aguillon or Aguillonius, a learned Jesuit, discussed binocular vision in his treatise entitled "Optics" published in 1613. He repeats the theorems of Euclid on the vision of the sphere, showing how much of a sphere each eye sees and how much both see together. He also demonstrates that half the sphere can be seen when the diameter of the apparent sphere is exactly the distance between the eyes. He applies the principle of seeing the sphere to all objects whatever form and proposes that everything about an object that is found within straight lines that can be drawn through any part of the visible perimeter of the object to the eye can be seen. Because within all these lines there is no part from which a straight line cannot be drawn to the eye.

Early Modern Period

In the intervening years from Aguillonius to the second quarter of the last century different writers offered various theories for the phenomenon of binocular vision but no important contribution was made with reference to its application in pictures until the time

of Wheatstone. In August 1838 he presented a paper on the physiology of vision to the British Association at Newcastle and exhibited an instrument which he called a stereoscope. With this instrument he was able to unite two dissimilar pictures taken from two slightly different angles of the same object and thus show depth or three dimensions. After Wheatstone had presented his paper and exhibit, Elliott, a mathematician from Edinburgh, Scotland, disputed Wheatstone's claim to being the first one to have discovered stereoscopic vision and to have invented an instrument to demonstrate it. As proof Elliott referred to a paper he wrote in 1823 to a class in logic at the University of Edinburgh, entitled "On the Means by Which We Obtain Our Knowledge of Distances by the Eyes." He was familiar with the eyes seeing two dissimilar images of the same object. He claimed that previous to 1834 he had thought of making an instrument to join two such dissimilar pictures. But he did not make such an instrument until 1839, when he was asked to write a paper on it for the Polytechnic Society of Liverpool. As photography had not yet been perfected he drew on glass two slightly different pictures of a landscape seen with three different distances represented. The most distant was the moon and sky and a stream of water reflecting the

moon. The middle distance was marked by an old cross represented about one hundred feet away, and in the foreground of the drawing was placed the form of an old tree with withered branches represented at about thirty feet from the observer. The moons in the two pictures were placed at a distance apart about equal to that of the eyes. In the right hand picture one arm of the cross just touched the disc of the moon, while in the left hand picture it covered over two thirds of the disc. The branch of the tree touched the outline of a distant hill in one picture, but was a full moon's breadth from it in the other. When seen in a stereoscope the two pictures showed depth with the above objects at three different distances.

Elliott's stereoscope was without lenses and depended upon the adjustment of the eyes to draw the two pictures together. Wheatstone's instrument had mirrors which were placed at a ninety degree angle, one in front of each eye and in such a way as to reflect the pictures into the eyes. The pictures were placed straight out to the right and left of the line of vision, one opposite each mirror.

About the same time Sir David Brewster entered the controversy. Being a physicist in his own right, he took issue with Wheatstone on his theories of stereo-

scopic vision. It was a lengthy controversy and became rather heated at times. Without going into any further details concerning the controversy, let it suffice to say that Brewster partly proved his superiority by inventing the first stereoscope with lenses such as we know it today. The American form in use until a few years ago was first made by our own Oliver Wendell Holmes of literary fame. Many of this type can still be found in old attics as a relic of the times when they used to be found on every parlor table in company with the big thick plush-backed family album.

In 1844 David Brewster wrote a paper for the Royal Society of Edinburgh, entitled, "On the Knowledge of Distance as Given by Binocular Vision." In this paper he described several interesting phenomena produced by the union of similar pictures, such as those which form the patterns of carpets and paper hangings. This led him to the construction of the lenticular stereoscope spoken of above, since Wheatstone's reflecting stereoscope was not very practical. For example, it required the two pictures to be mounted on two separate cards. The first lenticular stereoscopes were made of various materials, such as wood, tinplate, and brass. They were of all sizes, even to a small pocket size. Loudon, an optician of St. Andrews

and at Dundee, was given the privilege of making the first ones. Geometrical drawings were made and binocular pictures were taken by the slow photography of that day and lithographed by Shenck of Edinburgh. The pictures, stereoscopes, and the binocular camera and copying statues were written up and sent to the Royal Scotch Society of Arts and published in their transactions.

Brewster tried in vain to get opticians both in London and Birmingham to make lenticular stereoscopes and tried to get photographers to make stereographs. Failing, he went to Paris in 1850 with his instruments. There he showed them to Abbe' Moigno, the author of "L'Optique Moderne" and to M. Soliel and his son-in-law M. Duboscq, a Parisian optician, and to some members of the Institute of France. They were all delighted with the prospect of seeing this form of photography develop. Duboscq immediately set to work putting out stereoscopes according to the specifications by Brewster. He also had pictures made for them from living individuals, statues, bouquets of flowers and objects of natural history.

From then on Paris became the center of stereoscopic interest in Europe. In the great Exhibition in England in 1851 Duboscq exhibited a lenticular stereo-

scope together with a beautiful set of stereographic dauguerrotypes. It attracted the particular attention of Queen Victoria. So before the closing of the Crystal Palace Duboscq made an exquisite stereoscope just for the Queen. After this he received many orders from England. And in a short time the demand for stereographic pictures became so great that opticians of all kinds began making stereoscopes and photographers began producing stereographic pictures in large quantities. Even artists began making use of three dimensional pictures in their work. One artist in Paris actually copied a statue from a stereograph. Brewster claimed that in 1870 his lenticular stereoscope was used "over the whole world" and he estimated that a half million had been sold. Even discounting possible exaggerations in claims, stereographs must have been quite a fad at that time.

In 1859 Oliver Wendell Holmes wrote in the Atlantic Monthly about stereoscopic photography. He called them "double-eyed or twin pictures" and he seems to have been the first one to use the word "stereograph." He referred to the instrument for seeing these stereographs as a "squinting magnifier," because he explains that the two pictures can be brought together by squinting the eyes without an instrument. But he avers that that is both tedious and painful and to some

impossible." So he recommends the "squinting magnifier." Holmes was very enthusiastic about the stereoscope and claimed that the effect of looking at stereographs through this instrument produces "an appearance of reality which cheats the sense of its seeming truth." He even goes further in stating that the first effect of looking at a good photograph through a stereoscope will give you a surprise such as no painting can give. He says that the mind tends to "feel its way into the very depths of the picture."

These statements from Holmes are given to show how stereoscopic photography interested educated men of almost a century ago. Dr. Holmes was among the first on this side of the Atlantic to accept the three dimensional pictures. In fact he was so enthusiastic about the discovery that he designed his own stereoscope and promoted the use of this type of photography by selecting a travelogue series which he published in the Atlantic Monthly. He foresaw the practical use of this type of picture and insisted that it was "not a toy." The public acceptance of stereographs at that time, however, was not because of its practical use, but as a fad and a toy. Commercial interests were quick to take advantage of the upswing of public enthusiasm, providing a large percentage of the homes in the land with at least

one stereoscope and a few choice scenes from distant beauty spots of the earth. But it was only a fad and as a fad it soon began to wane. Only a few kept the embers of interest smoldering until another and a better opportunity for development might arise.

Recent and Present Development

Finally the opportunity came with the first World War when the government began to make aerial survey pictures in doubles for a three-dimensional study of topography. Old stereoscopes immediately came into demand, but very few could be found. Some stereoscopic photography was done by the Allied armies in France during World War I and was found very helpful in spotting camouflaged gun emplacements as well as learning about troop movements and other activities in the enemy camps. Major Hanson of the U. S. Army made a series of stereographs of the war and in his book published by the Keystone View Company he tells how a man's footprints in the grass can be spotted in a stereograph taken from a plane flying at an altitude of one mile. He also tells how by means of stereographs it was easy to tell whether a dark spot on the flat photograph was the entrance to a dugout or just a shell hole. To heighten the effect of depth the two pictures

were taken a hundred yards or more apart depending on the altitude of the plane taking them. Bushes looked like trees and shell holes like wells. Thus the slightest depression or elevation became noticeable. There was a great difference between a shallow roadside ditch affording insufficient shelter for troops that might be in it or a well-made trench. In case of camouflage the pictures would reveal the camouflage material as different from the surrounding environment and it was often possible to see through and clearly discern the guns and ammunition underneath.

Stereographic pictures having been adopted by the army are also again being taken up by the schools, especially the larger systems. In a recent book entitled "Modern Methods and Material for Teaching Science" by Heiss and others the following statement is made: "The stereoscope has a wide variety of uses. Several of its applications are in the field of education, surveying, and internal or microscopic examination of objects. Impending applications lie in the direction of large scale stereoscopic projection and stereoscopic motion pictures."¹ With modern developments, discoveries, and

1. Heiss, E. D., Obourn, E. S., and Hoffman, C. W.,
Op. Cit. p. 163.

inventions, the stereographic pictures are as easily obtainable now as any other form of illustrative material. With the added advantage of the third dimension it may well equal and even outstrip any other form of pictures in use for instructional purposes. Even some textbooks are illustrated with stereographs which can be viewed through a convenient folding type of stereoscope supplied with each book. And there are substantial rumors of even better things to come in the near future. There has already appeared in one of the monthly science publications an advance article of a new invention which makes it possible to secure in a single picture a three-dimensional illusion without the use of a viewer through which to see it. It is explained that the effect is brought about by a fine grating which is produced in the film itself. But even with all these strides forward in the construction and use of this newer form of visual representation there is still a great lack of appreciation of its value in the school room. Hoban says: "So valuable is the stereograph that it is difficult to understand why it has not been widely used--why so many stereographs repose in cases in some school closet or storeroom."¹

1. Hoban, C. F., Hoban, C. F., Jr., Zisman, S. B.,
Visualizing the Curriculum. p. 149.

There is much work to be done in preparing instructional material with three-dimensional pictures and adapting this material to the various modern class room situations. This is especially true of these stereopares, such as accompany this effort. The largest producer of stereographic pictures in this country, the Keystone View Company of Meadville, Pennsylvania, does not have any on the market and is not as yet ready to give out any advance notice of such a contemplated venture. It is possible that the present national emergency has retarded their progress in this direction.

Dr. J. A. Long of the University of California has done some work in stereographic photography of small objects in biology through an enlarging lens. He has published a small booklet entitled, "Apparatus for the Dissection and Study of Embryos." In this publication is shown the various types of apparatus used in doing the dissection and taking the photographs. In citing literature on the subject he refers to two articles he himself has written. When asked about references to literature on work of this type Dr. Long replied that he knew of none.

A thorough search of lists of publications on work being done in stereographic photography of physiological material has yielded no results. This type of

photography is in its infancy with practically the whole field of science before it.

The Tru-vue Company of Rockford, Illinois, and the Viewmaster Company of Portland, Oregon, are putting out transparencies of scenic views which are sold mostly at summer resorts and amusement parks. These companies are doing nothing in the educational field. The General Biological Supply House of Chicago, is putting out a few film strips on biological subjects to fit the Tru-vue stereoscope. Thus the matter of the growth and development of the stereographic method of visual representation is brought up-to-date.

CHAPTER III

THE STUDY

To conduct a successful science class in physiology the teacher has to have adequate material to illustrate what is being studied. It is a well known law of psychology that the mind goes from the concrete experience to the abstract thought, from individual cases to general laws. Hence any method of teaching science must have access to material that will supply the concrete experience. However, not just any concrete experience will do. It has to apply to what is being taught, and it has to be as real as possible. Concerning this very thing, William C. Bagley, the noted educator, writes: "Effective teaching depends very largely upon the ability to choose just the right details that will force home the important lessons: to provide an abundance of concreteness at just the right time."¹

Selection and Development of Teaching Units

With this in mind the subject matter of physiology was surveyed minutely and in detail and all the teaching units carefully listed. Out of that list of

1. Keystone View Company, Teachers Guide to the New 600 set.

units those were set apart that would lend themselves to stereographic photography. With this list in hand a few were selected and appropriate specimens to illustrate them were secured and photographed stereographically. These photographs were made into stereopares to be incorporated into units of study called guides or guide sheets. (specimens of these guide sheets are found in the appendix). Then there was the matter of organization--as to what best to put into each guide. In organizing the guide one important law of learning was kept in mind; namely, not to include too many ideas in each unit. Norsworthy and Whitley express it thus: "The psychological law is that only one object of thought, one 'conceptual system' can be in the focus of attention at any one instant of time."¹ This being true it would only be confusing to allow the student to study too many stereopares at a time. And the few selected for each guide have a definite bearing on the topic of the guide. This method gives each student more time to study each stereopare. Concerning the principle of learning here involved Anna V. Dorris has

1. Norsworthy, N. and Whitley, M. T., The Psychology of Childhood. (Quoted from Dorris, Anna V., Visual Instruction in Public Schools, p. 139.)

this to say: "Whether the educational environment with its rich stimuli and impressions produces any fundamental educative effects depends on the intensity of the appeal and the concentration of attention, which must be deep enough and prolonged enough to call forth reflective thought and reasoning."¹

To further clarify the basis of organization a psychological rather than a logical method has been followed. For example, instead of trying to divide the skeleton into types of bones, types of joints, and other such divisions, the skull is placed in one guide, the elbow in another one, and the foot in a third one, and so on. Thus, there has been avoided the confusion of studying a picture for one thing now and then later coming back to it for something else. Similarity of structure can be taken up in the class discussion or stereopares can be made with similar parts photographed together.

The guides or guide sheets mentioned above are headed with a title and are each divided into four sections. The headings of the sections in order from the beginning are: I What to do, II What to Read, III Re-checking your Knowledge, IV Self Testing Questions.

1. Dorris, Anna V., Visual Instruction in Public Schools, p. 139.

To follow out the psychological method mentioned above the guides are so constructed that in the first section of the guide each stereopare is exhaustively studied before the next one is taken up, except in a few cases where two stereopares represent different phases of the same object. In such a case the one is given a complete set of instructions to cover all of the possible features of it. Then the other stereopare is studied for those features which did not appear at all or incompletely on the first one. In some cases three or four stereopares show different phases. In that case the one that shows most detail and is the most striking or is the most characteristic of the part to be represented was given first place and the greater emphasis. The others were given no preference of order. However, each one was completely studied and in the instructional material attention was called to parts shown on the previously studied stereopares of the guide unit. These guides are especially designed to help the student get the most out of the stereopares. The guide contains detailed instruction on the points to be observed in each stereopare. It also raises questions which require thought as well as knowledge of facts in order to answer them. In the first section of each guide there is provision made for any other visual

means or aids to be used. For example: charts, models, actual dissections or stereopticon slides as the facilities of the school and the ingenuity of the teacher may dictate.

After the stereopares have been given an exhaustive treatment in the guide, a few appropriate reading references are added. The form used in calling attention to reading references may be changed to suit the fancy of the teacher. But it has been found of value to the writer in his class room situations to put in helpful hints with the references so that the student will have some idea of what each reference contains.

In the third section of the guide instructions, the attention of the student is called to the necessity for review and rechecking of the knowledge he has gained from the first two sections.

Then the final section consists of a set of test questions which the student should be able to answer without any further study. The answers should be in writing, each answer written out in a complete statement so that the teacher can easily check the answers. This is an individual test and shows how well the student has learned the assignment. It can also be used as an effective check on the students daily progress.

It is apparent from the description of a guide as used in this study that it calls for a great deal of

individual work on the part of each student. That may seem a little discouraging at first sight, but the writer's experience with individuals makes him feel that it is not only good for the student but often relieves the nervous tension which necessarily accompanies a long recitation period. And for something to give the student to study, what is better than a set of realistic pictures like these stereopares? As to the use of this type of picture for individual work, Dent writes: "It lends itself particularly to individualized work. Only one pupil can see it at a time. To the keen teacher . . . this is not a handicap but an asset. It makes necessary an emphasis on the individual aspects of education that have been so much neglected. Each sees his own relationship to the pictured situation and brings to the class discussion his own thoughts on the subject."¹

The above statements and the quotation from Dent will make clear why individual stereopares are used rather than a series of stereographic pictures on a film strip. There are many advantages in having individual pictures, some of which are: (1) The order of

1. Dent, E. C., The Audio-Visual Handbook, p. 48.

presentation in any one larger instructional unit can be easily changed when it seems desirable. (2) Fewer sets of pictures will be necessary as no picture will be tied up by being attached to one that is in use.

(3) The individual stereopares are more durable than the film strip without a protective covering. (4) The students will not be distracted by pictures on the film which do not apply to the particular guide being used.

(5) Since the stereopares are separate they can all be in use by different students without interfering with each other.

Organization and Filing

To keep the guide sheets loose even if a box is provided for them is not to be recommended. By far better, group them together in larger units, say, all of those on the bones in one group. Cover each of these larger groups with heavy manila wrapping paper cut to make a regular booklet cover. Then staple together this group, preferably with three staples. In the event a stapling machine is not available, it is quite possible to punch holes in each separate sheet and in the cover. Then they can be bound together with cord. Having thus bound or stapled all the sheets together into booklets, filing becomes a comparatively simple

matter. They can either be put into separate drawers in a closet or they can be placed on shelves in separate piles and the shelves labelled to facilitate finding them and also to make it certain that they are put back in the same place after they have been in use. Placing them in the order in which they are used in the course might be helpful. If the teacher has more than one class period of physiology it will not usually be necessary to have a booklet for each student. The booklets may be numbered and a number assigned to each student. Then the same booklets may be used for each class, it being required to leave the booklet in the room. That will save a great deal of trouble, since students often forget to bring their books to class and they sometimes mislay them. Most of the work called for can be done during class time. Any additional work can be assigned out of the textbook, which they can carry with them. It will therefore be unnecessary for the students to use the booklets outside the class room.

The stereopares and the stereoscopes must also be made available to the students. Since they are more expensive than the booklets and not as easily replaceable, it requires better organization to get the greatest

usefulness with a minimum of wear and loss. To do this, every stereoscope and stereopare should first be numbered. A place should be provided for the stereoscopes so they can be quickly checked at the end of each class period. A shelf divided into stalls, one for each stereoscope, would be helpful. Then a missing scope can be caught at a glance. The stereopares can be put into small pockets in a folder. See Figure 4.* These folders can be punched and put into a looseleaf binder to be stored in a convenient locker or cabinet. When in use, the folder containing the stereopares in use can be put out where the students may have easy access to them. Then at the end of the period any missing stereopares can easily be spotted. The checking of this material at the end of each class period is important as students often are forgetful or careless. It would be very easy for a stereopare to become closed up in a book and carried out of the room. By checking after each period the teacher can save himself much grief and distress. A reliable student may be assigned the duty of doing the checking.

* See page 40

How to Use the Stereopares

After having given the class an introduction to the work of the day, the guide booklets may be distributed. Each student, of course, is given his assigned booklet. If this is the first time the class has seen these booklets, it might be well to explain the method to them. Now they are ready to go to work. But one of the first things called for is a set of stereopares. Let it be assumed that an explanation has been given as to what stereopares are and how they are to be used. Since there will probably not be enough stereopares available to supply each student with one, it would be well to group the students into as many groups as there are stereoscopes, say, four. The next problem is to divide the available stereopares. Suppose there are two sets at hand. Since the guides of any large unit can be studied in any sequence with no effect on the learning efficiency, two groups can study the first guide and two the second. When these groups have finished the guides in hand they each can trade stereopares and study the guides which go with those stereopares. After that they follow up with the next guides in order as at first, only this time it will be the third and fourth guides respectively. Having finished

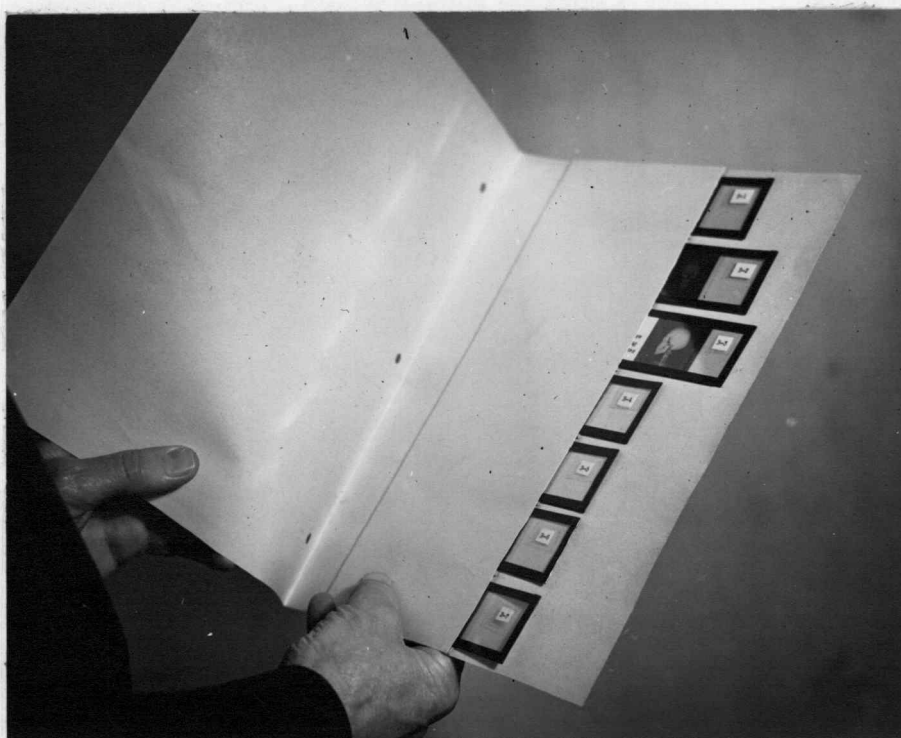


Figure 4. Folder for filing stereopares.

these they will again trade stereopares. By this means the class will be kept busy and still stay pretty well together. (Parenthetically, it may be explained why it is unnecessary to follow any given sequence in the guides. Say the larger unit is the study of the bones. In that case it will make no particular difference whether the head or the feet are studied first. The neck bones may precede the pelvis or follow and any joint may be studied before or after any other joint without doing violence to any educational principle.) In a class of thirty-two students, which is unusually large for science, there will be only eight students to each stereoscope. In an hour class period that will give each student ample time to examine each stereopare thoroughly. While each student in turn is studying the stereopares the others will be busy doing the reading assignments and other activities the teacher has laid out for the class.

Production of Stereopares

The photography of the stereopares and also their assembly was done by the writer. This is not said boastfully but rather to prove that any teacher can do it. The writer cannot even be classed as an amateur

photographer, as he practically had to learn everything in the process of doing it.

The Equipment

William Bush, a fellow teacher in the same school with the writer, kindly loaned his camera for the project. It was an old Recomar camera with a thirty-five millimeter attachment. The open lid in the back of the camera as shown in Figure 1* represents the ground glass back on which the camera is focused. After focusing on the ground glass the shutter and the lid are closed and the attachment is slid in place with full assurance that the camera is in focus for the next picture. The timing mechanism on this old camera was very unreliable. That was overcome by taking all the pictures on the time exposure, none being taken less than five seconds. Some taken late in the afternoon and indoors required over one minute exposure. The writer would advise using enough light to cut the time to not over ten seconds for the best results. Besides the camera, a Weston light meter, which belonged to the school, was available. It is not necessary to have the most expensive light meter, but it is difficult to guess the

* See page 9

lighting for good, clear detail.

The board on which the camera was mounted is an important part of the equipment for taking stereographic pictures. This board, as shown in Figures 5 and 6*, was made out of two pieces of Philippine mahogany, which were made to slide over each other. A rectangular piece of wood was fitted into a groove between the boards near the front edge to keep them parallel to each other at all times. An extra small piece of wood was fastened to the sliding board for the camera to rest on. This piece was necessary because of the shape of the camera and the position of the thirty-five millimeter attachment in the back of it. It will be noticed that in Figure 5 the top sliding board is in the left hand position and in Figure 6 it is in the right hand place. The slot in the sliding board just back of the camera is exactly three inches long. The bolt with the wing nut on it is fastened solidly to the board underneath so that it forms a stop for the upper board as it is slid back and forth. This sliding board made it possible to take each set of stereopare pictures exactly three inches apart--one in the left hand position and one in the right. The eyes are

* See page 44.

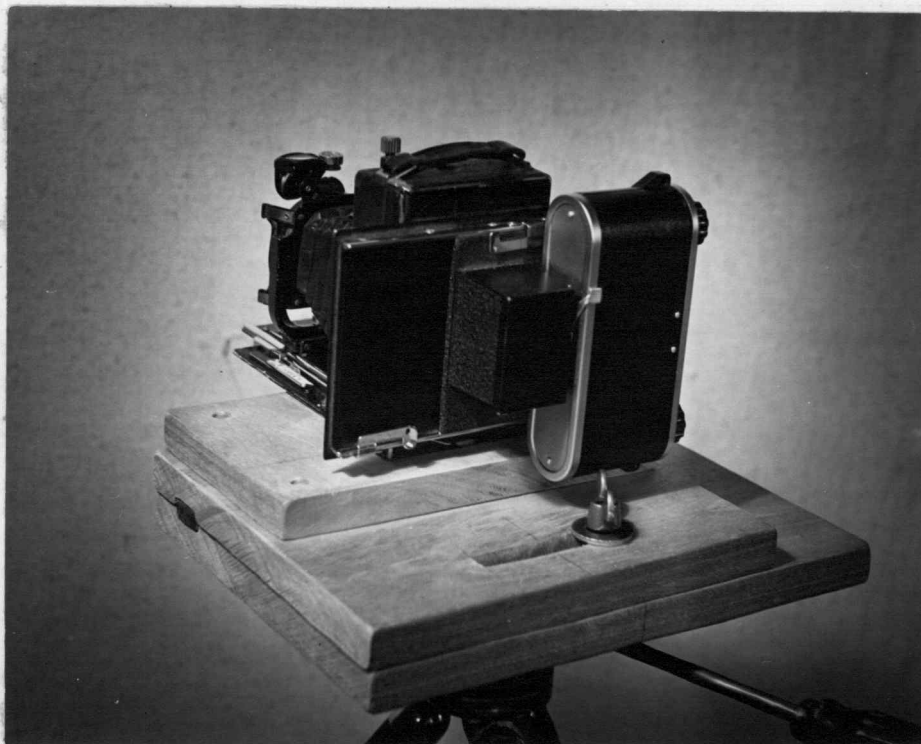


Figure 5. Position of camera for taking left hand picture.

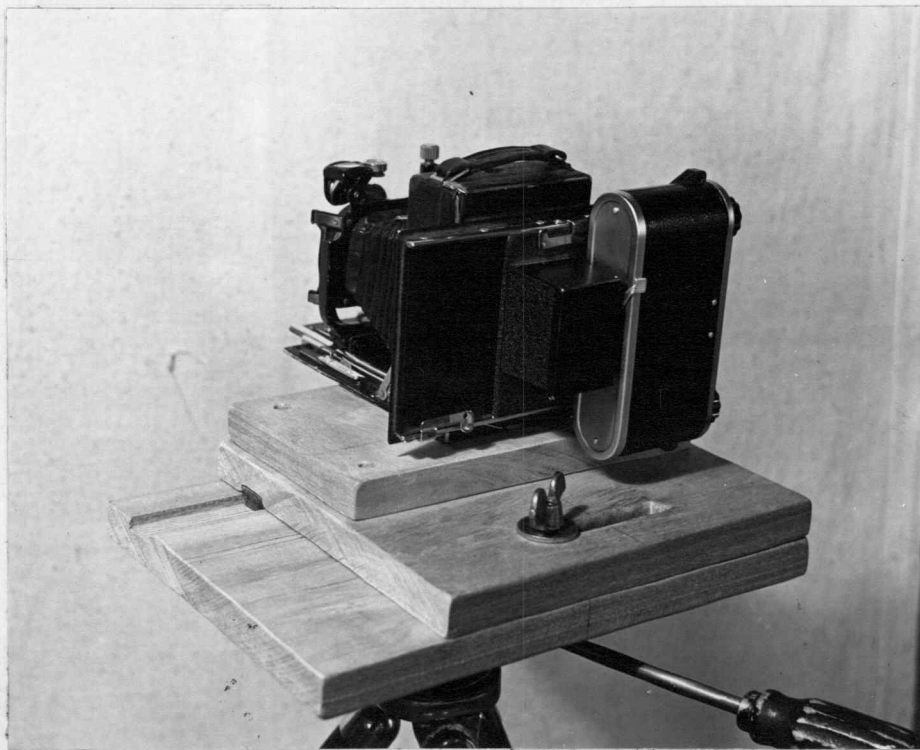


Figure 6. Position of camera for taking right hand picture.

from two and one-fourth to two and three-fourths inches apart, most of them being about two and one-half inches. Taking the pictures three inches apart has a slight tendency to exaggerate the sense of depth in the stereopares. In fact, when taking stereographic pictures of large hills and mountains it is necessary to take the pictures several feet apart and to get the best effect for distant mountains several hundred feet apart becomes necessary. This practice is required because our stereoscopic vision is not very effective beyond a couple of hundred yards. But for all close objects three inches apart is very effective and really gives better results than two and one-half inches. Taking them farther apart tends to make the exaggeration disturbing to the sense of proportion.

Other equipment was constructed by the writer as need arose. Figure 7* shows a frame set at an angle and containing a piece of plate glass. An electric light was placed back of the glass so that the pictures can be seen easily when they are placed over the glass. The pictures are set at the proper distance apart on a celluloid strip to give the stereoscopic effect when viewed through the stereoscope. This constitutes the first step in the making of a stereopare. The light

* See page 46.

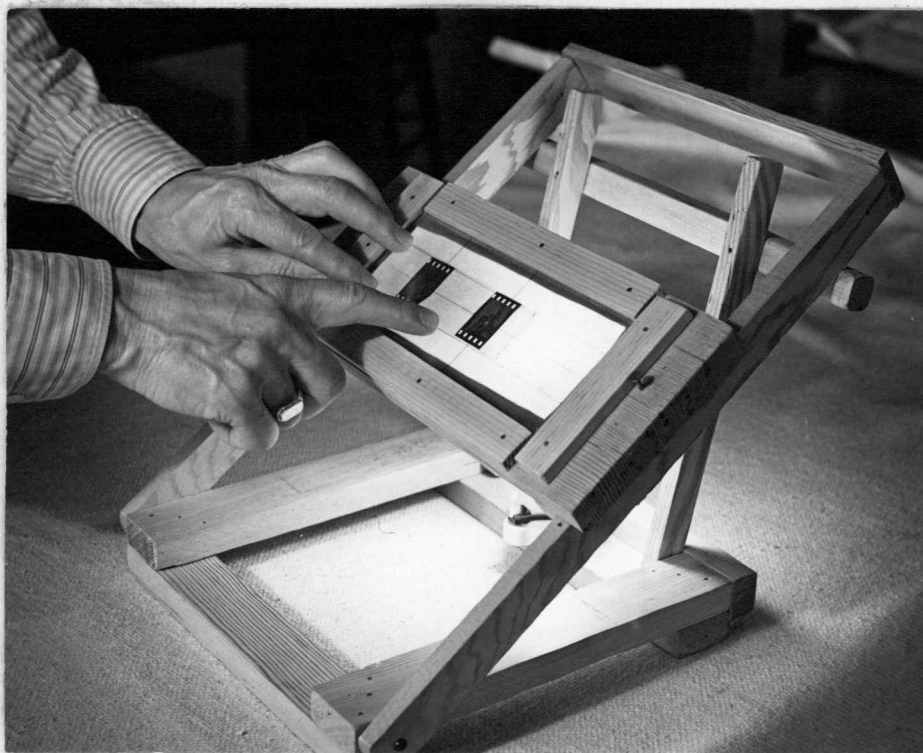


Figure 7. Frame for placing picture on stereopare.

is there because it is necessary to see the parts of the picture in order to place it correctly. A thin paper was placed under the glass and on this paper an exact outline of the stereopare was drawn. Also two vertical lines were drawn exactly two and one-half inches apart. These vertical lines helped to place the pictures the correct distance apart. A horizontal line was drawn through the middle of the outline of the stereopare also to help in setting the pictures exactly right. The pictures were then covered with a second strip of celluloid before the edges were bound with black tape. This scheme helps to protect the pictures from getting scratched and otherwise damaged while in use. When the cover gets badly scratched it can be replaced by a clear piece.

Figure 8* shows a clamping device to hold the stereopare while the black tape is being put around the edges. It is made of two blocks of wood placed perpendicular to a base board. Two side pieces are fastened to the solid upright block and the base with screws. The other upright is movable, being fastened

* See page 50.

to the side pieces by one screw on each side. The holes in the side pieces for these screws are made large enough to allow them to rotate with the movements of the movable block. A long bolt passes through the uprights with a wing nut on the end which goes through the movable block. By tightening the wing nut it is possible to secure a firm clamping hold on the stereopare. A rubber band was run through the holes above the bolt and fastened above each hole to help hold the stereopare temporarily until it is correctly adjusted in the clamp. The small horizontal blocks that form the actual clamping surface between the uprights were covered with rubber on the surfaces facing each other. The rubber surface prevents scratching the celluloid of the stereopares.

The trimming of the black tape was done by means of the trimming apparatus shown in Figures 2 and 3* and has already been partly described in the Procedure in Making This Study. The pieces of iron with the tin soldered to them are fastened with screws to a board. The one piece is six inches long and the other one two inches. After the black tape has been put around the edges of the stereopare in the clamping device, the stereopare is pushed under the overhanging tin edge of the trimming apparatus and a razor blade

* See page 12.

run along the edge cutting the tape straight. The razor blade is pressed lightly against the tape so as not to cut too deeply into the celluloid. After cutting the tape the loosened part is peeled off with a knife, leaving a black border around the edge exactly three-sixteenths of an inch wide. The reason a separate apparatus was made for trimming the ends was that it made for speed and convenience.

Thus it can be seen that the construction of apparatus for this study was in itself no small part of the work and required a certain amount of definite thought and planning.

Photographing

Since the writer does not class himself even as an amateur photographer, much of what was done in the photographic phase of this study would probably not pass inspection by a professional. However, the actual facts will be given not so much to prove the sub-amateur standing of the writer as to show the reader that photography of this type can be done with rather satisfactory results, even though the operator may know very little about it in the beginning.

The first problem was to set the stage for taking the picture. And here it may be said is really one of



Figure 8. Clamping device to hold the stereopare while it is being bound with black tape.

the most important steps in the whole process. Unless the specimen is properly placed with a contrasting background to bring out the points desired, there is not much that can be done about that picture after it is taken, except to take it again with the necessary changes. In every case the background should be a contrast to the color of the specimen. If the specimen is light in color, have the background dark and if the specimen has many dark parts in it, best results will follow with a light background. To bring out delicate tones in the shading of the specimen is a matter of experience. Frankly, the writer can say little about that except to refer the reader to the many excellent books on the market giving all that information. However, do not conclude from this statement that no satisfactory pictures can be made without the knowledge and skill necessary to produce beautiful shades and tones. If the camera is properly focused on the specimen and the lighting does not produce deep shadows, quite a satisfactory picture will result. The other rather obvious requisite should also be added; namely, the time of exposure. That naturally brings up the question of some way of measuring the amount of light available. This calls for a light

meter or some device to determine the intensity of the light on the object to be photographed.

The light meter which makes use of the photo-electric cell is the most reliable. Of course, good pictures can be taken without a light meter, but a certain amount of film is usually wasted in test pictures. The light meter generally pays dividends in the saving of film. And as far as exposure time is concerned, if there is enough light to record above the first quarter on the scale of the meter, there need never be a poorly exposed picture when a good light meter is used. A further warning about the lighting might be in order. Try to avoid sharp shadows and be sure to have enough light to get a reading well up on the scale of the meter. Photoflood lights will help, but are not absolutely essential. None were used in this study. When measuring the light, try to get as close to the surface of the object to be photographed as you can without shadowing it. The contrasted background will help get correct readings as it tends to make for uniformity. However, the reading should represent the light from the specimen and not the background.

The average teacher will probably not have a double lens camera and therefore will rely on a single lens,

moving the camera for the second picture. That was done in taking the stereopares exhibited in this study. In taking the second picture care must be taken in having the conditions of lighting, distance, and position as near like the first one as possible. The two pictures should really seem to be two copies from the same negative. However, do not throw away the pictures even if they aren't just exactly alike in shading and brightness, because the eyes are able to compensate for slight differences in that respect without any appreciable discomfort. But there is another condition that is more critical. That is the size and position of the specimen on the film. To get this condition the same in both pictures they must both be taken from a base line perpendicular to another line from the center of the specimen or object photographed. Such a position can easily be located by placing the sliding board to which the camera is attached perpendicular to an imaginary line drawn from the center of the specimen to the middle of the sliding board. This position of the camera is necessary because then the two pictures will be taken at exactly the same distance from the center of the specimen and therefore the two pictures will be exactly the same size. Since the distances are correct, the position will be satisfactory,

because the two pictures were taken from the same base line. However, here again the eyes will compensate for a slight difference in size, so it will not be necessary to spend too much time to get absolute accuracy. But, if the pictures are taken from an unusual angle, it will save trouble in mounting to have the two pictures in the same position on the film. If they are not, the film has to be trimmed so that they can be placed in like positions on the celluloid strip. In other words, the two pictures must be in exactly the same position on the mount to make it possible for the stereoscope to bring all parts together at the same time. It also creates quite an eye strain to have the pictures slightly out of line. More will be said about this under the assembling of stereopares. In focusing the camera on an object whose parts are unequal distances from the camera, focus on the center of the object. Adjust the diaphragm to a small stop and give it longer exposure. That will give a clear focus of all parts of the object.

Another variation of the above method of taking stereographs was suggested to the writer by Dr. J. A. Long of the University of California who has done a great deal of stereoscopic photography. He suggested to set the specimen on a revolving table and after

taking the first picture rotate the table a distance equal to moving the camera and take the second picture. This is very convenient for small objects and obviates the trouble of disturbing the camera. However, it is well to center the specimen over the center of the table; otherwise, the distance as well as the position of the specimen in relation to the camera is liable to change with the rotation of the table. To determine the distance to rotate the table a long flat stick can be attached under the table in such a way that it points directly out from the center of the table. Then by marking a point on the stick a distance from the center of the table equal to the distance of the camera from the center, the table can then be rotated enough to move this point three inches over the underlying surface. Such a movement will be equal to moving the camera that far. The table should be large enough to give a complete background for the specimen. Such an arrangement will facilitate changing the background with various colored cloth or paper. A rotating table is good only for taking pictures on the same plane with the base of the camera or possibly at a slight angle to the plane of the table. A sliding board arrangement for the specimen could be devised for a vertical position of the camera.

The film used as negatives for the pictures of this study is the Eastman Panatomic X. It is not a rapid film and therefore is better for the amateur. While it might not give as good results as a more sensitive film in the hands of a professional, it is less liable to show up the slight inaccuracies in lighting and exposure which are liable to occur when handled by the inexperienced. The writer bought this film in bulk and loaded the spools himself. This manipulation may seem difficult at first, but a little practice with an old film and in a dark room will soon give the beginner confidence to try a real film. The thing to remember is never to touch the emulsion side of the film with the fingers. The emulsion side of the film is always the side toward the spool. The bulk film comes in sections a little over five feet long. The sections are definitely marked with a notch so that there will be no mistaking the division point when you reach it. The film can easily be cut or torn off at those points.

Detailed instruction on how to load a spool will probably be unnecessary since each person usually develops a scheme of loading these spools that is best for him. The one thing that might possibly give trouble at first is to keep the bulk roll from dropping to the

floor. There is, however, little chance of that if the person sits close to the table or shelf on which he is working. As soon as the spool is loaded and put into its shell, be sure to put the remaining bulk film back into its can and cover it before turning on the light. The bulk film is just the same as the film you can buy already rolled, with about 20 per cent less cost. But forgetting to put it back into the can and covering it before the light is turned on can easily make it a loss rather than a gain.

Developing and Printing

For developing the negative film it is convenient to have a developing tank, a photographic thermometer, a small piece of good chamois skin or a soft viscous sponge, a 100 cc graduate, a funnel, a film clamp, a fine grain developer, stop bath, and "hypo" fixing bath. The most difficult part of this whole process of developing the film is loading the tank. This also has to be done in complete darkness, just like loading the film spool. First see that all the parts of the tank are placed where they can be found in the dark. Be sure the tank spool is adjusted to thirty-five millimeter film. Further details in loading the tank are probably unnecessary as any book on photography will give all the necessary instructions. Each person with

practice will develop a technique best suited to him. In practicing it is well to use a full length of old film and keep trying it in the dark until it can be done easily.

The spool with the film in it is placed in the tank and the cover secured in place. Now the lights may be turned on. The developer should next be checked for temperature. It should be somewhere between sixty and seventy degrees Fahrenheit. However, the exact temperature should be known. The length of time for developing is determined by the temperature. It is also determined by the number of times the developer has been used. Any good photographic manual will give this information. Immediately after the developer has been poured into the tank, the film should be gently turned for a minute to prevent the formation of bubbles and to start the developing evenly over the entire film. After the first minute it is sufficient to turn the film a couple of times every three to five minutes. Turning it too much tends to change the time of developing and possibly may affect the grain. When the developing time is up, pour the developer back into its bottle and immediately pour the stop bath into the tank. This chemical quickly stops any further development. The stop bath should be left on for about five minutes.

After pouring it back into its container, the fixing bath (hypo) is poured on. If the hypo is newly made it will do its work within ten minutes. The hypo dissolves out all the silver salts that have not been affected by the light, thus preventing any further effect of light on the picture. This characteristic of hypo gives it the name of "the fixing bath." Having drained the hypo back into its bottle, the film is now ready to be washed. This process is designed to wash out all the hypo and the dissolved silver salts. The wash water should have a temperature somewhere between sixty-five and seventy degrees Fahrenheit to get the best results. After filling the tank with water, agitate it vigorously for a minute or so and then pour it out. After that a steady but light stream of water should run into the tank for about thirty minutes. If it is convenient, a rubber tube may be attached to the faucet and inserted into the center of the tank. The lid may now be removed and the water can be allowed to flow gently for an hour. It is no harm in washing a little longer than necessary, but if all the hypo is not washed out it will cause discoloration and fogging of the film in time.

When taking the film out of the tank, put the film clamp onto the free end, take off the removable side of the spool, and lift the film out by the clamp and hang

it up on a nail. Take the chamois skin, which should be kept in water, squeeze it dry, wrap it around the film near the top and draw it slowly down the full length of the film while pressing it closely against both sides of the film. Two viscous sponges could be used instead of the chamois. This process is for the purpose of removing all free water, to prevent water spots and uneven drying. To prevent the film from curling while drying another film clamp may be fastened to the lower end or a clothes pin may be used instead of a film clamp. The film should be hung in a dry cool place where there is little or no dust. When the film is moist it picks up dust particles and lint very readily. The particles imbed themselves into the gelatine and are impossible to remove. The film will dry sufficiently to be handled in about thirty minutes, but it is best to let it dry for several hours. The longer drying will make it less easily scratched. To file films the Leica Manual recommends: "Roll film carefully, emulsion side in and store it in a dry, dustproof, clean box. A small rubber band slipped over the roll will prevent film from scratching."¹ In handling the film the same manual gives the following

1. Morgan, W. D., and Lester, H. M., The Leica Manual, p. 152.

warning: "Never permit fingers to come in contact with emulsion side of film either before or after developing. Never handle film except by its edges."¹

Those teachers who are not particularly interested in the process of developing pictures will not find the expense prohibitive to have it done commercially. But those who enjoy the work can find many excellent books and manuals on photography which will give detailed instruction on the various methods that are standard practice. As a warning let it be said that time and expense will be saved to follow the instructions carefully until a habit of accuracy has been established. For those who like to know the reasons for the various steps in the process of developing pictures, a further knowledge of the effects of the different chemicals can be secured from books on the chemistry of photography.

Another very convenient way of storing positive film while awaiting the time of assembling it into stereopares is to cut it in lengths so it will go between the leaves of a "good" magazine. By "good" is meant one with a glossy paper. This method of storing tends to keep the film from rolling and keeps it

1. Morgan, W. D., and Lester, H. M., The Leica Manual, p. 153.

flat. In the flat condition it is much easier to handle when it comes to assembling and making the stereopares.

How to Assemble Stereopares

This is a process that can be begun as soon as two dissimilar positives are available and belong together. However, it will probably save time to have enough pictures on hand to occupy several hours in the process of assembly. The paraphernalia required for the work has to be gathered together and it always takes a certain amount of time to arrange everything conveniently. This part of the work will occupy the same time whether one or a dozen stereopares are produced. To recount the experience of the writer may be helpful, though it is not intended to convey the idea that this is the last word in convenience and efficiency. He usually worked on a table about the size of a breakfast room table. Besides the positive films, which were kept safely between the pages of a magazine until ready for use, he had a pile of celluloid strips $5\frac{1}{4}$ " x $1\text{-}\frac{3}{8}$ ", a roll of black scotch tape, a pair of scissors, the adjusting frame, the trimming apparatus, a razor blade, a stereoscope, the clamping device, and

a typewriter (convenient but not necessary).

It will probably be clearer to the reader, if the process of making one stereopare is gone through first. Then there will be a follow up with comments on what difficulties the writer encountered in the process of learning, and how he overcame some of them.

First, a pair of dissimilar pictures were taken out of the magazine where they were stored and were cut apart with the scissors. They were next trimmed as to length to fit the celluloid strip. To do this the two pictures were put over each other and adjusted so that the images completely coincided. Then the top and bottom were cut square. Having adjusted the pictures to the width of the celluloid strip the next consideration was to make sure which was the left picture and which the right one. That could be discovered by sticking them on the celluloid strip temporarily two and one-half inches apart and then putting them in the stereoscope to see if they showed depth and looked natural. This would consume a great deal of time. So the writer learned to hold the two pictures up and squint at them. This scheme causes the eyes to spread and literally brings the two pictures together. Thus if the first attempt failed to show depth the pictures were switched and checked again. When it was deter-

mined which one was left and which one right, they were laid down in that position on some out-of-the-way place on the table.

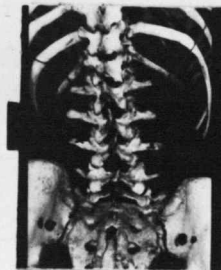
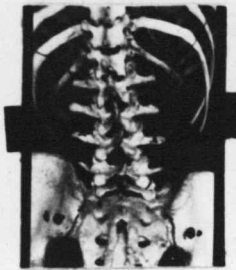
The next step was to place a strip of celluloid on the plate glass of the adjusting frame* in such a way as to fit over the outline which showed through from the paper underneath the glass. On this paper was also drawn two vertical lines two and one-half inches apart. One picture was fitted over one of these lines in such a way that the line could be seen through the picture. It was then fastened to the celluloid temporarily with bits of scotch tape along the two edges. The other picture was then placed over the other vertical line in a position corresponding to that of the first picture over its line. It too was fastened temporarily with bits of scotch tape. See Figure 9, step 1.** (Different pictures were used for each step purposely to give an idea of the possibilities in constructing stereopares, as well as breaking the monotony of the page.

The pictures were now ready for the first inspection through the stereoscope. If all parts showed depth clearly and without eye strain no further adjust-

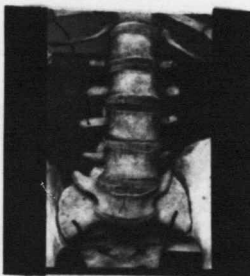
* See page 46.

** See page 65.

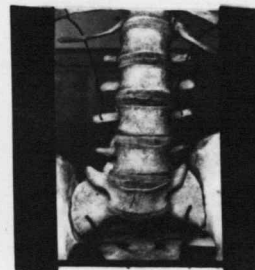
THE STEPS USED IN PLACING THE PICTURES ON THE STEREOPARES



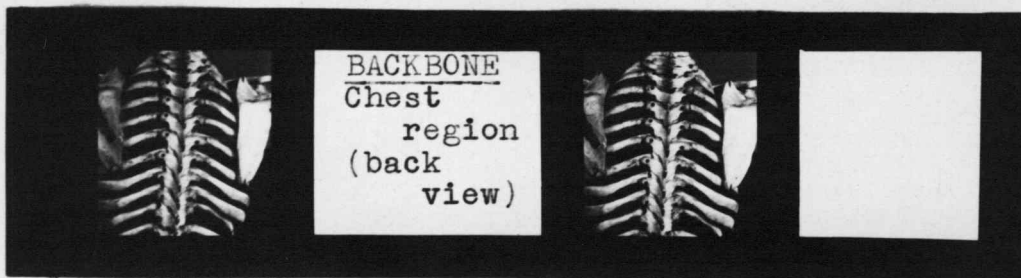
Step 1: The pictures are put in place on the celluloid strips and fastened temporarily with cellulose bits on the side edges.



BACKBONE
Abdominal
region
(front
view)



Step 2: The title is placed between the pictures and black tape is put along the side edges to secure the title and the pictures to the celluloid strip.



Step 3: A celluloid cover is put over the pictures and the edges are bound with black tape.

ment was made. However, some pictures had to be readjusted before they were exactly right. It is very important that all parts of the stereopair can be viewed without eye strain when looking at it through the stereoscope. After locating the pictures correctly on the celluloid, a title was typed on paper and cut to fit the space between them. A strip of black scotch tape three-sixteenths of an inch wide was pasted along the right and left edge of each picture and cut off even with the top and bottom edge of the celluloid. See step 2 in Figure 9.* The tape overlaps the edges of the pictures and helps to secure them more firmly to the celluloid. The tape also overlaps the edges of the paper label in the center, holding it in place.

Another method of adjusting the pictures on the celluloid was suggested to the writer by Professor George B. Cox. Make the frame of the adjusting apparatus shown in Figure 7 perfectly rectangular, with the surface of the glass slightly below the level of the frame. At right angles to the upper side of the frame hinge a couple of straight edge pieces with their right edges two and one-half inches apart. Let the right edge of the left piece be about one-half inch from the left end of the frame. Lay the celluloid strip on the

* See page 65.

glass along the lower edge of the frame, butt it against the left edge and let the two hinged pieces drop down over it. The proper pictures can then be placed quickly against the right edges of the two straight-edged pieces and fastened with the assurance that they are set correctly. This would necessitate the trimming of two adjacent edges (the left and bottom) of each picture so that the edges would be exactly the same in both with reference to the picture area. It would be relatively simple to get the edges uniform by superimposing the two transparent pictures so that every part of the one coincides exactly with the other one. Then the two required adjacent edges can easily be trimmed perpendicularly on a paper cutter. After that the proper pictures can each be quickly butted against its respective straight edge and fastened to the celluloid strip with film cement. An added convenience would be to have a mask made out of light gray paper to fit the stereopare and place that over the pictures instead of framing them with black tape. The title can be typed on the mask between the pictures.

The next step was to put on the celluloid cover. A piece of celluloid just like the one on which the pictures were fastened was put over the pictures and

after the edges were made even, the whole thing was put into the clamping device.* A strip of black cellulose tape (scotch tape) was cut a little longer than the celluloid strips. The tape was held out full length and brought up along the farther side of the top edge of the double celluloid strip in such a way that one-half of the width of the tape extended up beyond the edge. This half was folded over and smoothed down on the near side so that the edge was completely covered. This secured the two celluloid pieces together along that edge. The part of the tape which extended beyond the ends was trimmed off with a razor blade. All the other edges were likewise covered with black tape. When putting on the tape it was difficult to get it on straight, hence the edges of the tape had to be trimmed to make a neat looking job. The trimming was done with a razor blade. To guide it, the edge of the stereopare was pushed under the overhanging edge of the trimming plate** which was set so as to keep the blade three-sixteenths of an inch from the edge of the stereopare. The razor blade was held down on the tape as it was pulled along the edge of the metal guide. The trimmings were peeled off with a knife. Likewise the ends were trimmed.

This concludes the process of making a stereopare

* See page 50.

** See page 12.

and from the description it really doesn't seem difficult. All it takes is patience and perseverance.

The first stereopare made consumed an enormous amount of time compared to its particular value, but so does the first of anything that is new. When it is worthwhile it really is not so discouraging. With each one made the time was cut shorter until it finally became a distinct pleasure to see them take form. No doubt some time was wasted in pure admiration of the finished article.

Numbering is really not a part of the making of a stereopare and yet it is necessary for organization and handling. The numbers have been placed on the outside purposely so that at any time it seemed desirable to change them it could be done. Whatever numbering is convenient can be employed. The essential thing is to have some easy mark by which to file them and to refer to them in the guide sheets.

Refinements and Short-cuts in Making Stereopares

Going back to the making of a stereopare, here are some of the little tricks and conveniences the writer learned to employ in the various stages of the process.

The titles between the pictures were typed on ordinary typing paper.

To determine the space in which the title had to

be typed the celluloid strip with the pictures on it was laid on the paper and an outline made of the space between the pictures. The title was then typed in this space, leaving a little margin for the black tape. This piece was then cut out and put in its proper place between the pictures.

In putting on the black tape along the side edges of the pictures to secure them to the celluloid strip, it was laid on a piece of polished metal. The tape pieces were cut longer than the length of the pictures so that when they were put on they held the celluloid strip to the metal. Thus after putting on the first piece of tape the celluloid was held firmly to the metal making it easier to put on the other pieces. After the four pieces of tape had been pasted across the celluloid strip in their proper places they were cut off along the edge of the strip with a razor blade. This manipulation helped to make a neat-looking job.

The piece of metal mentioned above was a convenient surface on which to stick the scotch cellulose tape for the purpose of cutting out the proper widths and lengths of it. The metal did not affect the adhesive quality of the tape. Any hard smooth surface would be just as good, for example, a piece of glass.

The pictures were prepared before they were put on the celluloid by putting small bits of scotch tape one on each of the side edges. These bits of tape were so placed that they extended slightly over the edge of the picture. Then when the picture was properly placed it was an easy matter to put a little pressure on the bits of cellulose and thus fasten the pictures temporarily. In case they needed to be readjusted they could easily be loosened and moved.

The Stereoscope

The stereoscope used in this study is an adaptation of the "Tru-vue" stereoscope which was originally made for films exclusively. The slot through which the film passes is not big enough to take the double celluloid strip out of which the stereopares are made. Therefore the slot had to be enlarged. This was accomplished with two narrow pieces of plastic one-sixteenth of an inch in thickness, being inserted between the two pieces that form the front and back of the slot. Holes were drilled in the plastic for the screws which hold the two pieces forming the slot. Then the edges of the pieces of plastic which are turned toward the slot were sandpapered almost down to the screw holes. Thus the greatest possible width of the slot was secured.

Figure 10* shows the stereoscope before and after the adjustment was made. The stereopares are less than one-twentieth of an inch thick, which allows them to slide easily through the adjusted slot. This type of stereoscope has the advantage of having no parts that need adjustment for seeing the picture clearly. That makes it easy for the students. All they need to do is to insert the stereopare and then it is ready for study.

Some Educational Values of Stereographic Pictures

The foremost authorities on visual education are unanimous in their recommendation of the stereographic picture as a very efficient tool in the learning process. Dent writes: "The stereograph gives a conception of reality that is not given by any other picture. The third dimension gives actuality of form and a strong feeling of intimacy. Its impression on the student is tremendous. He feels that he is a part of the pictorial situation."¹ Comparing the stereograph and the motion picture as an aid to instruction, Hoban says: "As the motion picture occupies the preeminent position among pictorial materials for depicting action,

* See page 73

1. Dent, E. C., Op. Cit., p. 48.



Figure 10. Showing the stereoscope before and after the change was made to adapt it for stereopares. The right one is before, and the left one is after.

so does the stereograph occupy the position of pre-eminence among still pictures because of its ability to portray depth and perspective."¹ But in spite of this marvelous quality of stereographs they are not used a great deal. They were once quite a fad and were used extensively for entertainment in the home. Perhaps because they were extensively used in the past they are now thought of as old-fashioned. Hoban tells us about the time when they were widely used both in the home and in the schools. He then continues: "Somehow they became associated with things old-fashioned, and as a result the teacher abandoned one of the most effective of teaching tools."²

However, the stereograph is coming back, but in a new form. It is coming back in the form of a transparent film. The stereopticon slide has long been popular, because light can be transmitted through it and so throw the picture of the slide on a screen to be seen by a large group. Light does wonders to a transparent picture and especially if it is stereographic. The object stands out so clearly that it makes you get the same impression as if looking at the

1. Hoban, C. F., Hoban, C. F., Jr., and Zisman, S. B.,
Op. Cit., p. 149.

2. Ibid., p. 13.

real thing. When you look through a transparent stereograph it is almost the same as seeing the object through a window. The ease with which the light can be varied toward or away from a strong light source makes it extremely convenient for study. By this means some very striking effects are produced which help to bring out the various qualities of the object studied.

Stereopares studied through the remodeled stereoscope furnishes the physiology teacher with instructional tools that will be welcomed by his students. He also will find it convenient many times when he has a good specimen to fix it on a stereopare to be used when such specimens are not available. Thus by accumulating from time to time the excellent specimens which everyone is fortunate enough to secure now and then, he will soon have a library of stereopares second to none. Besides having the satisfaction of possessing a number of excellent stereopares, he will discover that they will increase his efficiency as a teacher and thus often ease his load, no small item for the overloaded teacher to consider.

The stereopares also will be especially helpful to those timid students who cannot stand to do a dissection or even watch it done. A well-made stereopare of such a dissection has in it all the essential

facts to be learned minus the unpleasant odors and the more or less bloody and messy appertenances which are always associated with a dissection. With some students this fact is really quite an item in determining even a life-long attitude toward their school experiences.

Stereopares may also be made in color. They will, of course, be a little more expensive, but that is offset by the value they have in depicting true colors of internal organs and blood vessels. By making a few colored stereopares from well-chosen subjects, it may be possible to interest the administration of the school to ask for additional funds for further expansion in this type of stereopares. Anything that has color looks even more real in a colored stereopare than it does in black and white.

CHAPTER IV

SUMMARY

The question of getting enough of the proper kind of visual material is often a problem with physiology teachers. To meet some of these problems an attempt has been made in this study to show how three-dimensional pictures can be used. It has been shown how any material and more especially that which is particularly good can be photographed and preserved in a form that is a good substitute for the real material which often is not available.

There is a need for a study of this type because the visual material required is not always available. The stereographic pictures of this study are shown to be able to fill in the gap caused by this deficiency.

The method worked out involves the construction and use of stereopares as an aid in teaching human physiology.

The material of this study was selected from material actually in use in the class room. Several different types of material were photographed to show the range of possibilities of this method. Out of all the material that lends itself to stereographic photography a random sampling was selected.

This study is limited to showing a method of study for human physiology used with stereopares. It is designed to be taught to beginning students in high school.

It is not a guide to the study of photography, though it does make use of photography in the making of the stereopares.

The fact that stereographic pictures are beginning to come into use in our schools does not mean that they are a new form of pictorial material. The idea of stereoscopic vision was known to the Greeks over two thousand years ago. Wheatstone was the first one to invent an instrument by which to view pictures that show three dimensions. This he did in 1838. Sir David Brewster was the first one to invent a stereoscope with lenses, the principles of which are still incorporated in our modern stereoscopes. Oliver Wendell Holmes designed a stereoscope which remained essentially the same up to very recent times. Some textbooks are now illustrated with stereographic pictures which are viewed through a convenient stereoscope accompanying each book.

The photography was done by means of a camera fastened to a sliding board. The first of each double picture was taken with the board slid as far as possible

to one side, usually to the left. Then the board was slid to the other side for the second picture. See Figures 5 and 6.* A stop allowed the board to slide only three inches. This distance gives a striking stereoscopic effect when the pictures are viewed in a stereoscope.

After the pictures were developed they were assembled into stereopares on an adjusting apparatus** which consisted of a plate glass with a light back of it. A thin paper under the glass had two dark vertical lines drawn on it two and one-half inches apart. The lines could be seen through the glass. A celluloid strip was put on the glass over these two vertical lines. One picture was fastened to the celluloid strip over the one vertical line and the other picture over the other line, and so adjusted that the parts over the lines were corresponding parts in the two pictures. Another celluloid strip like the first one was put over the pictures and the two strips were then bound together around the edges with black tape. A clamping device*** was constructed to hold the celluloid strips together while the black tape was being put on. To

* See page 44.

** See page 46.

*** See page 50.

make the black tape the same width all around it was trimmed in a trimming apparatus* by means of a razor. That completes the making of a stereopare.

To show the use of a stereopare, guide sheets were prepared. The first section of the guide asks the student to find things in the stereopare and raises questions which require study of the stereopare in order to answer them. Additional materials for study are suggested in this section. Then follows a section of reading references. The third section calls for review and the last section includes a set of self-testing questions by which the teacher can check the daily progress of the student.

The guides are given out to the students, one to each, and the stereopares and stereoscopes to groups of students. The number in each group is determined by the number of stereopares and stereoscopes available. When a group completes a guide unit, it proceeds to the next unit for which stereopares are available. The guide units may be studied in any order in the larger unit. This is possible because in a larger unit like the skeleton, for example, it does not matter whether the feet or the head are studied first. The method

* See page 12.

employed in working out the guides takes smaller units more as they suggest themselves to the learner than as they appear to the scientist who perceives more complex relationships.

The teacher having a set of guides worked out has the problem of organization and filing before him. This study suggests that the guide sheets be bound into booklets according to some large unit of study, such as "The Bones," or "The Muscles," For the stereopares, a looseleaf system with individual pockets for each stereopare was suggested.* The stereoscopes should be kept in some kind of "pigeon holes" with an identifying mark for each stereoscope. There should not be less than two sets of stereopares and four stereoscopes for an average-sized class. This number will give each student ample time to examine the stereopares called for in one day's work.

Attention is called to the advantage in this method of having stereopares of excellent material with which the teacher is personally familiar. It is also of great advantage to many of the students who dislike dissections to be able to study stereopares of material which they would try to avoid if it were real.

* See page 40.

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APPENDIX A

Guide Sheets

Unit 4. Bones

Guide Sheet

THE HAND

I. What to do.

- A. Stereopares numbered B-24 and B-25 are to be used with this guide sheet.
- B. First take B-24 and try to pick out the bones of the palm, the wrist, and the fingers in this picture. Did you know that you have many little bones in your wrist? How many are there? See the bone sticking out toward you on the upper left part of the wrist? Can you see the bone back of it? Those two bones form what is called the "heel" of the hand. Find it on the palm side of your wrist, straight back from the little finger.

In what part of your hand are the five bones shown below the wrist? Feel of your palm for the bones in it, especially the one back of your thumb. Which of those five bones are separately movable? To tell which are movable feel of your palm while you move your fingers. See the joints where the palm bones are attached to the wrist bones. Which of those joints, do you think, will allow for most movement?

Count the bones in each finger and in the thumb. Check on your fingers and see if you have that many bones in yours. Is there a bone under the nail? Examine the joints where the fingers are attached to the palm. That type of joint will allow movement in how many directions, would you guess? Try to move your own fingers at those joints. In how many directions can you move them?

Now look at the rest of the joints in the fingers. In what direction can they be moved? Try it on your fingers.

When the thumb opposes the other fingers, as in grasping something, in which joint is most of the movement? After locating that joint on your hand, find it in the stereopare. Could it possibly be the one between the wrist and the bone back of the thumb? That joint is called a saddle joint. Why do you suppose it is given that name?

- C. Now look at B-25. See if you can find all the parts of your hand represented in this picture, just as you did in B-24. Note the joints where the wrist and palm bones meet. Would you expect much movement in those joints? Note the

top part of the wrist bones where they are attached to the arm. Would you think that joint is very movable? Move that joint in your wrist in as many ways as you can. In how many directions can you move it?

Look at the joints where the fingers are attached to the palm. Can you see now why we can spread our fingers as well as close them over the palm? Seeing the back of the finger joints, does the shape of the joints seem to allow for sideways movement? Why?

D. Additional material: bones from the forelegs of animals; stereopticon slides of leg and foot bones of animals.

II. What to read. (Be sure to take notes on your reading)

A. Anatomy and Physiology - Kimber and Gray.

Contains a short description of the hand with labelled pictures.

B. Physiology and Human Life - Buddington.

A short description and a picture of the hand.

III. Recheck your knowledge.

A. Go over the stereopares again and see what you can remember about the bones and joints of the hand. Check with the guide to see what you

have forgotten.

B. Check the notes on your reading and study them.

C. Put away the stereopares, notes and other helps and write answers to the following questions.

Be sure your answers are complete sentences.

IV. Questions.

A. How many bones have you in your wrist?

B. Where is the "heel" of your wrist? How are the bones arranged to make it stand out like that on your wrist?

C. How many bones in your palm?

D. Which of the palm bones is the most movable?

E. (1) What movement of the hand is made possible because of the freedom of movement of that bone?

(2) What is the name of the joint which allows for this freedom of movement?

F. How many bones have you in each finger?

G. (1) Where are the joints which allow the spreading of the fingers?

(2) Why can you not spread the fingers in the other joints of the fingers?

H. Considering the shape of the joints, what would you say is the reason why most of the joints between the wrist bones are not very movable?

THE SKULL

I. What to do.

- A. Stereopares numbered B-1, B-2, B-3, B-4, and B-5 go with this guide sheet.
- B. Begin with B-1. Look at it carefully and see how many parts you can identify on your own head. Look for places where your eyes are, your nose, your lips, cheeks, forehead, cheek bones. Feel of the bony ring around your eyes. Try to find those bones in your face that stick out from below the eye sockets. This skull does not seem to have any bone in the tip of its nose. Do you? What does it feel like? What do you suppose happens to it when the body dies and the flesh decays?

Note how the cheek bones show the outline of the roots of the teeth. Can you feel that part in your jaws? Feel of your gums.

Can you see the two little holes in the lower jaw, one on each side of the chin? Put your fingers over that place on your own jaw. Can you feel a pulse there? What do you suppose those holes are for? See if you can find

another such set of holes under the eye sockets. Again try to feel a pulse under your eye sockets in the place corresponding to the holes you see in the skull.

C. In B-2 find all the things you found in B-1.

Note the irregular line over the top of the skull. It looks like the bone is cracked but it isn't. We all have that. Can you feel it in your head? It is pretty well covered up.

D. Next look at B-3. Again find all the things you saw in B-1 and B-2. Note where the lower jaw attaches to the head. Find that place at the side of your head in front of your ear. Feel of it while you move your jaw up and down and sideways. Can you feel the slender bone just above the joint of the jaw? With what bone in the face does it connect? Find some more of those crooked marks which look like cracks. Again try to find them in your own head.

E. B-4 is a close-up of the jaw joint. What seems to have happened to it? After seeing how it is made, do you think it might be possible to throw your lower jaw out of joint by

opening your mouth very wide? In how many directions can you move your jaw? Can you see any "cracks" in this stereopare that you did not see in the others?

F. Stereopare B-5 solves the mystery of the "cracks." This skull has not been broken. From this stereopare, what do you conclude that the "cracks" really are? Can you see any advantage in having jagged joints between the bones of the skull? Why do box makers use dovetail joints on their best made boxes? The bones of the head have these kinds of joints for the same reason. What is that reason? Note how many different bones there are in the face. How many can you count?

G. Additional material: skulls of animals; stereopticon slides.

II. What to read. (Be sure to take notes on your reading.)

A. Physiology and Human Life - Buddington. You will find in this reference an interesting description of the skull.

B. Healthful Living - Williams.

In this book you will find a short but interesting description of the skull. Pictures show how

the infant skull develops. The sinuses are explained and located.

C. Anatomy and Physiology - Kimber and Gray.

This book has colored pictures of the skull, each bone being colored differently.

III. Recheck your knowledge.

- A. Go over the stereopares quickly and again try to find all the things you have learned about the structure of the skull. Check on your own head for the parts.
- B. Look over your notes on the reading references.
- C. Now lay aside all stereopares and notes and write out answers to the following questions. Be sure to write complete sentences.

IV. Questions.

- A. Of what advantage is it to us to have our eyes set in bony sockets?
- B. Of what disadvantage would it be to have bone out to the tip of the nose?
- C. What is the purpose of the little holes in the lower jaw on either side of the chin and also on either side of the nose below the eyes?
- D. Where is the lower jaw attached to the head?
- E. In how many directions does this joint allow your jaw to move?

- F. What really are those "cracks" in the skull?
- G. Of what advantage is it to us to have such irregular joints between the bones of the head?
- H. How many bones are there in the head?
- I. What and where are the sinuses in the head?
- J. How might sinus trouble be caused by blowing your nose too hard when you have a cold?

Unit 4. Bones.

Guide Sheet

THE ELBOW JOINT

I. What to do.

- A. Stereopares numbered B-30 and B-31 are to be used with this guide sheet.
- B. Look at B-30 first. Note the shape of the joint. In what direction do you think such a shaped joint would allow movement? Try your own elbow and see in what directions you can move the bones in that joint. Why do you suppose this type of joint is called a hinge joint? Does it seem to work like a hinge?

What kind of movement does it seem to you can be made with the lower right bone, as you see it in the picture? Are there any movements you can make with your wrist that might require such a joint in your elbow? Twist your wrist and see if there is any movement in your elbow. Feel all around the elbow joint while you are twisting your hand. What do you think is the function of that extra joint in the elbow? Why do you suppose it is called a pivot joint?

See if you can find that sharp bone that sticks out to the left in the upper bone of the

joint on your own elbow. Remember you are looking at the front of the left arm. It is on the side of the elbow toward your body when the palm is forward.

- C. Now look at B-31. Do you see that deep notch in the upper bone and the knob sticking out toward you from the lower bone? See how far you can bend your arm backwards. What is there in your elbow that prevents your arm from bending backwards?

Notice the point of the bone sticking out to the right on the upper bone. That is the same one you saw on the left side in B-30. Have you ever hit that bone in your arm against anything hard? If you haven't, try bumping it against the edge of a table or a chair. Does it hurt? Why do you suppose that bone is referred to as the "crazy bone?"

- D. Additional material: a skeleton or just the bones of the arm; the bones from the upper part of the foreleg of a mammal; stereopticon slides of these bones.

II. What to read. (Be sure to take notes.)

- A. Anatomy and Physiology - Kimber and Gray.

See "Hinge joints" and "Pivot joints." A complete description of the arm bones is given.

B. Foundations of Health - Rathbone and others.

This contains some well-worded material on hinge joints.

C. Physiology and Human Life - Buddington.

A complete description of a hinge joint.

D. Healthful Living - Williams.

This text contains a complete description of a hinge joint with an illustration fully labelled.

III. Recheck your knowledge.

A. Recall what you saw in the stereopares and go over the questions and directions in the guide to refresh your memory.

B. Look over your reading notes carefully.

C. Now put aside the stereopares and your notes and proceed to the questions below. Be sure you write out the answers in complete sentences.

IV. Questions.

A. Why is the elbow joint called a hinge joint?

B. Why cannot the elbow joint be moved sideways as well as back and forth?

C. Why do joints move so smoothly?

D. What holds the bones together in the elbow joint as well as in all movable joints?

- E. Why cannot the arm be bent backward at the elbow?
- F. On what bone of the arm is the part called the "crazy bone"?
- G. Which bone in the arm twists or rotates on its long axis when you twist your hand?
- H. (1) What kind of joint makes this twisting movement possible?
(2) Where is this joint?

Unit 4. Bones

Guide Sheet

NECK VERTEBRAE

I. What to do.

- A. Stereopares numbered B-6, B-7, B-8, and B-9 are to be used with this guide sheet.
- B. Look at B-8 first. How many bones are there in the neck? (The bones of the neck as well as of the whole backbone are called vertebrae. The singular form is vertebra.) Note how they are separated by felt. Since you can bend your neck, what kind of material between your vertebrae, do you think, takes the place of the felt? Note the spiny projections in the back of the neck. Feel the bumps in the lower part of the back of your neck. That is the spiny projections of your neck. Can you see any reason for them?

See the bony processes extending out from the side of the neck. Observe the large holes between them. Feel of the sides of your neck for these processes. Press hard against the bones as you move the fingers over the side of your neck. Does it hurt in spots? What do you suppose comes out through these holes?

Observe how the vertebrae overlap each other just back of where the holes are between them. Why do you suppose such joints are called gliding joints? In which direction would these joints allow for most movement? Twist and bend your neck to find out. Why can you bend farther forward than backward?

Look at the top vertebra and see how it is different from the rest. In life it is attached solidly to the head. Would its gliding joint allow for freer movement than the other gliding joints? Is there any felt between it and the vertebra below it? How do you suppose it is attached to the other vertebrae?

- C. Take up B-6 next. Check on the number of vertebrae again. The neck begins with the first bone above the ribs. Look at the top bone again. Can you give an added reason why this bone can move more freely than the other vertebrae of the neck?

Notice that the bony projections extending out sideways have holes in the projections as well as between them. What do you suppose runs through these holes that might need the protection of bony walls?

- D. B-7 can now be studied. See how wide the neck vertebrae are. Note the black iron rod coming out at the top of the neck. Why can't you see it farther down in the neck? In life there must be something in where the rod is that needs protection. What do you suppose it is?

Look at the top bone again. What is there on the second bone that keeps the top bone from slipping off? Note how some of the projections in the back are split. Can you see how that might be an advantage when you bend your neck back?

- E. In B-9 look again for the peg which extends up from the second vertebra into the first. Can you see two smooth surfaces on the top vertebra, one on each side of the peg? What do you suppose sits on those places in life? Where is the joint which makes possible most of the twisting movement of the head?

- F. Additional material: animal vertebrae of the neck; stereopticon slides of the neck vertebrae.

II. What to read. (Be sure to take notes.)

- A. Anatomy and Physiology - Kimber and Gray.
A complete description of the neck vertebrae.
- B. Physiology and Human Life - Buddington.
A general description of vertebrae.

C. Healthful Living - Williams.

This text gives an interesting sideline on the structure and function of vertebrae.

III. Recheck your knowledge.

- A. Check again carefully the points you learned from the stereopares and the guide.
- B. Go over your reading notes to reinforce your memory on what you learned from books.
- C. Now you are ready to lay aside your notes and the stereopares and answer the questions below. Be sure to write complete sentences.

IV. Questions.

- A. What material is found between the vertebrae in life?
- B. What kind of joints are there on the sides between the vertebrae?
- C. (1) How are the top two vertebrae joined?
(2) How are the movements of the joint of the two top vertebrae different from those of the other vertebrae?
- D. What is the purpose of the holes on the sides between the vertebrae?
- E. Why can you more easily bend your neck forward than backward?
- F. What are the hard knots you can feel in the middle of the back of your neck?

Unit 4. Bones

Guide Sheet

THE FOOT

I. What to do.

- A. Stereopares B-26, B-27, B-28, and B-29 are to be used with this guide sheet.
- B. Begin with B-28. Can you tell which bones in the stereopare represent the different parts of your foot? How many bones in each toe? Note the size of the bones in the big toe and back of it. Are the bones leading to any of the other toes just as large? Can you see any reason why the bones should be larger on the big toe side of the foot? Which side of your foot seems to work the harder in balancing your body when you stand or walk?

Note how large the heel bone is compared to the other bones in the back part of the foot. Why this difference? What is the heel used for?

Does it seem to you that there can be much movement between the many small bones in the middle of the foot? How many are there, including the heel bone? Can you see any advantage in having many small bones rather than one large solid bone in that part?

- C. B-27 shows very little more than can be seen in B-28. However, you can locate the position of the heel better in this picture. Does it tend to be on the outside or the inside of the foot? Why on that side? On which side is most of the weight of the foot carried?
- D. B-26 gives a little better idea how the foot is attached to the leg. How many bones of the foot come in direct contact with the leg bones? From what you can see, in what direction would you say the joint between the foot and the leg allows most movement? What other movements are possible in this joint? Try it with your own foot.
- E. In B-29 note how the many small bones are fitted together to form an arch much like stones are used to build arches. How are these bones held together to prevent the arch from falling? Your text will tell you. Since this arch is not rigid like a stone arch, of what advantage is it to us to have such an arch in the foot? How does it feel to walk on your heels rather than your arches? Try it.
- F. Additional material: model of human foot, pic-

tures and impressions of normal and flat feet.

II. What to read. (Be sure to take notes on your reading.)

A. Healthful Living - Williams.

This text has a full description of the structure of the foot and how to care for it.

B. Anatomy and Physiology - Kimber and Gray.

This text gives the number of bones in the foot with information on the arches.

C. Physiology and Human Life - Buddington.

A full discussion on the hygiene of the foot.

III. Recheck your knowledge.

A. Look through the stereopares again and refresh your memory on all the points called to your attention in the guide.

B. Go over your reading notes carefully.

C. Now put all your study aids aside and try to answer the following questions. Be sure to write complete sentences.

IV. Questions.

A. (1) How many bones in each toe?

(2) How many pebble-like bones in the back of the foot, including the heel? (This part is sometimes referred to as the ankle.)

B. Why do you suppose the bones in general are larger on the big toe side of the foot than on the other side?

- C. Why is the heel bone so much larger than the other bones in that part of the foot?
- D. Why have many small bones in the ankle?
- E. (1) On which side of the foot is the heel?
(2) Why on that side?
- F. What movements can you make with the joint connecting the foot to the leg?
- G. (1) Where is the main arch of the foot?
(2) Where are there other arches in the foot?
- H. Why does toeing out tend to break down the arches when you stand or walk?
- I. What part of a properly fitted shoe should be roomy?
- J. What are some ways in which high heels might affect a person's health?

Unit 4. Bones

Guide Sheet

CHEST REGION

I. What to do.

- A. Stereopares numbered B-12, B-13, and B-15 are to be used with this guide sheet.
- B. Begin with B-12. How many pairs of ribs do you see? How many pairs of ribs are fastened to the breast bone? Do the ribs fasten directly to the breast bone or is there something between the ribs and the breast bone? In life that dark looking material is white pliable cartilage. Can you move your ribs? Why is it necessary that they be movable? What organs are protected by the ribs? Why would it not be better to have a solid bony wall to protect these organs?

Observe the attachment of the ribs in the back. To what are they attached? Viewed from the front what seems to hold the vertebrae together? Note the white discs between the vertebrae. Try to find out more about them in your reading material.

- C. Put B-13 in the stereoscope next and further observe the attachment of the ribs to the

backbone. How many pairs of ribs are there to each vertebra? At how many places is each rib attached to each vertebra? Note the side projections of each vertebra in this region.

What seems to be the function of these projections? See also the spiny projections overlapping each other along the middle of the backbone. See if you can feel them along your own backbone. They are the bumps you can feel in the middle of your back. What kind of joints join the vertebrae together in the back part of the backbone? Check on the movements you think that type of joint will allow by trying them yourself. Feel of the bumps in your back as you bend your back and straighten up. Try twisting movements. Why can you not bend as far backward as forward? Why can the upper part of the chest be bent back farther than the lower part? See the distance apart of the spiny projections in those two parts. That will help you answer the above question.

- D. Look at B-15 and note the holes in the sides of the backbone close to where the ribs are attached. What structures do you suppose once

extended out from those holes? Look it up in your reading references. Note how the inner ends of the ribs are fastened to the heavy part of the vertebrae. Also observe the joints where the ribs are attached to the side projections of the vertebrae. What sort of movements of the ribs do you suppose those joints would allow? Note that all of those joints are not the same. Which ones are deeper, the upper ones or the lower ones? From this fact, would you conclude that the upper or the lower ribs are the most movable?

E. Additional material: separate human vertebrae; animal vertebrae; ribs of animals.

II. What to read. (Be sure to take notes on your reading)

A. Anatomy and Physiology - Kimber and Gray.

The chest region is fully treated, giving all the ribs and vertebrae. Parts of a vertebra are also shown.

B. Healthful Living - Williams.

This text has an interesting section on the chest and also treats the backbone rather completely.

C. Physiology and Human Life - Buddington.

Find the axial skeleton.

D. Health Essentials - Address and others.

An interesting discussion under the "Spine."

III. Recheck your knowledge.

- A. Go through the stereopares again and see how much you can recall of what you have learned. Go over the questions above and see if you have answered all of them.
- B. Check on your reading notes to see whether you have all the facts pretty well in mind.
- C. Put away all your helps--the stereopares and the reading notes. Now try to answer the questions below. Be sure to write complete sentences.

IV. Questions.

- A. (1) How many pairs of ribs have you?
(2) How many are fastened in front?
- B. What holds the ribs to the breast bone?
- C. (1) Why not have a solid bony wall to protect the organs of the chest?
(2) Why have movable ribs?
- D. What holds the vertebrae together in life as indicated in the stereopares you have observed?
- E. Most of the ribs are attached to each vertebrae in how many places?
- F. How many vertebrae have ribs attached to them?
- G. What part of the vertebrae of your backbone can be felt as bumps in the middle of your back?

- H. What structure on the chest vertebrae prevents you from bending backward as far as forward?
- I. What kind of joints in the backbone allow twisting movements?
- J. What structures extend out through the holes on the sides of the backbone between the vertebrae?
- K. Considering the structure of the joints between the ribs and the vertebrae, why is there likely to be less movement in the upper ribs than in the lower ones?

THE PELVIS

I. What to do.

- A. Stereopares B-19 and B-20 are to be used with this guide sheet.
- B. Look at B-19 first. Which of these bones are called hip bones? Feel of your hips and locate the edge of the flat bones you see in the stereopare. How many hip bones are there in the pelvis? Do the hip bones come together in the back or are they both fastened to another bone? These three bones make up the pelvis. Does the pelvis seem to be as strong in the front as in the back? How do the hip bones seem to be fastened together in front? What rests on top of the bone between the hip bones in the back part of the pelvis? Why is it important to have that part strong? What value do you see in having the hip bones flat and flaring out in the upper part? There may be several reasons, but try to give one or two. It might help you to look up in some textbook what organs lie inside the pelvis.

Note how the leg bones are joined to the pelvic bones. What possible movements would joints like that allow? Observe how the ball-shaped part of the leg bone fits into a socket in the pelvic bone. Considering the shape, what would you suggest as a good descriptive name for such a joint?

- C. Take a look at B-20. Note that the pelvis is tilted slightly forward. In which direction does that tend to curve the lower part of the backbone, forward or backward? How does that help to balance the weight of the body on the legs? Pay attention to the bone holding the hip bones together in the back. It is called the sacrum. The end of this one has been broken off. In life there is a small tail bone on the end of the sacrum. When sitting up straight on what part of the pelvis does your weight rest? Does that balance the weight on the pelvis? When you slide down in a chair what part of your pelvis takes the weight? Does it seem to you that the tail bone and the sacrum are fitted by structure to bear the weight of your body as comfortably as the lower part

of your pelvis?

- D. Additional material: animal bones of the pelvis for comparison. Stereopticon slides of the pelvis.

II. What to read. (Be sure to take notes)

- A. Anatomy and Physiology - Kimber and Gray.

A complete description of the pelvis. Pictures to show the difference in male and female pelvis.

- B. Physiology and Human Life - Buddington.

A short description of the pelvic girdle.

- C. Foundations of Health - Rathbone and others.

Gives some of the important facts about the pelvis. Has a labelled illustration.

III. Recheck your knowledge.

- A. Reexamine the stereopares and go over the guide to refresh your memory on the points required.

- B. Review your reading notes.

- C. Without any help from pictures or notes try to answer the questions below. (Write answers in complete sentences.)

IV. Questions.

- A. (1) How are the pelvis bones fastened together in the back?

(2) How in front?

- B. Why is it necessary that the pelvis be stronger in the back part than in the front?
- C. Of what value is it to us to have flat, flaring hip bones?
- D. (1) What movements of the legs are possible because of the type of joint where the leg fastens to the pelvis?
- (2) What is an appropriate name for that type of joint?
- E. How should the pelvis be tilted to properly balance the weight of the body on it?
- F. (1) When you slide down in a chair on what part of the pelvis do you tend to throw your weight?
- (2) Since the above posture does not balance the weight on your bones, what structures of your body must put forth more energy to hold you up?
- G. Why are you likely to get more tired sitting slouched in a chair than in sitting up straight?

Unit 6. Internal Organs

Guide Sheet

INTERNAL ORGANS OF FROG

I. What to do.

- A. Stereopares numbered O-1, O-2, O-3, O-4, and O-5 are to be used with this guide sheet.
- B. Begin with O-1. What organs do you recognize? Does the white carrot-shaped organ on the left side of the frog, right side of picture, resemble a stomach? And the coiled tube running down the middle--does that look like intestines? You have seen liver in the butcher shop. Do the dark pieces between the front legs look anything like liver? Look for the spleen, a dark spot within the first coil of intestine near the stomach. Find the heart up among the liver. It is hidden between the lobes of the liver in the middle and is a lighter color than the liver. Do you see the gall bladder under the liver? It is a little larger than the spleen. This was a female. Find the egg tubes on the left of the intestines. What color do they appear to be? How can you tell them from the intestines?
- C. Now look at O-2, and find all the different organs you saw in the first stereopare. Those

two inflated bags sticking out at you resemble what organs you have seen in other animals? What organs in you take in air? Observe the lobes of the liver. They are easily counted. How many are there? Notice the little round black object between the inflated lungs and below the heart. Does that look like a gall bladder? If this was a colored stereopare that would be green. Note how the lungs look like a couple of ears of corn. What do you suppose the "kernels" represent? Do you suppose they might be air cells through which the frog absorbs air?

- D. Now turn to stereopare O-3. What organs have been taken out? What has been done to the esophagus (the tube through which the frog swallows)? How does the diameter of the esophagus compare with that of the stomach? Knowing that frogs swallow their food whole, can you see any advantage to the frog to have a large esophagus? What is the advantage? Can you find the heart over on the left side?
- E. O-4 shows what parts that you did not see in the other pictures? What do you suppose is the function of that thin tissue under the

intestines? Note the fine gray lines in it. They represent blood vessels. Could it be that this thin tissue is a way for the blood vessels to enter the intestines? It is called the mesentery. Try to find something about it in your text. See the parsnip-shaped part at the end of the intestines. That is all the large intestine the frog has. From what you can see in this picture would you say that the frog has a relatively long or short set of intestines? Meat-eating animals have shorter intestines than grass-eating animals. In which class do frogs belong? What is the black object in the mesentery? You saw it within the first coil of the intestines in the first picture.

F. Finally look at O-5. Do you recognize any parts of the frog that you did not see in the other stereopares? What is that sharp ridge running along the middle of the body? Do you recognize the soft-looking, dark material lying along the rear part of the back? Do they look anything like kidneys? Note how large they are compared to the frog. Did you notice how all the organs of the frog are different

from those of animals like the cat or rabbit.

- G. Additional material: demonstration dissection of a freshly-killed frog.

II. What to read. (Be sure to take notes)

- A. Biology for Beginners - Moon and Mann.
 - B. Handbook of Reptiles and Amphibians - Slevin.
- The above books will give you information on the internal organs of the frog.
- C. Any other texts that contain required material may be used.

III. Recheck your knowledge.

- A. Look through the stereopares again to refresh your memory on the location and appearance of the internal organs of the frog.
- B. Go over your reading notes carefully.
- C. While your information is fresh, put away the stereopares and your reading notes and answer the following questions. Be sure to write complete sentences.

IV. Questions.

- A. Where is the frog's stomach located?
- B. (1) How many lobes or parts are there in the liver?
- (2) How large is the liver compared to the other organs?

- C. Where is the liver located?
- D. (1) Where are the lungs located with reference to the liver?
(2) Is there any tissue separating the lungs from the liver and stomach?
- E. What are the little divisions in the lungs which look like kernels of corn?
- F. Where is the heart with reference to the liver?
- G. (1) What is the mesentery?
(2) What is its function?
- H. Of what advantage is it to the frog to have a relatively large esophagus and stomach?
- I. Frogs and other animals with relatively short intestines live on what type of diet?
- J. Where are the kidneys of a frog located?

Unit 7. Digestion

Guide Sheet

TEETH COMPARED

I. What to do.

- A. Stereopares numbered T-1, T-2, T-3, and T-4 are to be used with this guide sheet.
- B. Begin with T-1. Look at the teeth of the two skulls. In what way are the teeth of the monkey like our own? Count the teeth. You can see just half of them. How many teeth have you? Is that more or less than the monkey has?

Do monkeys eat about the same type of food as we do? Have you ever seen monkeys eat peanuts? Note the shape of the front teeth of both skulls. What can teeth of that shape be used for? What do you use your front teeth for? How do the front teeth of the monkey help him eat a banana? Does a monkey swallow peanuts whole or does he chew them like you do? What are the back teeth of the monkey used for? What do we use our back teeth for? Can you see any reason why a monkey should have the same type of teeth as we have?

The monkey seems to possess one type of teeth which is not shown in the human skull.

Which one is that? Count five teeth from the back tooth in the human skull and you have the corresponding human tooth. That is sometimes called a canine or dog tooth. Can you guess why? Look in a mirror and find your canine tooth. Count four teeth back beginning with the first tooth on either side of the middle of your mouth. Is it as long and sharp as that of the monkey? Do we require a long sharp canine tooth? Why do you suppose a monkey has such a tooth?

- C. Take up T-2 next. In what way are horses' teeth like ours? Count the number of chewing teeth the horse has. What does a horse eat? Why does a horse need more and larger chewing teeth than we do?
- D. T-3 may now be observed. How are the dogs' teeth different from ours? What does a dog eat, especially when he goes out to hunt for his food naturally? Why cannot the dog chew grass and hay? Can he chew raw vegetables? Because of the shape of his teeth what is the best type of food for dogs? Considering the natural food of dogs, of what value are the fangs? The fangs of a dog correspond to which type of human tooth?

E. In T-5 you see teeth that are very different from ours. In what ways are they different? Count the teeth of the snake exclusive of the fangs. With that type of teeth is it possible for a snake to chew its food? Note how sharp the teeth are. Why do you suppose the points turn backwards? How can you tell by the teeth of this snake that he belongs to the poisonous variety?

F. Additional material: assortment of human and animal teeth. Animal skulls showing different types of teeth. X-rays of teeth. Stereopticon slides of teeth.

II. What to read. (Be sure to take notes)

A. New Biology - Smallwood.

B. A Biology of Familiar Things - Bush, Dickie, and Wrunkle.

C. The above books will give you information on the teeth of animals.

D. Use your text for human teeth. Find the types of teeth and the number of each and location.

E. Any other available texts containing the required material may be used.

III. Recheck your knowledge.

A. Go over the stereopares carefully again and recall all the things you were asked to observe.

Run through the guide and see that you can answer all the questions.

- B. Review your reading notes.
- C. Having made a thorough review, put aside the stereopares and your notes and write out answers to the questions below. Write complete sentences.

IV. Questions.

- A. (1) Judging by its teeth, what kinds of food does a monkey eat?
(2) In what way are our teeth like those of the monkey?
- B. (1) What kind of teeth does a horse have that makes it possible for him to eat hay and grass?
(2) Why does not a horse wear his teeth down to the gums?
- C. (1) How do meat-eating animals chew their food?
(2) Of what value are the sharp fangs to them?
- D. Why would it be a strange sight to see a snake moving his mouth as though he were chewing something?
- E. How does a snake eat?
- F. How can a snake's teeth be of help to him when he eats?

APPENDIX B

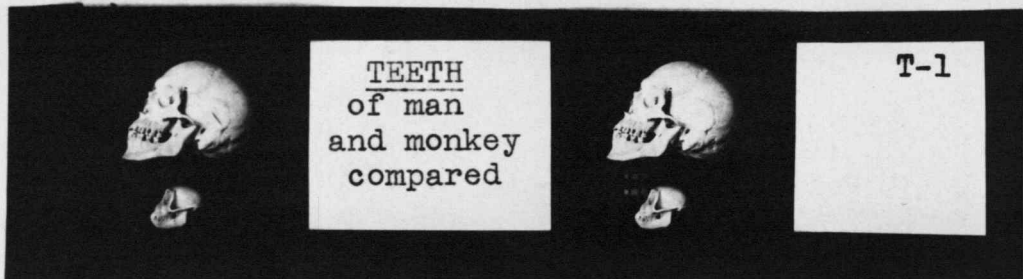
Samples of Stereopares

SAMPLES OF THE SIZE AND SHAPE OF THE
STEREOPARE USED IN THIS STUDY

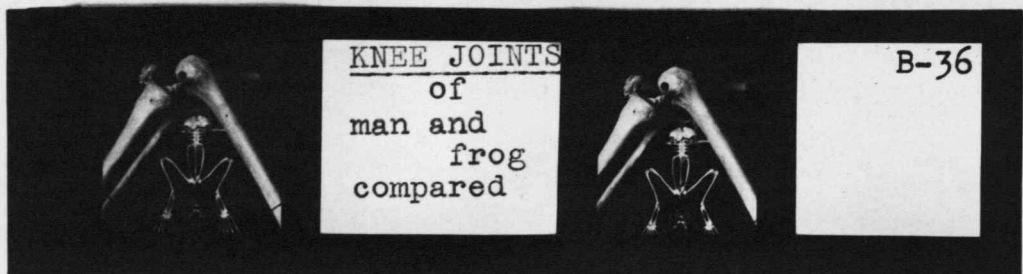
x1



Stereopare used in the guide on THE SKULL



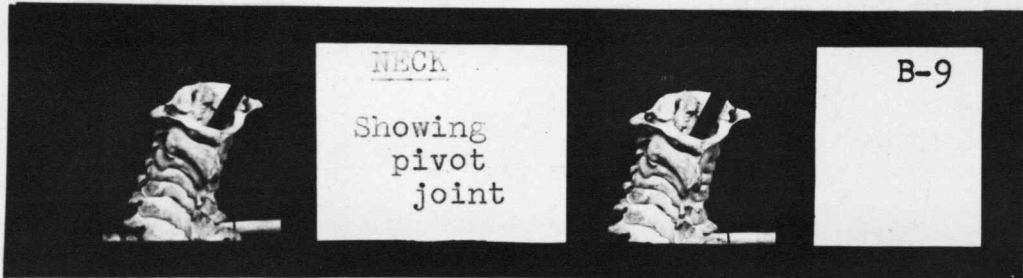
Stereopare used in the guide on THE TEETH COMPARED



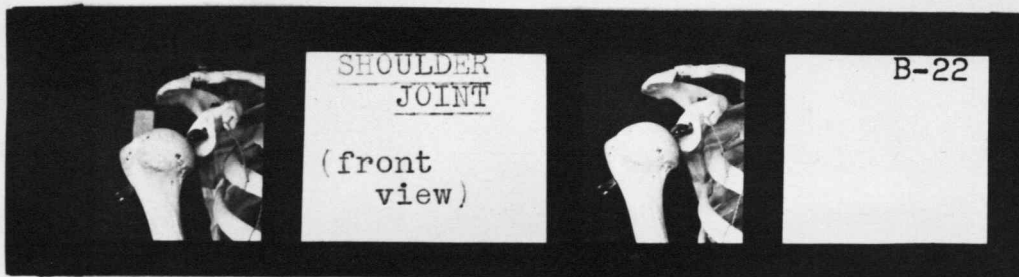
Stereopare used in the guide on COMPARATIVE ANATOMY
KNEE of FROG and MAN COMPARED

SAMPLES OF THE SIZE AND SHAPE OF THE
STEREOPARES USED IN THIS STUDY

xli



Stereopare used in the guide on THE NECK VERTEBRAE



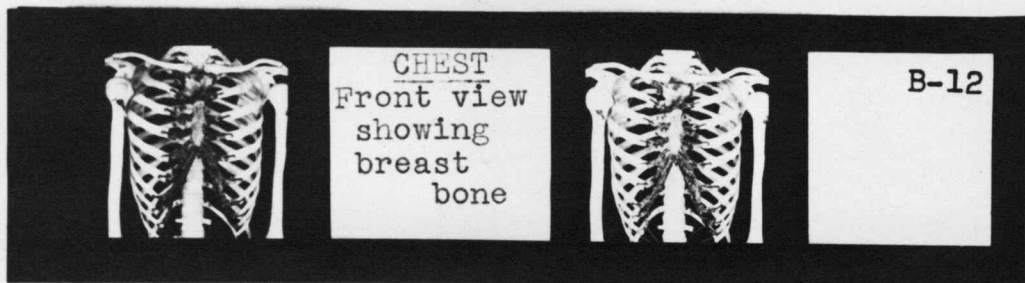
Stereopare used in the guide on THE SHOULDER JOINT



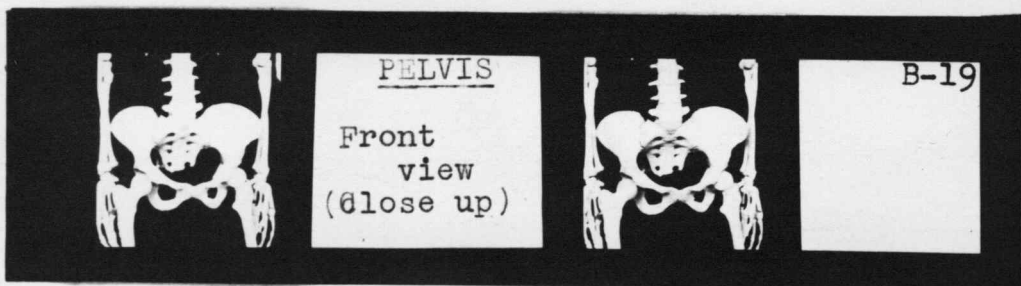
Stereopare used in the guide on THE CHEST REGION

SAMPLES OF THE SIZE AND SHAPE OF THE
STEREOPARES USED IN THIS STUDY

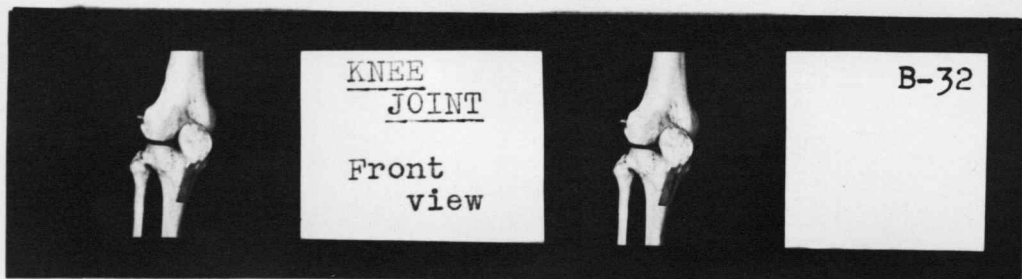
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Stereopare used in the guide on THE CHEST REGION



Stereopare used in the guide on THE PELVIS



Stereopare used in the guide on THE KNEE JOINT