PRIMARY

MICROSCOPY AND CHIROLOGY.

BY ALBERT HEN'SHIRE, A. M.

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PRIMARY MICROSCOPY

—AND—

BIOLOGY.

A TEXT BOOK

FOR THE USE OF STUDENTS IN

HIGH SCHOOLS, NORMAL SCHOOLS AND

ACADEMIES,

BY

ALBERT SCHNEIDER, M. D.

"Valcet quantum valere potest."

FAIRBURY, ILL.,
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1890.
TO

CLIFTON SCOTT, B. S., M. D.,

INSTRUCTOR OF NATURAL SCIENCES IN THE NORTHERN ILLINOIS NORMAL SCHOOL.

THIS WORK IS DEDICATED.

IN ADMIRATION OF

HIS ABILITIES AS TEACHER AND IN REMEMBRANCE OF MANY ACTS OF KINDNESS SHOWN TO THE AUTHOR WHILE A PUPIL UNDER HIS GUIDANCE.

Entered according to Act of Congress, in the year 1891, by
ALBERT SCHNEIDER, M. D.,
In the Office of the Librarian of Congress, at Washington.
This work is intended to acquaint the student with the elements of Microscopy and Biology. It is not complete in any of its parts. It is presented for the purpose of meeting a demand in our more elementary institutions of learning, and to create a desire in the student to investigate Nature and its Laws for himself. The course of study as laid down in our public schools, normal schools and academies is such that one can not become a master in the field of biology. Those who do not have unlimited time and a well lined purse to carry on scientific investigations, can only hope to acquaint themselves with the rudiments and first principles as presented in this little work. Afterward, if desirable, they can continue in some first-class college or investigate for themselves.

The student before entering upon this work is supposed to have mastered the elements of chemistry and physics, and also geometry and trigonometry. The laboratory work is so arranged as to save both time and extra labor.

*Microscopy.*—Here are presented the construction and uses of the simple and compound microscopes, the formation of images and the refraction by lenses, etc. Some hints on the purchasing and care of a good microscope. Much could have been added which would however only have been tiresome to the beginner.

*Biology.*—A brief introduction gives the student some idea of the extent of this field of investigation, but he should
not allow this to discourage him. The different steps are so arranged as to make clear to the student what he is expected to do. He is earnestly advised not to rely too much on the outline, but to investigate and reason for himself the "why" and "wherefore" of every step he takes.

There is a purpose in the arrangement of this work. The various steps are not placed as if by chance. Therefore the student should not omit anything.

The author will feel amply repaid if he has aided in creating in his fellow student a love for the study of Biology.

A. Schneider.

Dixon, Aug. 30, 1890.
ERRATA.

Page 7....For “phylosophy” read “philosophy”.
Page 12....For “refractoin” read “refraction”.
Page 13....Fig. 6, top a’ should be a.
Page 16....In Article 38, Proportion 5, introduce +IHG.
Page 22....For “triblet” read “triplet”.
Page 27....For “trible” read “triple”.
Page 31....For “trible” read “triple”.
Page 33....For “miccometer” read “micrometer”.
Page 46....For “olear” read “clear”.
Page 51....For “evist” read “exist”.
Page 57....For “Denterostomata” read “Deuterostomata”.
Page 59....For “mowers” read “mouers”.
Page 72....For “animal” read “vegetable”.
Page 73....For “mubticellular read “multicellular”.
Page 78....For “chitinous” read “chitinuous”.
Page 82....For “No. 2 SO₃” read “Na₂SO₃”.
Page 82....For “Potassium” read “Potassium”.
Page 83....For “Tartarate” read “Tartrate”.
CHAPTER I.

MICROSCOPY.

(1) MICROSCOPES.—(Gr., mikros, small; and skopein, to view.)

Objects which are too small to be seen by the naked eye are brought into view by an instrument called a microscope. The simple microscope was the first to come into use. A simple microscope consists of a single lens or a system of lenses by means of which the object is viewed directly. The time and manner of its discovery is not definitely known. There is no doubt that the ancients were acquainted with its use. Ptolemy in his "Optics" gave a table of the refractive indices for glass and his results agree quite closely with those of to-day.

The discovery of the microscope may have been by accident or by design. It is known that Jacharias Jansen & Son constructed microscopes as early as 1590. In the year 1685, Stellati gave a minute description of the bee which he could only have done with the aid of the microscope. By its means Leeuwenhoek made his wonderful discoveries. In 1673 he discovered red globules in blood. In 1677 he discovered infusoria in stagnant water. His microscopes were so constructed that he required a new one for every two or three objects.

From the time of Jacharias Jansen till the construction of corrected lenses many forms of microscopes were produced by scientists and opticians of Italy, France, Germany and England. They used only one kind of glass in the manufacture of their lenses. The holders for these lenses were of all descriptions and forms. The great hindrance to the perfection of the simple microscope was spherical and chromatic aberration. About 1815 Wollaston and Frauenhofer
gave their attention to the improvement of these defects. They used two kinds of glass having different refractive indices, namely crown and flint glass. Euler made an achromatic objective in 1776. When the greatest magnifying power of the simple microscope, consistent with the greatest possible correction for spherical and chromatic aberration had been obtained, it was believed by scientists and opticians that the climax in microscopy had been reached. Even after the invention of the compound microscope such men as Wollaston and Biot predicted that the simple microscope could not be excelled by the compound. It is not definitely known when the first compound microscope was made. It could certainly not have taken an optician long to comprehend the necessary principles for the construction of the compound microscope after fully understanding the simple. In the ancient and middle ages scientists were more interested in astronomy than in biology, whence it came that the telescope preceded the microscope. The principles of construction are very much the same in the two.

In the compound microscope we have a lens, or a combination of lenses acting as one lens, forming a real image; this image is further magnified by a second lens or system of lenses. In the simplest form only two lenses are necessary; one to form the real image, the second to further magnify the real image. We could have an indefinite number of systems of lenses, each succeeding one magnifying the preceding real image. By placing the eye in the focus of the uppermost system we would see a virtual image of all the several real images. The reason why we do not use more than two systems is because the image would appear indistinct on account of too much light being absorbed in passing through so many lenses.

Only a few years ago microscopes and works treating on microscopy could only be bought by the wealthy, but now the wonderful mechanical aids of to-day and the large number of dealers in microscopical material has made them comparatively cheap. Rapid strides are being made in the im-
provement of the microscope. Fifty years ago no one would have dreamed of the improvements of to-day, and it is to be hoped that fifty years hence the microscope of to-day will be a thing of the past, for there is nothing seemingly so perfect but it may be made more perfect.

(2) PHYSICS.—(Gr., physike; L., physica, natural philoso-

phy.)

Nearly every person with good eyesight can look down the tube of a microscope and view an object which, of course, has first been prepared and placed on the stage by an expert, but very few know how that image is formed and brought to the eye greatly magnified. Some of the laws of optics with demonstrations are introduced here that the student may get a more thorough understanding of the subject than he would from the ordinary high school text-book on philosophy. It is true one may become quite skilled in the manipulation of the microscope and not know anything about optics. Yet for his own benefit and in order that he may be able to satisfy in-
quisitive semi-scientists he should acquaint himself as far as possible with the mechanics and mathematics of lenses and mirrors.

(3) IMAGES.—(L., imitari, to imitate.)

An optical image consists of a collection of focal points, from which light either really or apparently radiates. When we see rays collected from real focal points we have a real image. When we see rays collected from apparent focal points we have an apparent or virtual image.

(4) A real image can be projected upon a screen, a vir-
tual image can not.

(5) The apparent focal point can exist only as long as perceived by the eye. The real focal point can exist independent of the eye.

(6) Rays diverging before reflection will diverge at the same angle after reflection.
(7) Rays converging before reflection will converge at the same angle after reflection.

(8) Rays parallel before reflection are parallel after reflection.

(9) Images formed by plane or convex mirrors are always virtual. Those formed by concave mirrors may be either.

(10) The general effect of a concave mirror is to produce convergency of rays.

(11) The general effect of a convex mirror is to produce divergency of rays.

Fig. 1.

Apparent or virtual image formed by a plane mirror.

(L., mirare, to wonder.)

(12) Let m n in fig. 1 represent a plane mirror and A B an object before it. Let the objects position be such that the reflected rays will enter the eye at H. From A and B let fall perpendiculars on the mirror, produce them till a E = A E and b G = B G. Now rays from A will seem to radiate from the apparent focus a., and all those from B at b., and all intermediate points between A and B will seem to focus at similar points between a. and b. Therefore the object and image are equally distant from the mirror.
A C and a c are equal because they are two perpendiculars between two parallel lines, $B G = b G$ and $A E = a E$, therefore by substitution and subtraction $B C = b c$; the angles $A C B$ and $a c b$ are equal because they are both right angles, hence $A B = a b$ and $B A C = b a c$; that is, the image by a plane mirror is equal in size, equidistant and equally inclined with the object.

(13) Changing the position of the eye does not change the position of the image by a plane mirror.

![Fig. 2.](image)

CONJUGATE FOCI.

(14) When rays which radiate from a point are reflected by a concave or convex mirror they are again brought to a real or apparent point. These points are interchangable and are called conjugate foci.

If the radius of the mirror and the distance of one focus are given the distance of the other focus may be determined.

(15) In fig. 2, let radius of mirror = $r$; the distance of one focus $A E = m$, and the other focal distance $a E = n$.

The angle $A B a$ is bisected by $C B$. Therefore $A B : a B : A C : a C$, but since $B E$ is very small, $A E : a E : A C : a C$. Substituting,
(1) \( m : n : : m - r : r - n \).

(2) \( m r - m n = m n - n r \).

(3) \( m r - 2 m n = - n r \); or, \(- m r + 2 m n = n r \).

(4) \( 2m n - m r = n r \); or, \( m (2n - r) = n r \).

(5) \( m = \frac{n r}{2(n - r)} \) Q. E. D.

(6) \( n = \frac{m r}{2(m - r)} \) Q. E. D.

Fig. 3.

**IMAGE BY A CONCAVE MIRROR.**

(16) In a concave mirror when the object is placed between the center of curvature and the principal focus the image is real, inverted and enlarged. It is real because the image can be projected on a screen. It is inverted because the axes cross between the conjugate foci. It is enlarged since it subtends the angle of the axes at a greater distance than the object. \( d b \) bisects \( a b c \), . . . \( a d \cdot d c : : a b : b c \). As \( b c \) is greater than \( b a \) so is \( d c \) greater than \( a d \). \( a d \) and \( d c \) measure the distances of object and image from the center of curvature.

Note.—Other problems in concave and convex mirrors should be assigned for demonstration.
LENSES.—(*L.*, *lens, a lentil.*)

(17) A lens is a transparent medium having at least one curved surface. The most common forms are six in number shown in fig. 4.

Fig. 4.

(18) A, A double convex lens has a common base and two equally or unequally convex surfaces.

(19) B, A plano-convex lens has one side convex, the other plane. It is simply a segment of a sphere or half of a double convex lens.

(20) C, The meniscus or convexo-concave lens has one surface concave, the other convex. The convexity exceeding the concavity.

(21) A, B and C have the general effect of double convex lenses.

(22) D, A double concave lens has two equally or unequally curved surfaces.

(23) E, The plano-concave lens one surface plane the other concave.

(24) F, The concavo-convex lens has one surface convex, the other concave, the concavity exceeding the convexity.

(25) D, E and F have the general effect of double concave lenses.

Note.—It is supposed that the student understands the general effect upon light on passing through the various lenses.

(26) Lenses of to-day are nearly all made of crown and flint glass. Crown and flint have different refractive indices and are used in order to correct spherical and chromatic aberration as will be explained further on.
REFRACTION.—(L., re, back, and frangere, to break.)

(27) Refraction is the change in direction that a ray of light undergoes in passing from one medium into another.

(28) The angles of incidence and refraction are on opposite sides to the perpendicular of the surface.

(29) In the same media the ratio of the angles of incidence and refraction are the same for all inclinations of the ray.

Fig. 5.

(30) In fig. 5 A C is refracted to E and a C to e, so that A D : E F : : a d : e f, then by inversion E F : A D : : e f : a d.

(31) This constant ratio is called the index of refraction. It is found by dividing the sine of the angle of incidence by the sine of the angle of refraction.

Let \( i = \) index of refraction. Then \( i = \frac{\sin A}{\sin F} \frac{D}{E} \)

(32) When the ray of light passes from air or some other medium into the substance it gives the comparative index.
When the ray of light passes from a vacuum into the substance it gives the absolute index.

(33) The following table gives the absolute indices of refraction:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Absolute Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamond</td>
<td>2.45</td>
</tr>
<tr>
<td>Carbon Disulphide</td>
<td>1.69</td>
</tr>
<tr>
<td>Oil of Cassia</td>
<td>1.63</td>
</tr>
<tr>
<td>Flint Glass (mean)</td>
<td>1.6</td>
</tr>
<tr>
<td>Quartz (mean)</td>
<td>1.55</td>
</tr>
<tr>
<td>Canada Balsam</td>
<td>1.54</td>
</tr>
<tr>
<td>Crown Glass (mean)</td>
<td>1.53</td>
</tr>
<tr>
<td>Alcohol</td>
<td>1.37</td>
</tr>
<tr>
<td>Water</td>
<td>1.34</td>
</tr>
<tr>
<td>Ice</td>
<td>1.31</td>
</tr>
<tr>
<td>Air</td>
<td>1.000294</td>
</tr>
</tbody>
</table>

—Olmstead's Philosophy.

(34) Substituting in article (31).

\[
\text{(1) } i = \frac{\sin a}{\sin a'}
\]

\[
\text{(2) } \sin a = i \sin a'
\]

Also (3) \[
\sin a' = \frac{1}{i} \sin a''
\]

\[
(2) x = (3) = (4) \sin a = \sin a'' \quad \text{the ray } S \text{ and } S' \text{ are parallel, that is the incident and emergent rays by a refractive medium having parallel plane surfaces will be parallel.}
\]
REFRACTION BY A MEDIUM BOUNDED BY INCLINED PLANES.

(35) A transparent medium bounded by inclined planes is called a prism. The angle included by the planes is called the refracting angle and the planes are called deviating planes.

(36) The total deviation by a prism is equal to the sum of the angles of incidence and emergence diminished by the refracting angle.

(37) In fig. 7 let A B = the incident ray and C G = the emergent ray. G D H will equal total deviation.

\[
\begin{align*}
(1) \quad G \ D \ H &= D \ B \ C + D \ C \ B. \\
(2) \quad i - i' &= e - e'. \\
(3) \quad G \ D \ H &= (i - i') + (e - e') = (i + e) - (i' + e').
\end{align*}
\]

Because of the perpendiculars at B and C, C K y and K B r are similar right angled triangles, therefore \( p = r \).

also (4) \( p = i' + e' \)

hence (5) \( i' + e' = r. \)

Sub.in(3)= (6) \( G \ D \ H = i + e - r. \) Q. E. D.
To find optic center of convex lens.

(37) The incident and emergent rays which enter and leave a lens at the points of contact of two parallel tangents will be parallel according to Article 34. The point where such a ray cuts the axis of the lens is called the optic center. It may become necessary to produce the axis.

In fig. 8, a and b are the points of contact of the parallel tangent planes. The radii C a and C' b being perpendicular to these planes are parallel to each other.

Hence (1) Angles o and o' are equal.

And (2) Angles at P are equal.

Therefore (3) Triangles C a P and C' b P are similar.

Represent C' b, one radius, by r and C a the other radius by r. Represent thickness of lens measured on the axis by t,
and distance from optic center to surface by e. From 1, 2 and 3 we get

\[ C^1 P : C P : : C^1 b : C a. \]

Sub. \[ r^1 - e : r - (t - e) : : r^1 : r. \]

\[ r^1 r - r e = r^1 r - (r^1 t - r^1 e) = r^1 r - r^1 t + r^1 e. \]

\[ -r^1 e - r e = - r^1 t. \]

\[ e (r^1 + r) = r^1 t. \]

\[ e = \frac{r^1 t}{r^1 + r} \] Q. E. D.

**Fig. 9.**

(38) The relative distances of the conjugate foci can be determined when the refractive index and radii are known. Let \( x = \) refractive index and assume that the angles of incidence and refraction are so small that their ratios are the same as the ratios of their sines.

Then \[ RGP : (=KGI) : IGH : : x : 1. \]

By div. \( KG I = IGH : IGH : : x - 1 : 1. \)

Substituting \( KGH : IGH : : x - 1 : 1. \)

\[ KHG : IHG : : x = 1 : 1. \]

\[ 3 + 4 = 5 KGH + KHG = IGH : : x - 1 : 1. \]

But \[ KGH + KHG = BKF = KR + KFR. \]

And \[ IGH + IHG = PIC = IC + IC = I C'. \]

Therefore \[ KRF + KFR : IC + IC = : x - 1 . 1. \]
The angles at R, C, C₁ and F are as the reciprocal of the distance from L., therefore substituting in (8) we have,—

\[(9) \frac{1}{RL} + \frac{1}{FL} : \frac{1}{CL} + \frac{1}{C'L} : : x-1:1.\]

**To Find Principal Focus:**

(39) In that case \( \frac{1}{RL} \) would equal \( \frac{1}{\infty} \) and let the principal focus equal \( F \) then 9 in Art. 38 would equal:

\[(1) \frac{1}{\infty} + \frac{1}{F} : \frac{1}{CL} + \frac{1}{C'L} : : x-1:1; \frac{1}{\infty} = 0.\]

Hence (2) \( \frac{1}{F} : \frac{1}{CL} + \frac{1}{C'L} : : x-1:1.\)

Formulae 9 and 2 may be applied to any form of lens.

**To Find the Power of Any Lens.**

(40) The reciprocal of the principal focal length of a lens is called its power.

From 9 in Art. 38 we find,

\[(1) \frac{1}{RL} + \frac{1}{FL} = (x-1) \left( \frac{1}{CL} + \frac{1}{C'L} \right)\]

And 2 in Art. 39 equals

\[(2) \frac{1}{F} = (x-1) \left( \frac{1}{CL} + \frac{1}{C'L} \right); \text{ therefore.}\]

\[(3) \frac{1}{F} = \frac{1}{RL} + \frac{1}{FL}\]

\[(4) F = \frac{RL x FL}{RL + FL} = \text{power of lens.}\]

Fig. 10.

(41) To find the power of a combination equivalent to a single lens:

Let a ray parallel to the axis be incident at \( R \) and \( ST \) be
the emergent ray. Draw RC parallel to ST. AC will represent the focal length of a single lens having the same deviation as the above combination. AX is the focal length of A. Let a represent the distance between the lenses. Then BX = AX − a. If we regard T as one of the foci then X must be the virtual conjugate of lens B corresponding to T. Let f equal focal length of A and f1 equal focal length of B. Then,

\[
\frac{1}{f} = \frac{1}{B} - \frac{1}{B X} \quad \text{Art. 40.}
\]

But \(2\) \(BX = f - a\).

Therefore \(3\) \(\frac{1}{f_1} = \frac{1}{B} - \frac{1}{f - a}\)

\[
\frac{1}{f} = \frac{1}{B} + \frac{1}{f - a}
\]

\[
\frac{1}{B} = \frac{f_1 + f - a}{f_1(f - a)}
\]

From similar triangles ACR, BTS and XAR, XBS, we have,

\(6\) \(BT : AC : : BS : AR : : BX : AX\).

But AC equals F the focal distance of the combination. Therefore \(7\) \(BT : F : : BS : AR : : BX : AX\).

\[
\frac{BT}{F} = \frac{BX}{AX}
\]

\[
BT \times AX = F \times BX.
\]

Sub. \(10\) \(\frac{f_1 (f - a)}{f_1 + f - a} \times \frac{f}{f} = F \times (f - a)\)

\[
\frac{f_1 + f - a}{f_1 (f - a)} \times \frac{f - a}{f} = \frac{1}{F}
\]

When the lenses are in contact \(a = o\).

\[
\frac{1}{F} = \frac{1}{f} + \frac{1}{f_1} \text{ from which we get:}
\]

\(42\) The power of a combination of two lenses in contact is equal to the sum of their respective powers.

The above formula can be applied to any number and form of lenses.

Due attention must be paid to the signs of the powers.
IMAGES.—(*L.*, *imago*, image.)

(43) Lenses form a great variety of images. Their size and position depend on the kind of lens and position of the object. If in a convex lens the object is placed between the principal focus and the lens, the image will be virtual, erect and enlarged. If the object is further from the lens than the principal focus the image will be real, inverted and enlarged. All real images are inverted.

In the compound microscope there are two kinds of images formed, one real, the other virtual.
(44) Fig. 11 shows the simplest form of the compound microscope. a is the object glass or objective. The object is placed a little beyond the principal focus, when a real, inverted and enlarged image is formed at d, this real image is further magnified by the eye piece A. This second image is virtual and enlarged. The relative positions of the objective and eye piece change the magnifying power. It is necessary to form two ratios to find magnifying power of objective. The diameter of the object is to the diameter of the image as the distance of the object from the objective is to the distance of the image from the objective, that is: \( b \frac{T}{d} = d \frac{b}{x} \) x. A similar proportion may be formed for the eye piece: \( c \frac{e}{d} = f \frac{A}{e} \). The magnifying power of the objective times the magnifying power of the ocular gives full magnifying power.

**PRACTICAL PROBLEMS.**

(1) In a prism the angle of incidence is \(30^\circ 41'\), the refracting angle is \(25^\circ 30'\). What is the total deviating angle?

(2) Find conjugate focus of a convex lens whose radius is seven inches and whose refractive index is 1.6. One focus being 3 feet from optic center.

(3) Find power of above lens.

(4) Find principal focus of a convex crown lens whose radius is 12 in.

Note.—Teacher should assign some twenty similar problems.

**MICROSCOPES.**

Microscopes, as before stated, are of two kinds, simple and compound. There are at present only a few important forms of the first. These we will now consider. Theoretically the spherical lens will give the highest amplifying power, but it was soon found that as amplification increased, spherical and chromatic aberration increased also; hence it became impracticable to use the highest powers. These effects of ab-
erration increase toward the periphery. In the Coddington lens which consists of a sphere of glass, this defect has been partially corrected by cutting a deep groove around the margin and filling it up with some opaque material to cut off the distorted marginal rays. This lens focuses very near the object. Fig. 12 represents a section of the Coddington lens.

The Stanhope magnifiers consist of a double convex or a plano-convex lens. It is so ground that the plane or least convex surface is just in focus for the object. Good results are obtained from this lens but it is less convenient than some other form as the object must be fastened to the surface. Both the Coddington and Stanhope magnifiers are in use yet, but are rapidly making way for more convenient forms.

Sir David Brewster was the real inventor of the Coddington lens. It received its present name from a Mr. Carey who constructed one for Mr. Coddington and supposed he was the inventor. Fig. 13 shows a Stanhope lens.

Wollaston and Frauenhofer made partially corrected doublets, that is two lenses in contact, one double convex of
crown, the other plano-concave of flint glass. John Browning constructed achromatic triblets which were very useful as they focused at three times the distance that the Coddington lenses did and hence made it easy to examine opaque objects. Steinheil, a German optician, made similarly constructed lenses which he termed "aplanatische loup en" (aplanatic lenses) having a magnifying power of 5.5 to 24 diameters. Figs. 14 and 15 show a doublet and a triplet.

COMPOUND MICROSCOPES.

Before attempting to do anything in microscopy the student should have a thorough understanding of the mechanical construction of the compound microscope. Under the guidance of an instructor he should be shown the various parts and their modes of operation. Skill in microscopy is only to be obtained by diligent study and patient practice. Before commencing any investigation the student should lay aside all preconceived ideas and rely principally on his own observations, for "things seen are not as things heard." It is not necessary that the beginner should have all the expensive accessories belonging to a microscope. They are sometimes convenient and save time, but one having mechanical skill and ingenuity can make contrivances for himself that will answer the purpose very well.

We will now consider the parts of the compound microscope and a few of the most important accessories. The first thing to be considered is the stand. The office of the stand is to hold the objectives and oculars in their respective positions.

Stands are built on two models, Jackson and Ross. In the Ross model the body is supported on a transverse arm, this is again supported on the summit of a racked stem which can be moved up and down by a wheel and pinion. The body itself is permanently fixed. In the Jackson model the body has the rack-work attached to it and is supported for a great-
er part of its length on a solid base. Very few stands are now made on the Ross model because it is less firm and durable than the Jackson. The Ross stand leaves nothing to be desired if well made. But taking it all in all the Jackson is the best stand for either cheap or costly instruments.

The base or foot is that portion of the stand upon which the other parts are supported. It should have three points of support, never more, because three points will always rest firmly no matter how uneven the surface may be. Some are of a triangular or horse shoe shape. The one having the three points of support is the best.

The second part of the stand is the pillar. It is fastened to the foot and has upon its summit the joint or axis. There may be one or two pillars. They should always be firm and strongly made.

The third part of the stand is the arm which is connected to the pillar by the axis and supports some of the principal parts of the instrument.

The fourth part of the stand is the body which is the tube portion working upon the arm by means of a rack and pinion. It holds the objective, ocular and draw tube. The tube is generally made of brass. Some are nickle plated and all are black on the inside so as to prevent the reflection of light. The standard length of the tube is six inches. The lower end of the tube contains an extra piece called a nose-piece into which the "Society Screw" is cut.

The "Society Screw" is so called because it was established by the Royal Microscopical society of London, They agreed that the threads on objectives should be cut of uniform size and the screws should have equal diameter. All objective makers who have adopted the resolutions of the London society can interchange their objectives and use them with any stand. Never purchase an instrument that has not the "society screw."
OBJECTIVES.—(L., ob, against, and jacere, to throw.)

Before explaining the construction of objectives and oculars we shall first consider chromatic and spherical aberration.

By chromatic aberration (Gr., chroma, color; and L., abberans, to deviate) we mean a separation of the prismatic colors due to their difference in refrangibility. To produce a distinct image all the colors must be together, hence we always have indistinctness accompanied with the separation of the colors. Different substances have different dispersive powers. This fact was discovered by Dolland, who thereby removed a great obstacle to the perfection of optical instruments.

Below we give the dispersive powers of a few substances much used in optics:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Refractive Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil of Cassia</td>
<td>0.139</td>
</tr>
<tr>
<td>Almond Oil</td>
<td>0.079</td>
</tr>
<tr>
<td>Flint Glass</td>
<td>0.052</td>
</tr>
<tr>
<td>Flint</td>
<td>0.052</td>
</tr>
<tr>
<td>Crown Glass</td>
<td>0.036</td>
</tr>
<tr>
<td>Diamond</td>
<td>0.038</td>
</tr>
<tr>
<td>Plate Glass</td>
<td>0.032</td>
</tr>
<tr>
<td>H₂ S O₄</td>
<td>0.031</td>
</tr>
<tr>
<td>C₂ H₆ O</td>
<td>0.029</td>
</tr>
<tr>
<td>Rock Crystal</td>
<td>0.026</td>
</tr>
<tr>
<td>Blue Saphire</td>
<td>0.026</td>
</tr>
<tr>
<td>Ca Fl₂</td>
<td>0.022</td>
</tr>
</tbody>
</table>

—Olmstead.

We will suppose that two prisms, one of crown and the other of flint be so ground that the refracting angle will separate the violet 5¹ from the red ray. In order to do this, the crown prism whose dispersive power is 0.036 must refract the ray 2°19¹, because \( \frac{5¹}{0.036} = 2°19¹ \). The flint prism whose dispersive power is 0.052 must refract the ray 1°36¹; because \( \frac{5¹}{0.052} = 1°36¹ \). Place these prisms together base to edge. Then the crown glass will refract the beam downward 2°19¹ and the flint glass will refract it upward 1°36¹. Now the dispersive powers of the two prisms acting in opposite directions and with the same force (5¹) will just neutralize each other. The colors are therefore united and still the beam is refracted downward (2°19¹) — (1°35¹) = 44¹.
It can readily be seen how the same effect can be produced by means of lenses. A convex lens of crown glass may produce a certain amount of dispersion; this may be neutralized by a concave lens of flint according to the explanation given above.

In practice it is found that when the violet and red rays are brought together, all intermediate points do not meet at exactly the same point, because the prismatic colors are not separated by like intervals. Opticians usually correct those rays which affect the eyesight most powerfully.

**SPHERICAL ABERRATION.**

Spherical aberration is due to the fact that the rays near the margin are more refracted than those toward the axis. The more nearly the lens approaches a sphere the greater will be the spherical aberration. In earlier times and at present in cheap lenses, this defect was corrected by means of a diaphragm which would cut off the distorted marginal rays. Now the correction is made by using lenses of an elipsoidal form or by using wider back lenses.

**Fig. 16.**

In fig. 16 a, represents the appearance of a ruled plate as seen through an aplanatic lens, that is one free from spherical aberration; b, represents the same plate as seen through a non-corrected convex lens, and c, as seen through a noncorrected concave lens.

The objective is that part of the microscope which forms
the real image and is screwed into the lower end of the *tube*. Objectives consist of a series of lenses ground to suitable curvatures depending upon the desired magnifying power and angular aperture. These lenses are held in place by the *mount*. Objectives are generally spoken of in terms of their amplification. The standard of comparison being the magnifying power of a single lens having the given focal length. For example, a one-fourth inch objective does not focus one-fourth inch from the object but has the same magnifying power that a single lens would have with a focal length of one-fourth inch. The one-fourth inch may focus much nearer than one-fourth of an inch, that depending upon the angular aperture. The wider the angle the nearer it will focus to the object. Objectives are spoken of as high and low powers. All below the one-fourth inch are called low powers, the fourth inch and above are called high powers.

By aperture we mean the opening made by the extreme marginal rays meeting at the focus. Much controversy existed in regard to aperture. Some claiming the high angles were best and others favored low angles. Nearly all opticians have come to the conclusion that it is always best to have the highest possible angle. Aperture is either given in degrees or its numerical value. Air angle may range from 10° to 175°. Some opticians have made lenses claiming to be "infinitely near 180°." This seems almost impossible as some allowance must be made for the thickness of the cover glass. The student will readily understand that the wider the angle the more rays will be utilized in forming the image, and hence better definition and truer image. It is also plain that high angles will focus very near the object and therefore allow but little working distance and room for vertical illumination. All objectives having a higher aperture than 175° must be used as immersion objectives, that is some transparent liquid must be placed between the object and objective having a higher refractive index than air as water, oil, or balsam. These liquids increase refraction and allow the objective to
focus farther from the object. The beginner should not get the high angle objectives as they require delicate manipulation and skill to do successful work.

Instead of giving a separate angular value for each of the various immersion fluids, a comparative numerical value is given in which the air angle is considered to be the standard. The numerical aperture is found by multiplying the sine (natural) of the semi-air angle by the refractive index of the immersion fluid used.

Objectives are either made of a double or trible system of lenses. Low powers and angles may be made of a single system. Most triblets have a single front lens, a double middle and a trible back lens. "Wenham's Formula" is a trible combination having a flint concave of a trible middle to correct the aberration of the single anterior and posterior crown lenses.

There are also separable and adjustable objectives in the market. The student is advised not to buy or use them.

**EYEPIECES OR OCULARS, (L., oculus, eye.)**

The eye piece slides into the upper end of the draw tube and forms the virtual image. There are three kinds of oculars in use, the Huyghenian, solid and orthoscopic. The most common variety is the Huyghenian so named after its inventor who first used it with his telescope. It consists of a small upper lens called the eye lens and a larger lower lens called the field lens and diaphragm between, not midway, but nearer the field lens in the ratio of 1: 3. They are sometimes called negative eye pieces because the convexity is turned from the eye. High powers are termed "deep" and low powers "shallow," these terms refer to the curvature of the lenses. Solid eye pieces were the invention of Mr. Tolles. They are called solid because they consist of one solid piece of glass on the ends of which the proper curvatures are ground. A groove is cut into the glass at a proper distance
between the two ends and filled up with some opaque substance to answer for a diaphragm. They are used principally with high powers. The orthoscopic ocular consists of a trible eye lens and a single field lens with no diaphragm. It is well adapted for micrometer work.

Eye pieces are not made of the same size, hence the oculars of different makers can not be used with other microscopes.

Oculars are generally named A, B, C, D etc., but the D of one maker will not have the same amplification as the D of another maker. American manufacturers name theirs like the objectives, two inches, one inch, one-half inch, etc., according to their magnifying power.

In selecting good objectives the following qualities are to be considered:

(1) Working distance.
(2) Definition.
(3) Freedom from distortion.
(4) Penetrating power.
(5) Resolving power.

Working distance.—By working distance is meant the distance between the object and lens when in focus. It depends upon the aperture and magnifying power. Great working distance is valuable for dissecting purposes and the examination of opaque objects. But when an object has been prepared and mounted for transmitted light there is no need for more working distance than will admit of the use of the cover glass.

Definition.—This is the most important property of objectives and should always be taken into consideration. It depends on the absence of both forms of aberration. An objective that is achromatic and aplanatic will have perfect definition. The image by such an objective will appear distinct to the very edge. There should be no discolorization or
distortion. Be sure to test an objective for definition before buying.

Freedom from distortion.—This depends on the correction for spherical aberration. Those whose field of vision should be well defined under one focusing, margin as well as center. As a test object the "Nobert band plate" is very much used. It consists of a plate of glass with lines ruled upon it ranging from 1,000 to 112,000 to the inch. The lines should appear parallel and straight.

Penetrating power.—It is that property by virtue of which several planes of an object may be seen at one focusing. It depends on two things, accommodation depth of the eye and depth of focus. These depend on the aperture and amplification. The higher the power and aperture the less penetration. For some reason the accommodating depth of the eye does not decrease as rapidly as the depth of focus.

Great penetration is useful in examination of opaque objects and in the examination of transparent objects that can not be cut thin.

Resolving power.—This is another very important property and depends always wholly upon large aperture combined of course with correction for sphericity and chromatism. As a test the "Nobert test plates" are used having lines ruled on them ranging from 10,000 to 200,000 to the inch. Mr. Møller has made what he calls a "test platte" (test plate) upon which he has mounted twenty diatoms having striations ranging from 3,000 to 92,000 to the inch. The better the resolving power the more of these lines can be seen to every linear inch.

The draw tube is supplied with most monocular microscopes. The draw tube slides into the tube, at the upper end is a milled collar which acts as a stop. The eyepiece is fitted into the upper end and by this means the draw tube becomes an aid in increasing the magnifying power. Some of these
tubes are plain and others are divided into inches and parts so that results may be noted.

*Coarse adjustment* is a contrivance for moving the body back and forth quickly. It is done by means of a rack and pinion, and sometimes by merely sliding the tube in an outer sheath. The rack and pinion is far more preferable.

The *fine adjustment* is used after an approximate focus has been obtained by the coarse adjustment. It is attained by a fine thread acting upon the body directly or by means of levers.

Both adjustments should be very sensitive. They should have true fittings and gearings, anything to the contrary gives evidence of poor workmanship.

The *stage* is that part upon which the object is placed for examination. It is attached to the arm and may be either fixed or revolving on an axis. The stage should be made very hard and smooth. Glass stages are the best.

The *mirror* is placed below the stage on the sliding and swinging mirror bar so that it may be turned in any direction. Mirrors are generally either plane or concave. Most all mirrors have two surfaces one plane the other curved. Experience and a knowledge of optics will give the best information as to their proper use.

The *diaphragm* is a contrivance with which to regulate the admission of light. They are of two kinds — wheel and iris diaphragms. The wheel diaphragm consists of a disk with holes of different sizes. The iris diaphragm consists of a number of movable shutters. These are made to open and close, similar to the human iris, by means of a thumb screw. Diaphragms are either attached to the stage or sub-stage. The proper position for the opening is as near the slide as possible.

The *sub-stage* is a ring below the stage to receive various
accessories. It is generally provided with an adjustment to regulate its distance from the object.

The bull's eye condensor is a double or plano-convex lens mounted on a stand for the purpose of concentrating light upon an opaque object. Its use and manipulation depends upon its construction.

The sub-stage condensor is attached to the sub-stage. It consists of a combination of lenses and is corrected for both forms of aberration. It can only be used with satisfaction by advanced students.

Double and triple nose pieces are useful when it is desired to quickly change objectives. They may be made to hold objectives of different powers which can be swung in and out of focus whenever desirable. Those holding three, four or more objectives are generally too clumsy.

Microscope Tables.—When two or more microscopists are at work at the same time it is convenient to have a revolving table as it saves a great deal of rising to change places in observing. The table should have three supports and should be well made. One that creaks and is loose at every joint is worse than useless. The larger the table the more can conveniently work at the same time.

Microscope Lamps.—The best time to work is day time, using the light from a white cloud on a sunny day. Never use direct sunlight; it is too bright. When it becomes necessary to use artificial light an ordinary student lamp can be used. To protect the eyes all superfluous light may be cut off by a shade. To get the most intense light turn the edge toward the object, but if quantity of light is required rather than intensity the flat side may be used. The student should be careful not to use too much light as it sooner or later ruins the eye sight. Lamp light gives a very objectionable yellow
tint to objects; this may be corrected by colored glass. Blue glass very effectively corrects this defect. The blue glass used by chemists does very well.

Camera Lucida, (L., camera, an arched roof; and lucida, bright.)—The student should always delineate objects under examination. The image is thereby more firmly fixed in his mind, besides it teaches him to observe more closely. He will be surprised to find that he observes things which he would not have noticed otherwise. The camera lucida and neutral tint reflector are contrivances used with the microscope in drawing images of objects under examination. The student of average ability can construct the neutral tint reflector for himself. Take an ordinary cover glass, incline it 45° to the eye lens of the ocular, so that the center of cover glass and center of eye piece will coincide, fasten it in its place by some contrivance. Now incline the tube of the microscope till it is at right angles to the pillar. The cover glass will refract the image at right angles. The eye looking down through the center of the cover glass will see the image projected on a paper placed below on the table. The position of the light and mirror must be changed to produce the proper illumination. Be careful not to have too much light where you are going to draw. A prime object in drawing is to produce exact representations. The student should use paper ruled into squares. Place a cover glass ruled in squares on the diaphragm of the ocular; this projects the image of the squares with the image of the object. By this means very exact work can be done. Amplifications and reductions can be made at will. Cut off most of the light from the paper on which the image is projected, so that it will appear in clearer outlines. Get a good, sharp lead pencil and trace the outline of the image on the ruled paper. It is well to use a tinted cover glass, as it gives a better defined image. The student will be surprised to find what he can accomplish by this simple means.

The camera lucida consists of a prism, and is used in the same manner as the tint reflector.
**MICROSCOPY.**

*Micrometer,* (Gr., *mikros*, small; and *metron*, measure). This is a contrivance for measuring all microscopical objects. In the present age of progress the metric system is coming more and more into use; hence it is best to get those micrometers ruled according to that system. They are generally ruled to millimeters, tenths and hundredths. Our best scientific works give all measurements in that system. The stage micrometer is placed on the stage of the microscope, just below the object slide. It can only be used directly with low powers, as the object and micrometer must be in focus at the same time. With high powers another method may be employed. Make a drawing of the object by means of the camera lucida. Now replace the object by the micrometer, and draw its markings over the previous sketch. Simple inspection will show the magnitude of the object.

Eye-piece micrometers slide into the ocular just over the diaphragm. These micrometers must be corrected for different powers. The actual experience, directed by a teacher, is best here.

Numerous other accessories could be mentioned, but the beginner is advised to purchase only those that are absolutely necessary, as they are generally very costly and are too much of a strain on the purse. The beginner will also soon find, to his sorrow, that he can not use them. Never buy anything because it is cheap; rather because it is good. The person who buys a microscope, or anything else, because it is cheap is the loser in every case. Some advice on the purchase of a microscope might be in order:

1. Make up your mind as to what you want before you make up your mind to buy.
2. Select a good, strong, Jackson stand in which all the gearings work smoothly. It should always admit of the use of the more important accessories.
3. Select good objectives, and test them before buying. This is of special importance.
MICROSCOPY.

4. Select good oculars and test them.
5. Deal only with reliable firms.
6. Take good care of your instrument. Do not let every one handle it, especially those who know nothing about microscopy.

A little advice on keeping a microscope might be in order:

When through using the microscope separate the various parts as much as is necessary, and wipe them perfectly clean and dry with a silk handkerchief or a piece of chamois skin. Rub up and down, lengthwise, with a light, brisk movement. When through wiping no finger marks should be seen anywhere. Place the various parts in their proper places in the microscope case. Do not throw half finished mounts, slides, cover glasses, botanical specimens, etc., helter skelter into the case. The microscope case was made for the microscope only. After being certain that everything is in its proper place, lock the case and put the key in your pocket or some other place where you know it can be found when wanted. Keep the microscope, or any other scientific instrument, in a dry place, away from chemicals.
CHAPTER II.

BIOLOGY.

Biology, (Gr. bios, life; and logos, discourse.) or natural history, is the science which treats of the organic world in its various forms and relations. It includes the entire fields of zoology and botany. The two are inseparably connected. Scientists have so far been unable to draw the dividing line.

In all scientific investigations a systematic classification and arrangement is necessary, not so much for the original researcher, but that it can be properly presented and understood by those who follow in the field of investigation. Biology, as the word signifies, is a life discourse, and treats of the composition and corelation of organic bodies; it is, therefore, distinct from mineralogy, which treats of minerals, or inorganic substances. For convenience sake biology is divided into zoology and botany.

Zoology is the science which treats of animated nature. It can first be divided into structural zoology, which treats of the organization of animals. Structural zoology is divided into anatomy, which treats of the constitution and formation of animal bodies; and physiology, which treats of the functions of the organs of organized bodies in a healthy state. Pathology treats of functions in an abnormal state. Anatomy separates first into descriptive anatomy and histology. This divides again into skeletology, which comprises osteology and syndesmology; and sarcology, which comprises myology, neurology, angiology, adenology, splanchnology, and dermatology. Secondly, anatomy separates into embryology, which is the doctrine of embryonic development; and, thirdly, morphology, which treats of the anatomical conformation of
parts. Homological anatomy treats of the relation of different parts in the same individual. Comparative anatomy treats of the relation of like parts in different individuals. Philosophical anatomy treats of or inquires into the mode or model upon which the animal body is formed. Morbid anatomy treats of organic structure in a diseased state. Historical zoology treats of the successive appearance and disappearance of animals in the various ages. It is divided into geological zoology, which treats of animals now extinct, and recent zoology, which treats of animals now living. Theoretical zoology attempts to explain the possible origin of life and species. Space will not permit the giving of a complete outline of biology.

The actions of living matter are called its functions. These functions, though very numerous, may be resolved into three kinds—(1) functions which effect the material composition of the body, and determine its mass, which is the balance of the process of waste on the one hand, and assimilation on the other; (2) the functions that subserve the process of regeneration, which is nothing more nor less than a detachment of a part having the power to develop into an independent whole; (3) functions by virtue of which one organ has the power to exert an influence upon other organs in the same body, and thus become a mode of molar motion. The first may be termed sustentive, the second generative, and the third correlative functions. The most complex body is merely an aggregate of cells.

Among the more simple forms of animal life known to biologists is the amœba, closely resembling a white blood corpuscle, and consisting almost wholly of an undifferentiated mass of protoplasm. Generally there are present one or more nuclei, although these may be absent. This simple organic structure possesses all the most important fundamental vital properties found in the most complex body known. (1) It is contractile. It can produce within itself a change in form and position by what is so well
known as the "amoeboid movement. (2) It is irritable, or automatic. When it comes in contact with a foreign body motion is the result. This is not passive but active motion. In fact, the amöeba is rarely at rest. (3) It is receptive and assimilative. It has the power to take up and assimilate portions of certain substances for food. (4) It is metabolic and secretory. That is, the protoplasm undergoes a continual change. The protoplasm now existing breaks up and is removed, while a new protoplasm is formed from the food taken up. (5) It is respiratory. It takes in oxygen, which is required in the oxidation of food, and gives out carbon dioxide, which is the result of oxidation. (6) It is reproductive. The individual amöeba represents a unit; after a time this unit divides into two separate units capable of again subdividing.

Many eminent biologists have attempted to explain the possible origin of life and species. Some theories have been advanced, but none of them have yet been able to stand alone. They fall to the ground as soon as their promulgators cease to support them. We might say that life is a series of changes, both in structure and composition, wrought by some intangible, incomprehensible force, such changes always taking place without destroying the identity of the individual. The most plausible theory, or rather, hypothesis, in regard to the origin and development of species is that of evolution, brought to its present perfection by Charles Darwin. He defines it as a changing from the homogeneous to the heterogeneous, from the general to the special, from the simple to the complex. It is, essentially, a process of differentiation, a method of progress from generalized types to those more special and complex—a changing from a lower to a higher individuality.

This hypothesis is by no means recent. It existed among the ancient philosophers. An old cosmological myth was that, at first, there existed a chaotic mass or mundane egg, from which all things successively emerged.
Thales taught that in the beginning every thing was in a fluid state, from which some great, self-existing force formed all things. Anaxagaros taught that, at first, all consisted of atoms, infinitely numerous and eternal, among which order and arrangement was produced by a self-existing, intelligent power or god. This was opposed by Democritus and Epicurus, who taught that chance, and not God, wrought, in infinite time, out of numberless atoms, all existing things.

No student in biology can afford to jump at conclusions. He must lay aside all preconceived ideas and notions, must allow nothing to come in the way of sound judgment. Foremost among all the foundation upon which evidential knowledge is to be placed, must stand every test brought to bear against it; for, if the foundation is rotten, the superstructure will fall to the ground, no matter how well it may be planned.

Not until the perfection of the compound microscope was it possible to make any real progress in biology. By means of it we have discovered the ultimate constituents of organized bodies, the cells, and have been enabled to study the lower forms of the organic world, such as the algae and bacteria. In comparatively recent time eminent biologists believed that cells and minute organisms could originate de novo; but it has been conclusively shown that every living cell sprang from a pre-existing cell. Of course, leaving out of consideration the question as to where the original cell or ovum came from.

The animal and vegetable world is composed principally of four elements: oxygen, hydrogen, nitrogen and carbon. The first three are gases; the last, carbon, is a solid. Carbon has the property of interchanging its combining power, which accounts for the many carbon compounds found in nature. The predominance of gaseous elements in the organic world is supposed to account for its high degree of molecular mobility, and, according to Herbert Spencer, "that comparative
readiness displayed by organic matter to undergo those changes in the arrangement of parts which we call development, and those transformations of motion which we call functions." The primary form into which the four elements enter is the semi-fluid substance called protoplasm, which is almost the sole constituent of the lower forms of animal life. Combined in different forms, these elements enter into all the compounds found in the animal and vegetable world.

In the entire organic world nothing is at rest. There is a continual change and interchange of cells and cell substance; this change always tends toward a higher individuality. The time will come when the present genera and species will make way for higher organizations, as much higher than we are as we are higher than those who lived before the great glacial epoch. We can only affirm that in judging the future by the past. We have noted the steady progress of development, and we have no cause to think that we are now at the acme of all progressive development.

As has been stated, the biologist has so far been unable to draw the dividing line between the animal and vegetable kingdoms. It is very probable that the lowest forms of animal and vegetable life existed together. No doubt, the highest developed plant, as well as man, sprang from the same primordial mass of protoplasm. Beginning with Haeckel's moners, the two great kingdoms begin to separate, each in its line, rising to a higher degree of development. These two kingdoms developed because one was the supporter of the other. What one discards the other uses. No third or fourth organic kingdom developed, because it was not needed. In the future nature may be in demand of entirely different organisms than we now find.

The beginner is advised not to study unknown forms of life till he understands those which have been described.
Below is given an outlined differentiation between the lower typical forms of vegetable and animal life:

### UNICELULAR PLANTS AND ANIMALS.

#### ANIMALS.

1. **Composition.**
   - 1. Protoplasm.

2. **Parts.**
   - 1. Cell Wall.
     - 1. Albumen.
   - 2. Cell Contents.
     - 1. Nitrogenous Substances.

3. **Assimilation.**
   - 1. Endosmosis.
   - 3. Albumen.

4. **Exosmosis.**
   - 1. Carbon Dioxide.

5. **Reproduction.**
   - 1. Division.
   - 2. Budding.

6. **Form.**
   - 1. Irregular.

7. **Size.**
   - 1. Microscopical.

8. **Motion.**
   - 1. Generally in motion.

In the animal kingdom, the paramecium may be taken as a typical example for examination, and in vegetable kingdom some of the numerous forms of desmidia.

#### PLANTS.

1. **Composition.**
   - 1. Protoplasm.

2. **Parts.**
   - 1. Cell Wall.

3. **Assimilation.**
   - 1. Endosmosis.
   - 3. Albumen.

4. **Exosmosis.**
   - 1. Oxygen.

5. **Reproduction.**
   - 1. Division.
   - 2. Spore Formation.

6. **Form.**
   - 1. Spherical.
   - 2. Oval.

7. **Size.**
   - 1. Microscopical.

8. **Motion.**
   - 1. Generally motionless.
BIOLOGY.

Before entering upon any kind of work see that you are prepared and supplied with the necessary material for a beginner in biology. Some of the reagents can be omitted till they are absolutely necessary.

MATERIAL FOR A BEGINNER.

1\(^{st}\) Microscopes.
1\(^{st}\) Compound Microscope.
1\(^{st}\) Accessory.
1\(^{st}\) Objectives.
1\(^{st}\) One inch.
1\(^{st}\) One-fourth inch.
1\(^{st}\) Oculars.
1\(^{st}\) A or one inch.
1\(^{st}\) B or \(\frac{1}{4}\) inch.
3\(^{rd}\) Bull's eye condensor.
4\(^{th}\) Neutral tint reflector.
5\(^{th}\) Camera Lucida.
6\(^{th}\) Micrometers.
6\(^{th}\) Stage.
2\(^{nd}\) Dissecting Microscope.
3\(^{rd}\) Simple Microscope.
1\(^{st}\) Coddington Lens.
2\(^{nd}\) Stanhope Magnifiers.
2\(^{nd}\) Doublets.
2\(^{nd}\) Triblets.
3\(^{rd}\) Achromatic.
2\(^{nd}\) Dissecting case.
1\(^{st}\) Dissecting knives.
2\(^{nd}\) Scissors.
3\(^{rd}\) Forceps.
2\(^{nd}\) Straight.
2\(^{nd}\) Curved.
4\(^{th}\) Blow pipe.
5\(^{th}\) Camel's hair pencil.
6\(^{th}\) Dissecting needles.
3\(^{rd}\) Microtome.
4\(^{th}\) Turn table.
5\(^{th}\) Slide Centerer.
6\(^{th}\) Pipette.
7\(^{th}\) Alcohol lamp.
8\(^{th}\) Glass slides.
1\(^{st}\) Smooth edge.
2\(^{nd}\) Rough edge.
9\(^{th}\) Cover glasses.
1\(^{st}\) Various sizes.
10\(^{th}\) Labels.
11\(^{th}\) Slide boxes.
12\(^{th}\) Pencil drawing outfit.
13\(^{th}\) Reagents. (See recipes.)
1\(^{st}\) Hardening agents.
1\(^{st}\) Alcohol. [solution.
2\(^{nd}\) Bichloride of mercury.
3\(^{rd}\) Tannin solution.
4\(^{th}\) Chromic acid. [sium.
5\(^{th}\) Bichromate of potas-
6\(^{th}\) Osmic acid.
2\(^{nd}\) Softening agents.
1\(^{st}\) Acetic acid.
2\(^{nd}\) Glycerine.
3\(^{rd}\) Potash.
4\(^{th}\) Soda.
5\(^{th}\) Ammonia.
6\(^{th}\) Caustic soda.
7\(^{th}\) Nitric acid.
3\(^{rd}\) Dehydrating agents.
1\(^{st}\) Phosphoric acid.
2\(^{nd}\) Potassium carbonate.
3\(^{rd}\) Calcium Chloride.
4\(^{th}\) Heat.
4\(^{th}\) Bleaching agents.
1\(^{st}\) Chlorinated soda.
2\(^{nd}\) Chloride of lime.
3\(^{rd}\) Chlorate of potassium.
4\(^{th}\) Bichromate of potas-
5\(^{th}\) Nitric acid. [sium.
Before one can do satisfactory work with the various reagents their actions upon different tissues must be understood.

Among the hardening agents alcohol is the best and most used. It absorbs moisture very readily without destroying the fresh appearance of the tissue. It must be remembered that it dissolves gums and resins used in microscopical work. Bichloride of mercury is a very efficient preparatory hardening agent. It is supposed to act by forming insoluble albuminoid compounds. It must be borne in mind that it is a powerful poison. Tannin is used for gelatinous substances. It is used to inject blood vessels to prevent the passage of coloring matter through them. Weak solution of chromic acid combined with the bichromate of potassium is a good hardening agent for nervous tissues. Osmic acid in 1 per cent. solution is much used for protoplasmic substances. It is very poisonous.

Softening Agents.—Acetic acid diluted with about four times its amount of water is much used. It renders tissues quite transparent. It dissolves phosphate and carbonate of lime. It can be combined with glycerine as a preservative fluid. Glycerine is probably most used. It prevents the dry-
ing up of tissues. The alkalies all have a similar action upon most tissues. They are much used with vegetable tissues. Nitric acid is sometimes used as a softening agent. It must be borne in mind that it combines with metals of which the instruments, etc., are made.

Dehydrating Agents.—These might have been given with the hardening agents as water absorbers are also hardening agents. Among the most important are anhydrous, phosphoric acid, and concentrated sulphuric acid. The tissues are not placed in contact with them but in a separate place under a bell jar or some other air tight vessel. Potassium carbonate and calcium chloride are used in a similar manner. Dry heat is much used for different purposes, such as drying specimens for mounting and driving air bubbles from under cover glasses.

Bleaching Agents.—Chlorinated soda and chloride of lime are much used in bleaching vegetable tissues, also chlorine. How to generate chlorine will be explained in another chapter. Always eliminate all traces of these reagents after the tissue is sufficiently bleached. This may be done by means of a solution of sulphite of soda, 15 grains to the ounce of water. Turpentine is used to remove the intensity of color from insect skeleton. Turpentine dissolves many of the varnishes and finishing agents used in mounting.

Solvents.—The strongest solvents are the acids. A knowledge of chemistry will indicate when and where to use them.

The alkalies will dissolve oils and fat, forming a soap. Alcohol dissolves resinous substances. Benzol and benzine dissolve iodine, fat, gum, resins, rubber, etc. Turpentine, ether and chloroform are good solvents for fats and most resins. Water is the best universal solvent. Plenty of it should be used. The object of solvents is to remove foreign matter. Cleanliness is very desirable in microscopical work.
Staining Fluids.—Carmine is best adapted for animal tissue while logwood is best for vegetable tissue. It is best to buy the fluids ready prepared. All dealers in microscopical instruments keep them. There are many other staining fluids, but those two mentioned are the only ones necessary for the beginner.

Mounting Mediums.—Pure Canada balsam is the best and most used. Dammar and mastic are also much used. Care is necessary in using glycerine. Water is only used for temporary mounts.

Finishing Agents.—Oxide of zinc is used to protect the edges of the cover glass.

Carmine, ultramarine, lamp black, virdigris, etc., are used with some vehicle in making colored rings. (See receipes.)

STARCH. \((C_6\ H_{10}\ O_5)\)

The examination of starches and pollen is introduced here because they are easily obtained and will enable the beginner to become somewhat accustomed to the manipulation of the microscope, at the same time affording useful information.

Starch is one of the most important carbohydrates. It is very abundantly diffused throughout the vegetable kingdom. There is no plant in which it cannot be found during some stage of its existence. When purified it is a white, glistening powder which gives rise to a crackling sensation when rubbed between the fingers. It consists of firm, minute granules, varying in size and shape. Each granule consists of a series of layers deposited upon each other causing the appearance of concentric markings. These markings are arranged around a point which is generally eccentric in position called the hilum. The appearance of the concentric rings are due to the fact that the various layers are
alternately harder and softer in comparison with each other which produces a difference in refractive power and hence the striations.

Make temporary mounts and examine first with low power and then with the $\frac{1}{4}$-inch objective.

**Starches.—Laboratory Work.**

1\(^1\) Potato starch.
   1\(^2\) Hilum.
   2\(^2\) Concentric rings.
   3\(^2\) Shape.
      1\(^3\) Irregular pear shaped.
   4\(^2\) Size.
      1\(^3\) From 2.5 to 62.5 m. m. m. in diameter.
      2\(^3\) Comparative size.
   5\(^2\) Admit a drop of solution of iodine under cover glass.
      1\(^3\) Note result and explain.

2\(^1\) Wheat starch.
   1\(^2\) Hilum.
      1\(^3\) Round or transverse.
   2\(^2\) Concentric rings not distinct.
   3\(^2\) Shape.
      1\(^3\) Disc like, flattened.
   4\(^2\) Size.
      1\(^3\) 2.5 to 35. m. m. m. in diameter.
      2\(^3\) Comparative size.
   5\(^2\) Admit a drop of solution of iodine.
      1\(^3\) Note result.

3\(^1\) Oat starch. (See 1\(^1\) and 2\(^1\)).

4\(^1\) Corn Starch. (See 1\(^1\) and 2\(^1\)).

(a) Boil some starch with diluted sulphuric acid ($H_2S_O_4$). This process will convert it into a substance having the same chemical composition as starch but turns the plane of polarization to the right, hence it is called dextrine. (L., *dextra*, right, to the right.) By continuing the boiling dextrine is converted into sugar.
(b) Carefully heat some starch in about 120 parts of water. The cellulose, which is insoluble, will settle to the bottom as a turbid deposit while the granulose form a perfectly clear solution.

(c) Iodine test for starch.

(1) Heat some starch solution, add solution of iodine, no visible actions takes place. Allow it to cool and note results.

(2) Iodine must be in a free state. Solutions of iodine salts will not do.

(3) The presence of a third organic substance will generally interfere with the test.

POLLEN.—(L., *pollen*, a fine flour.)

Pollen is that part of the flower which develops the germinating power of the ovule.

The student is supposed to be sufficiently acquainted with botany to understand the growth and development of plants. The stamens are simply modified leaves. The filament represents the stem of the leaf, while the anther represents the blade or leaf proper. The epidermis of the anthers is very much like that of the leaves only that it contains no stomata and generally no chlorophyll. The anthers or spore cases have a homogeneous parenchyma whose cells are closely crowded. After a time new cells develop within the case and rapidly multiply. These form the pollen. The sun's heat causes the pollen case to break open when the pollen escapes as a very fine powder and falls upon the stigma.

We shall now describe a pollen grain more closely. It is simply a cell consisting of a cell wall and cell contents. The external cell wall or extine is what gives the pollen its form and color. All the many beautiful markings of the pollen which are always constant in the same species, are due to the extine. Hence from the examination of the pollen
we may name the flower to which it belongs. The extine is formed out of a secretion from the internal coat or intine which directly envelops the viscid, protoplasmic, fertilizing fluid.

The manner in which the pollen reaches the ovule is very interesting. It is well known that the stigma is continually covered with moisture. When the anther bursts open the comparatively dry pollen grain falls upon the stigma and is retained there by the thin viscid fluid. Osmosis takes place; the more thin fluid of the stigma passes into the pollen and also causes the hard, brittle extine to burst open at the surface which is in contact with the stigma. This allows the extensible intine to protrude. Osmotic action continues between the pollen and those cells of the stigma which are in immediate proximity. On account of the greater viscidity of the pollen fluid it gains more by endosmosis than it loses by exosmosis. This causes the stigma cells to shrink and create a space for the passage of the extended pollen membrane which we will now call the pollen tube. The reason that the intine does not simply expand on the surface of the stigma is because of the weight and resistance offered by the hard extine, and some directive influence not mentioned.

The intine continues to grow and extend downward by the above described process till it reaches the ovule. It is yet a question of doubt whether the pollen tube enters the ovule or whether it simply comes in contact with it and the fertilizing fluid passes into the ovule by osmotic action.

Pollen.—Laboratory Work.

Select the pollen of some species of flower. That of the hedge bind weed is a good example to start with on account of its size and simple form.

Place some pollen dust on a clean slide and cover with cover glass. Examine first with low power then with the \(\frac{1}{4}\)-inch obj. and B ocular.
BIOLOGY.

1st Form. Note carefully.
2nd Size. Measure carefully.
3rd Parts.

1st Extine.

1st Markings. Note carefully. Make drawings on good paper and keep for future reference and comparison.

2nd Color.

2nd Intine. Press slightly on cover glass. This will rupture the extine and allow the intine to protrude. Note its extensibility and comparative toughness.

3rd Fertilizing fluid.

1st Composition.

1st Fat. Smash some pollen on a piece of paper. It will leave grease spots.

2nd Starch. Admit some solution of iodine under cover glass and note results.

Carefully examine twenty species of pollen in your vicinity before proceeding to the next.

FERMENTATION.—(L., ferveo, I boil.)

Fermentation is a species of metabolic change in organic substances developed and maintained by the life action of low forms of micro-organisms called the germs of fermentation, each fermentation caused by its peculiar germs. In fact, in noticing the similarity between fermentation and infectious diseases it was believed that the latter also are forms of fermentation. Henle, in 1840, expressed the belief that living organisms, probably of vegetable origin, were the cause of acute specific diseases. Bassi and Audouin, in 1838, had discovered the fungous nature of the muscardine disease in silk worms. In 1836, Schwan found that fermentation was caused by living cells apparently of vegetable origin. These investigations and discoveries led to two theories as to the cause of fermentation—1st, the germ theory, and 2nd, the physical theory. The germ theory, which is now accepted by the ma-
jority of the scientific world, was first introduced by Astier, Schwan and Cagniard, and brought to its perfection by Pasteur. It gives for the cause of all fermentations a microscopic germ. Alcoholic fermentation is taken as the typical example. It is caused by the *sacharomyces* or *torula cerevisiae*, a living organism which is always found where alcoholic fermentation takes place. These organisms are unicellular, multiplying by division. They require for their food sugar and nitrogen. The chief products of their life action are alcohol and carbon dioxide. The germ theory, during its infancy had powerful opponents. The principal ones were the believers in the physical theory and the advocates of spontaneous generation. The physical theory, started by Willis and perfected by Baron Liebig, teaches that fermentation is due to peculiar molecular action, that is the molecules underwent motor decay. This molecular motion was capable of being transmitted to other unstable organic compounds. This action was called "catalysis" or "catalytic" action. (Gr., *kata*, downwards; and *lyo*, I dissolve.) The physical theorist could not explain why the first molecule underwent motor decay any more than the germ theorist could explain the origin of the original organism or germ. Hence it is seen that Liebig and his followers accounted for fermentation without the intervention of bacteria. They acknowledged the presence of germs, but explained their presence by saying they were the result and not the cause of fermentation. Spontaneous generation was strongly advocated by the physical theorists. Bastian affirmed that organic substances, having undergone molecular decay, will cause the origin *de novo* of certain fungi. The germ is present because the change wrought in the substance has made it the proper food for the germs to feed upon. A very simple experiment will show the fallacy of spontaneous generation. Take two flasks, both filled with organic substances capable of undergoing fermentation. Sterilize both by boiling so that there is a certainty that no living germs or spores are present, and hermetically seal one flask by means of the blowpipe. Let the other re-
main open. After a time the open flask will contain numerous living organisms while the sealed flask will show no signs of life.

Both theories have good arguments pro and con, but the germ theory has by far the greater claims for being the true theory. (1) Under no circumstances will fermentation take place without the presence of germs. (2) A given species of germ will always produce a certain kind of fermentation. (3) Introducing germs into a sterile substance will at once develop the process of fermentation. (4) Culture fluids have been made in which it could be demonstrated that none but a given species of germs were present. Such a culture fluid always caused its peculiar kind of fermentation.

LIFE.—(A.-S., *lif.*)

The great problem of life is as difficult of comprehension as it is important. What is life? There is no definition that is unassailable. The truth of this no one more fully realizes than the scientist. Our knowledge of life is too meager and the data from which to form conclusions are too few to give us a real conception of the relations of living substance to its surroundings. The definition given in the introduction to Biology is by no means perfect, nor is the one I am about to give. We might say that life is that relation of force to matter which produces a substance capable of a cyclical change. By this cyclical change is meant birth, growth, reproduction and death. These changes we observe in all living substances. The conception of the first change is almost axiomatic. We can not conceive of a living substance without its being brought into existence. The idea of growth is closely related. Birth itself implies growth. The consideration of reproduction and death is more puzzling. It might be asked why does a living substance after a certain stage of development reproduce its kind and then die? Why does not the original living sub-
stance continue to exist without reproducing? It would essentially bring about the same final results. In all living cells we notice certain senile changes which finally render them incapable of performing their necessary function and death is the result. Why these changes take place is not known. It can be readily understood that death necessitates reproduction, else the race could not exist.

We notice certain conditions necessary to life. They are moisture, temperature, light and air. In all living matter we find a large amount of water in its composition. That this degree of moisture is considerable can be seen for example in the amoeba and human body. Absolutely dry matter is incapable of living or of producing life. It is easy enough to understand why this should be. Living bodies must be more or less pliable that they may imbibe and assimilate food, that they may grow internally and that they may move about in search of food. (The extension of roots into the soil and of trunk and leaves into the air, and other movements may be considered as metabolic movements in plants.) Water being a very mobile substance will partially impart its mobility to those bodies containing it. Water does not go into chemical union with living bodies. It enters, exists in and leaves the body as water. Many of the lower organisms, as the fungi, may be reduced to a state of considerable dryness before life is destroyed. In this state they show no signs of kinetic life and are to all appearances dead, but as soon as they are brought into contact with moisture and a certain degree of warmth they show signs of life. The actual amount of moisture required to maintain life varies in different organisms. The range of limit is quite narrow, for example, in man and quite broad in fungi.

Temperature is closely associated with life. All vital phenomena of assimilation, movement, reproduction, etc., are manifest within a certain range of temperature. As temperature passes the limit of this range life ceases. The limit varies greatly with different organisms and with the
amount of moisture present. Generally it is found that a greater degree of heat and cold can be borne when in a comparatively dry state. Fungi have been exposed to a dry heat of 120° to 140° C without being killed while none are supposed to survive a temperature of 100° C when in a moist condition. No satisfactory experiments have been made upon higher animals. Here the conditions of life are so complex that it is very difficult to come to any definite conclusions. In regard to cold it has been found that the temperature of torula could be reduced to —60° or —75° C in a dry state before life action ceased; while in a moist state —5° C was sufficient to kill them. It is known that some of the protozoons flourish in the snow and ice fields of the arctic regions and in high latitudes of the temperate zones. We also find diatoms in the arctic and antarctic seas. As a rule the maximum temperature which organism can bear is much less variable than the minimum.

Light being so closely related to heat makes it at once easy to comprehend that it must be necessary to life. Though we find living organisms growing in absolute darkness, for example fungi, plants in dark cellars and some cave animals, though we find that light retards the growth of plants, yet they required light originally to bring them into existence. All living substances receive the influence of sunlight more or less, either directly or indirectly. It is known that light penetrates to some depth in soil and to a much greater depth in water. Most organisms living to some depth under the soil and water come to the surface more or less and are exposed to the sunlight.

Spectrum analysis has shown us that light has caloric and actinic properties besides its well known luminous property. The most important chemical action that light exerts is in the growth of plants. The various organic compounds in the vegetable world owe their origin to the sunlight acting as a reducing agent. Chlorophyll and starch production cease almost wholly in its absence. Starch is supposed to be
produced by the action of sunlight and chlorophyll; others again claim that starch is formed by small bodies called leucoblasts. The best authorities seem to agree that starch originates in chlorophyll and other coloring substances, but mainly from these colorless starch generators called leucoblasts. These are small and often hard to find. *Iris Germanica* affords a good example in which to search for and study them.

Air is necessary to life because it consists of and holds in suspension those substances required to sustain life action. Free oxygen is taken up by all animals. Plants take up C₂O₄, N₂H₃, aqueous vapors, etc. Nitrogen acts only as a diluent, else oxydation would go on too rapidly. H₂O holds air in solution for the fish and other water animals.*

One must keep in mind the relationship of plants and animals. One is dependent on the other. Whatever is required by one is also directly or indirectly required by the other. They both undergo a continual process of integration and disintegration, a continual change in form. In nature there is nothing independent. All combine to form links in an endless chain.

As already stated, not the smallest particle of matter is lost or useless, neither is the expenditure of energy or force. The death of a plant or animal is only the act of giving nourishment to some living plant or animal. The kinetic energy of life in the present generation is finally stored as potential energy to be again converted into kinetic energy in some future generation. Thus force and matter are co-existent, immutable and indestructible.†

*Space does not permit a fuller discussion of moisture, temperature, light and air. The student is requested to freshen his memory on those subjects in some standard work on physics; also the chemism of plant and animal life should be reviewed.

†Some of my statements are necessarily broad, hence the student is earnestly advised to do some independent thinking in order that he may comprehend and not be misled. Confucius has rightly said, "Study without thinking is labor lost."
Having briefly considered some of the properties of life it might be well to consider its source and the relation of inorganic and organic matter. We have good reasons to believe that at one time this earth was a large nebular mass revolving in space. At this time it consisted of elementary substances in a gaseous state. Where these substances came from is impossible to say. As already stated we can not well believe otherwise than that force and matter were co-existent and eternal, having no beginning and hence no end. This matter acted on by this peculiar force became arranged and rearranged. Finally the formation process made the environments suitable for the production of inorganic compounds. The greatest factor to bring about these chemical combinations was heat. We can produce compounds artificially by causing elements to unite chemically on the application of heat. This chemism continued for ages till an exterior crust began to form. It will be unnecessary to state that at this time living matter could not exist. All the conditions were foreign to life as we know it. Water existed in the form of steam and vapor, the semi-solid crust was heated to a high temperature. By and by the temperature was sufficiently reduced to allow the crust to harden and water began to condense in pools, seas and rivers. Now we have the foundation from which all subsequent life, vegetable and animal, sprang. The same forces that formed inorganic compounds out of the nebular mass continued to work and finally produced organic matter endowed with a life principle, (mind, consciousness, soul). This first life was produced from the inorganic compounds at hand. No new elements or compounds were added. Living matter contains the same elements that non-living matter contains. The life mystery (life principle) is to be sought for in the combination of these elements.

Chemists have been able to produce organic and inorganic compounds in the laboratory, but no chemist has so far been able to produce an organic compound endowed with a life principle, not even the simplest. Living matter is too complex for our present knowledge of chemistry. This life
principle we find in all living matter—in the amœba as well as in man. It has not been located in any particular part of the body. We know that it exists only from the fact that we can observe its manifestations. This life principle is the same in quality in all organisms. The only difference is that of quantity.

The "instinct" of the dog is essentially the same kind of manifestation as the wonderful "reasoning" in man. The closer we study Biology the more are we convinced of that fact.

Spontaneous generation has been the subject of much controversy. Its advocates had a strong following and still has a few great scholars who teach that under suitable conditions and surroundings some of the lowest forms of life can originate de nova, that is spontaneously. Yet, the more careful observers have been the more they are convinced that Virchow's dictum, "Omnis cellula ab cellula," is true. There has been no positive proof given that life, even the simplest, can or does originate spontaneously. If that be the case and admitting that the theory of evolution is true, where did the primordial germ or cell come from? The only reasonable explanation is this: Though life does not originate spontaneously now, some time in the past the conditions and environments must have been suitable to develop a primordial germ or germs. This first living substance was no doubt aquatic, neither vegetable nor animal, of the simplest structure, similar to our amœba. It was the primal parent of all living matter.

It must be borne in mind that the process of evolution has been at work or rather can be traced back to the remotest part of our earth's history. It formed a nebular mass; it formed inorganic and organic substances; from these it developed species after species, each succeeding generation more perfect than the preceding until the climax was reached in man. This process does not stop here. It will continue through all ages. We note changes to a higher perfection
before our very eyes. The human race as a whole is progressing; the whole animal world develops more complex species; the vegetable world produces more highly specialized forms. Those structures that cannot fulfill the requirements of the evolution theory become extinct.

What is the life principle (mind, soul, consciousness.) What is its source? Is it something separate from the body? The correct theory seems to be that the life principle is concomitant with and dependent upon organization of matter. Matter must be combined and arranged as it is in the amœba before it will manifest the life action of an amœba. It must be arranged as it is in man before it can or will manifest a definite "reasoning" faculty. We find that the more highly developed an organism is the more highly developed is its life principle. A morbid change in the body produces a corresponding change in the life principle. For example, compare the "soul" of a chronic dyspeptic with that of a man in good health. Since mind (life principle, consciousness) is the result of organization of matter it ceases with death or the disorganization of matter.

In conclusion, I will give a schematic presentation of the development of animal and vegetable life according to the evolution theory. It is general and by no means perfect. It will be noticed that the animal kingdom is somewhat higher and later in development than the vegetable; algae are higher than fungi, etc.

Space is too limited in a small work like this to go into detail. The student is advised to read standard authors on the subject of Biology. Remember the fact that you can not become a real scholar in any branch of science unless you are in favor of free thought and unless you are willing to study wholly unbiased and unprejudiced by preconceived notions.

About one week should be devoted to the study of life. Lectures by the professor in charge, supplemented by reading reference books in a good library are recommended.
Inorganic Matter
YEAST, Torula Cerevisiae, (L., torus, a knot; and cerevisia, beer.)

The torulæ have long been known by their power of producing fermentation in saccharine substances. The whitish substance that collects on the surface and bottom of fermenting substances, for example, beer consists almost wholly of these organisms. They are microscopic cells, consisting of cell wall and cell contents, ranging in size from 1-1,000 to 1-2,000 of an inch in diameter. A cubic inch of yeast may contain over a billion cells. Their structure is very simple, a comparatively tough cell wall and a translucent, viscid protoplasmic fluid. In the smaller cells (the undeveloped younger cells) may be found a roundish more viscid portion, which is termed the nucleus or cytoblast (Gr., cytos, a cell; and blastos, germ). In reproduction the cytoblast separates into two or more independent portions. These surround themselves with a membrane thus forming new cells. Reproduction goes on very rapidly. Sometimes a number will adhere together, forming a "string" or "group." Generally there is formed a more clear portion within some cells termed a "vacuole" (L., vacuus, empty) whose presence and function is not explained.

On the addition of $\text{H}_2\text{S}_4\text{O}_4$ it is found that the cell wall has two coats, an external and internal. The internal coat, which resembles the intine in pollen, will contract with protoplasm. The external coat remains unchanged. Chlorophyll is not present during any stage of its existence. Assimilation takes place by asmosis. The torulæ, like the fungi, will multiply in the dark and in sunlight.

Whether the torula belongs to the animal or vegetable kingdom is a question hard to decide. It contains no starch, no chlorophyll, it absorbs oxygen and gives off carbon dioxide, it exists and multiplies without sunlight; these prop-
erties would indicate that it was not a plant but a member of the animal kingdom. But the fact that the external cell wall consists of cellulose and that it has the power of forming protein out of a non-proteid compound, such as ammonium tartrate, makes it almost decidedly a plant. If the scientific world would permit we might class it with Haeckel's mowers or third kingdom. But the majority are satisfied to call it a plant, so it is probably better to adhere to their decision in order to avoid confusion.

Laboratory Work.

Wash a little yeast so that nothing but the cells remain. Place some on a slide and cover with cover glass. Examine with \(\frac{1}{4}\)-inch objective and B ocular.

Yeast (Torulæ).

1\(^1\) Size.
1\(^2\) Measure carefully with micrometer.
2\(^2\) Comparative size. (See note.)

2\(^1\) Structure.
1\(^2\) Cell wall or sac.
1\(^3\) Transparent, homogeneous.

2\(^2\) Protoplasm.
1\(^3\) Less transparent.
2\(^3\) Often dots more or less transparent.
3\(^3\) Vacuole, not always present.
4\(^3\) Cytoblast or nucleus.

3\(^1\) Form.
1\(^2\) Make drawings of five or six cells.

4\(^1\) Composition.
1\(^2\) Cell wall.
1\(^3\) Amit a little iodine solution under cover glass to which has been added a drop of \(\text{H}_2\text{SO}_4\). The sac stains bluish. This is the test for cellulose.

2\(^2\) Protoplasm.
1\(^3\) Iodine solution gives only a brownish discoloration, hence no starch is present.
2 Add a drop of caustic soda and copper sulphate solution. A violet color proves that the protoplasm is a proteid substance.

5 Physiology.

1 Origin of torulæ.

1 Fill two flasks with culture fluid. Sterilize by boiling flasks, contents, cork and all. Hermetically seal one and allow the other to remain open. Examine the contents of open flask from time to time. It will soon be found that the open flask contains torulæ. After a time open the sealed flask and examine. No torulæ will be found. This proves that the torulæ do not originate de novo. It proves very likely that torulæ in a dry state float in the open air thus gaining access to the flask. Where did the original torula come from?

2 Growth of torulæ.

1 Fill three flasks, one with pure water, another with a 10 per cent. solution of sugar, the third with the culture fluid. Sterilize all three by heating to the boiling point for a short time. Add a little yeast to each. Set them aside and watch from time to time. In which flask does fermentation begin first? In which is it the most active?

3 Life force of torulæ.

1 It is already known that boiling will destroy torulæ.

2 Fill three flasks with culture fluid. Keep them at different temperatures. One at 80° F., the other at about 40° F., the third at about 15° F. In which is fermentation most active?

3 Dry some yeast by a moderate temperature. This does not destroy its activity.

Note.—Examine different kinds of yeast. Baker’s yeast will probably be most easily procured.
AMOEBA.—(Gr., amœba, change.)

The amœba is very interesting because it represents the lowest form of animal life, consisting almost wholly of undifferentiated protoplasm. A description of its properties has been given in the introduction to Biology which the student is advised to re-read. Amœba can generally be found in stagnant water containing decaying vegetable matter. An infusion of vegetable matter in water exposed to the sunlight will almost certainly contain amœba, besides many other forms of protozoons.

Amœba are very simple in structure. The external limiting layer or ectosarc can not properly be called a distinct membrane any more than an oil globule can be said to have an external coat. The ectosarc is simply of a somewhat different consistency than the more internal portion. The protoplasm generally has numerous small granules scattered through it. Sometimes a clearer portion called the vacuole or contractile vesicle may be found in the protoplasm which generally contracts with great regularity. The function of this contractile vesicle is not definitely known. It is supposed to pump water in and out of the body.

The amœba is rarely at rest during life. Its continual change in position and form is due to its power of extending and retracting any portion of the ectosarc. These prolongations are called pseudopodia, meaning "false feet." These pseudopodia enable the amœba to move from place to place and aid in finding and grasping its food, and also aid in digesting it.

The food of the amœba consists mostly of vegetable organisms. It appropriates these by wrapping itself around them, thus making a temporary stomach of the ectosarc. As soon as it has assimilated all that it requires it unwraps itself, and allows the useless portions to float away. Some biologists claim that the food passes through the ectosarc into the protoplasm and the undigested particles pass out through the same channel.
The form of the amœba when at rest is spherical. This may be proven by reducing the temperature to the freezing point or raising it to about 100° F., or by a moderate electrical shock. Either of these processes will render the amœba powerless and leave it in a spherical form. A strong electrical shock will kill them.

Laboratory Work.

Place a drop of water containing amœba on a slide. Cover with cover glass. Avoid pressure. Examine with \( \frac{1}{4} \)-inch objective and B ocular.

Amœba.

1\textsuperscript{1} Form.
1\textsuperscript{2} Note the continual change.
2\textsuperscript{2} Note the development of a pseudopodia. The ectosarc prolongs first then the protoplasm follows after, often with a sudden rush.
3\textsuperscript{2} Make drawings at intervals of five seconds.

2\textsuperscript{1} Size.

1\textsuperscript{2} Different in different species. Measure several.

3\textsuperscript{1} Structure.

1\textsuperscript{2} Ectosarc.
2\textsuperscript{2} Nucleus. Sometimes absent.
3\textsuperscript{2} Vacuole or contractile vesicle. Note its slow diastole and rapid systole.

4\textsuperscript{2} Foreign bodies which have been swallowed.
5\textsuperscript{2} Admit some iodine solution. If there is any blue coloration it is due to starch granules which have been swallowed.

4\textsuperscript{1} Kinds.

1\textsuperscript{2} Look for encysted forms. Some come to rest spontaneously, assume a spherical form and secrete around themselves a structureless sac.

2\textsuperscript{2} One species has very long and slender pseudopodia.

Note.—Compare the amœba with white blood corpuscle.
BLOOD CORPUSCLES.

Place a drop of blood well diluted with water on a slide and cover with cover glass.

Blood Corpuscles. (Human.)

1° Red corpuscles.

1° Relative number compared with white. Varies from 600 to 1,000 in health.

2° Form.

1 3 General form, disk.
2 3 Surface, concavo-convex on both sides.
1 4 Convexity near margin.
2 4 Concavity in center.
3 4 Proof of form: If seen a little beyond the focus the center appears dark; if a little within focus the margin appears dark. Due to the fact that the convex and concave surfaces can not be brought to a focus at the same time.

3° Size.

1 3 Measure carefully with micrometer.

4° Color.

1 3 En masse, red; single corpuscles, pale yellow or almost colorless.

5° Movements.

1 3 None, except probably Brownian.

6° Tendency to collect in rolls (roleux.)

7° Crenated margin on becoming dry.

8° Nucleus.

1 3 None visible. Some physiologists claim that the form of the red corpuscle is due to the contraction of its nucleus

2° White corpuscles.

1° Form.

1 3 Spherical, changeable.

2° Size.

1 3 Measure with micrometer and comparative size.

3° Motion.
1\textsuperscript{st} Amoeboid. Closely observe a corpuscle for a few minutes. The change in form takes place very slowly. Make drawings at intervals of one minute.

2\textsuperscript{nd} Nucleus, generally present.

3\textsuperscript{rd} Granular contents.

Note 1.—Examine the blood of amphibians, birds, insects, etc., and make comparisons.

Note 2.—The standard for finding comparative size of microscopic objects is the red corpuscle.

**Cappillary Circulation in Web of Frog's Foot.**

Catch an ordinary frog and put it in a bag just large enough to hold it with the exception of one hind leg. Sew the bag shut and tie it frog and all on a wooden stage in such a position that if the free extremity is extended the web of the foot will just come under the objective. By means of thread tie the foot with toes extended over the opening which you have made into the wooden stage for the transmission of light. Finally tie the whole on the stage of the microscope.

The foot can not be tied so that it will remain absolutely quiet.

(a) Focus carefully and make your observations while the frog is quiet.

(b) Observe elasticity of red corpuscles, elongating and bending to adapt themselves to a given capillary.

(c) White corpuscles have a tendency to adhere to the sides of vessels and to migrate through the walls.

(d) There is no visible difference between venous and arterial blood. Determine the difference by the direction of flow.

(e) Observe effects of stimulants applied to frog and foot.

Note.—There is no test known to science by means of which human blood can be unmistakably distinguished from all others. The spectroscope is said to have accomplished what heretofore has been impossible.
MOUNTS FOR THE MICROSCOPE.

TEMPORARY MOUNTS.

Temporary mounts are such not intended for future examination. The mode of preparing them depends on the substance to be examined, for example vegetable tissues can not be mounted like starch granules, nor pollen like blood corpuscles. It would be impossible to describe each case in detail. Only some general advice can be given. Good judgment and reason will do the rest.

(a) See that the slide and cover glass are perfectly clean and dry.

(b) See that the substance to be mounted is free from as much foreign matter as possible.

(c) Do not place a "hand full" of the substance on the slide, but only enough to show all the parts you wish to see. Be sure that you do not place it all in a nice heap in the center of slide, so as to make it impossible for light to pass through it.

(d) The mediums most used for temporary mounts are water and glycerine. Keep in mind the effect these mediums have upon the various substances for examination. The principal use of the medium is to dilute. For example if undiluted blood were placed on a slide it would be impossible to see separate corpuscles.

(e) Place a cover glass (use only the circular) on the substance. It retains the substance in place, spreads it evenly, and prevents the too rapid evaporation of the mounting medium.

(f) Bear in mind the effect of heat and cold on what is to be examined.

(g) Remember that cleanliness is a virtue much to be desired in everything especially in microscopy.
NEEDLE PREPARATIONS.

Mounts prepared by means of needles, called dissecting needles, are termed needle preparations. They may be either temporary or permanent mounts. The skillful microscopist can do very satisfactory work by means of his dissecting needles, although the mounts may be lacking in the beauty of finish found in those cut with a microtome.

(a) Prepare two dissecting needles by fastening two medium sized needles, heads down, into wooden handles of convenient size and length. The needles should be highly polished and sharp. If they are rusty it is almost impossible to work with them. If desirable they may be bent in any shape by first heating them to redness.

(b) It is very essential that one should have a dissecting microscope. There are a great variety in the market, for instance the "Handy dissecting microscope" of the Bauch & Lomb Optical Co., which I think can be had for one dollar. Their "Excelsior" with three lenses costs $2.75. If one has the means to make the investment it is best to get a good binocular. Any person, however, with a little ingenuity can construct a very creditable dissecting microscope for himself as follows: Take a sound block of wood an inch thick, four or five inches wide and about six or seven inches long. In the middle of one end of this block of wood which we will call the stand, place upright a heavy (½-inch) piece of wire about four or five inches long. Take a good large cork in which make two holes, one for the heavy wire in the stand and the other for a thinner wire which is to be bent so as to form a right angle with the heavy wire. The extremity of the second wire furtherest away from the cork is to be bent in a suitable shape to hold the lens. That is all that is necessary. By means of the cork you can focus up and down. By means of the second wire which works in the cork the lens may be swung from side to side. The lens of any simple microscope can be used. A plate of glass may be placed on the stand so as to give a smooth clean surface to work on.
Any kind of hand rests may be placed on either side of the stand. Having, by a little ingenuity and mechanical skill, devised the necessary apparatus you may begin preparing mounts. It can be readily seen that only soft tissues, such as muscle, tendon, fascia, etc., can be used.

(a) Take a piece of tissue about the size of a pin head, place it on the glass plate of your dissecting microscope and begin to separate the ultimate fibres by means of your dissecting needles. Keep the tissues moistened with an alkaline solution (NaCl sol.). Tease just as long as there is any thing left to tease. The ultimate fibres must be separated. It is a tedious task, but practice patience which you must do before you can become a microscopist or anything else. After being convinced that the substance is sufficiently teased proceed to the next.

(b) Remove as much moisture as possible by means of blotting paper. Drop a few drops of 85% alcohol on tissue, allow it to remain a few minutes, then remove by means of blotting paper. The alcohol hardens and contracts the ultimate histological elements somewhat, thus making them more conspicuous under the microscope. It also prevents decomposition of tissues.

(c) Now add a few drops of staining fluid. Carmine is probably the best for animal tissue. Allow it to remain till well stained. The object of the staining is not to make the mount appear more beautiful but to render the various histological elements more prominent. The nucleolus stains more heavily than the nucleus, and the nucleus stains more heavily than the cell contents. Remove staining fluid by means of blotting paper. If stained too much wash out excess by means of washing bottle.

(d) Fix the stain by allowing specimen to remain for a few minutes in acid alcohol. (See recipes). Remove alcohol.

(e) Now put on a drop of oil of cloves. This makes the tissue transparent. Remove oil and dry the specimen in a moderate temperature.
(f) Mount in balsam and finish like any permanent mount.

Note 1.—Be careful not to have too much tissue on the slide. Remember that a very small particle will appear large under the microscope.

Note 2.—Do not have the fibres all in a bunch but separate them as much as possible.

Note 3.—Do not be slovenly and careless. Good mounts can be kept for a long time.

Preparing Animal Tissues to be Cut by Hand or with a Microtome.

Some soft tissues can not be teased and mounted as has been described in the foregoing process. For example glandular tissues, such as liver, kidney and parotids; also such tissues as lung, cartilage, muscular tissues with trichina in situ, etc. They require special preparation. It would be impossible to describe the best way for mounting each tissue. The student must keep in mind the nature and composition of the tissue he is about to work upon and the properties and actions of the various reagents he is going to use.

The following process is general. Does not apply strictly to any one tissue. The different steps throughout this book are arranged with the supposition that the student spends at least one hour a day in the laboratory.

Preparing Tissue for Section Cutting.

(a) Preparing specimen.—Cut the tissues in pieces one inch square or less. Make either longitudinal or transverse squares or both. Wash away blood, dirt, etc. Then place in a cold saturated solution of Hg Cl₂. Leave it one hour, then remove and wash free from all traces of the sublimate. (See recipes.)
(b) Hardening.—Place in 65% alcohol for twenty-four hours. Then in 85% alcohol for twenty-four hours. Now examine the tissue to see if it is nearly hard enough, if so place in 90% alcohol for one hour. If not nearly hard enough, it must be allowed to stand for another twenty-four hours or more in fresh 85% alcohol.

(c) Staining.—Place the tissue in the staining fluid twenty-four hours, till stained throughout. (Cut and see.)

(d) Fixing the stain,—Place in 70% alcohol to which has been added a few drops of H Cl. Leave an hour or so, till it turns a bright scarlet with carmine stain. It must not be stained too much.

(e) Dehydrating.—Place in 70% alcohol for twenty-four hours. Remove and place in absolute alcohol for one hour.

Clearing.—Place specimen in oil of cloves for twenty-four hours. The oil dissolves the alcohol and makes the tissue transparent.

(f) Prepare for Imbedding.—Place the specimen in equal parts of oil of turpentine and paraffine heated over water bath for half an hour. Do not boil it. Then into paraffine heated over water or sand bath for one-half hour.

(g) Imbedding.—Make a paper box suitable to the size of the specimen. Place in it the specimen, and imbed it in melted paraffine.

Note 1.—This is one of the many ways of preparing a specimen for the microtome and probably one of the very best. The different steps are so arranged as to save you both time and extra labor.

Note 2.—Observe each step and study out "why" you should do this and that. Remember that the various tissues treated alike will not give like results.
BIOLOGY.

CUTTING SECTION.

(a) Cutting with a microtome.

(1) Make either transverse or longitudinal sections.
(2) Cut as many sections as desired, and place in a clean box properly labelled.

(b) Cutting by hand.

(1) Do not cut too thick.
(2) Hold the section firmly in the left hand, and draw the razor at full length, evenly and smoothly toward you.
(3) Do not "saw off" a section.
(4) Cut one section, look at it and if you think it is thin enough, mount it and see; if not thin enough, discard it and try to do better the next time.
(5) Keep razor and specimens dry and clean.
(6) Last, but not least, keep your razor sharpened to the keenest edge.

MOUNTING A SECTION.

(a) Cleaning slide and cover glass.—Remove all foreign matter by proper agents. Wipe perfectly dry with a clean cloth.

(b) Remove paraffine—Lay one end of cleansed slide on some eminence, so as to incline it about five degrees. Place a section near center of slide. By means of pipette drop some benzine on the upper edge of the slide and let it run down. Allow all paraffine to dissolve and wash away.

(c) Removing benzine.—Remove as much benzine as possible by means of a dry cloth and blotting paper.

(d) Drying.—Warm the slide with specimen moderately till dry and then place specimen on exact center of slide. Find exact center of slide by means of slide centerer.
(e) Mounting.—Place a well cleaned cover glass on top of the section. Deposit a drop of balsam around the margin of the cover glass; capillary attraction will draw it under and spread it evenly. Press slightly and carefully, perpendicularly on the cover glass.

(f) Examining the section.

(1) Examine with low power, (1-inch) objective. See if it is of right thickness, and if it shows the proper arrangement of tissue.

(2) Examine with high power, (¼-inch) objective. See if it shows all the histological elements, cells, nucleus, nucleui, etc. If the section does not meet a microscopist’s expectations, remove from slide at once.

(3) If it is a good section remove air bubbles from under cover glass by carefully heating over spirit lamp till bubbles escape.

7th step.—Finishing.

(a) If the section is a good one, lay it aside for several weeks, till balsam is dry; then remove all superfluous balsam by means of knife, alcohol, and dry cloth.

(b) Place on a turntable and make a ring of oxide of zinc around the margin of the cover glass. It may be artistically finished by means of colored varnishes.

(c) Labelling.

(1) Paste label on the right hand of the slide, (the upper side). Put on name of section, whether cross section or longitudinal; below that, your name and date.

(2) It is well to place label also on opposite end on which write reagents used: 1. What hardening agent. 2. Embedding material. 3. Staining fluid. 4. Mounting medium.

Note 1.—When examining a slide under the microscope, try to see what there is to be seen. Do not merely satisfy a
morbid curiosity. Study what is before you in some standard treatise on the subject.

Note 2.—Examine first with low power, and then with high power. In using the microscope, handle with care. Learn to keep both eyes open and to use them alternately, so as not to ruin your right eye.

VEGETABLE TISSUE.

Raw material for this branch of study can be found everywhere. The vegetable kingdom furnishes more interesting object for study than all other classes put together. Starch, which is so plentifully distributed throughout the vegetable kingdom, has been described elsewhere; also pollen. Among the lowest forms of animal life are the algæ. (L., alga, sea grass). They are easily procured and afford an interesting study. They grow in water and may be found in the ocean coloring its water, in rivers, lakes, ponds, ditches, etc. The green scum so often seen on the surface of stagnant water consists of these small plants. Put some vegetable tissue in a beaker full of water and expose it for several days to the sunlight. It will contain a large number of algæ.

LABORATORY WORK.—Algæ.

Place a drop of water containing algæ on a slide and cover with cover glass. Examine with ¼-inch objective and B ocular.

Algæ.

1 Kinds.

1° Single celled or unicellular.

1' Spindle like.

2' Rod like.

4' Spherical.

1" As to form.

1' Spindle like.

2' Rod like.

4' Spherical.
Many celled or multicellular.
1\(^{2}\) Double celled.
2\(^{2}\) Those in which cells are united so as to form a string. Often very long.
3\(^{2}\) Those in which cells are united in a group.

2\(^{1}\) Structure of a single cell.
1\(^{2}\) Cell wall.
2\(^{2}\) Cell contents.

3\(^{1}\) Composition.
1\(^{2}\) Cell wall
1\(^{3}\) Cellulose.
2\(^{3}\) Earthy salts.

2\(^{2}\) Cell contents.
1\(^{3}\) Albumen.
2\(^{3}\) Coloring matter, generally colorophyll.
3\(^{3}\) Starch granules.
4\(^{3}\) Oily substance.

4\(^{1}\) Assimilation.
1\(^{2}\) Endosmosis.
1\(^{2}\) From the water in which they live they take in C\(_2\)O\(_2\) and N\(_2\)H\(_4\).
2\(^{2}\) Exosmosis.
1\(^{3}\) Give off oxygen.
2\(^{3}\) Surround themselves with a slimy coat.

5\(^{1}\) Admit a drop of iodine solution under cover glass and note results.

6\(^{1}\) Make exact drawings of the different kinds of algae.

7\(^{1}\) Take two beakers containing algae, place one in the sunlight, the other in the dark. Note results.

The following process for mounting vegetable tissue is general, hence the student must use judgment in what he is
about to undertake. Vegetable tissue is plenty and easily procured and with care very nice mounts can be made.

**Preparing for Section Cutting.**

(a) Bleaching.—Get two wide mouthed ounce vials. Provide one with a perforated rubber cork. In one vial place some MnO₂ and HCl, insert the rubber cork containing the short end of a U-shaped delivery tube. Pass the other end of the tube into the second vial containing water and the vegetable tissue. Chlorine will now be generated. \( \text{MnO}_2 + (\text{HCl})_4 = \text{MnCl} + (\text{H}_2\text{O})_2 + \text{Cl}_2 \) which bleaches the vegetable tissue. Allow it to stand for twenty-four hours.

(b) Eliminating chlorine.—Place the tissue in a solution of Na₂S₃ (one part of Na₂S₃ to 30 parts of H₂O) for half an hour, then rinse thoroughly with pure water.

(c) Remove air from tissue.—Place it, immersed in 20% alcohol, under the receiver of an air pump. Pump till bubbles cease to be given off. Diluted alcohol prevents the formation of algae and other vegetations.

(d) Prepare for imbedding.—Dry by means of blotting paper, then dip into Davis’ solution, withdraw and allow to drain on blotting paper till surface is dry.

(e) Imbed, cut and mount same as animal tissue. Sections must be cut as soon as possible, else the tissue will become too dry and hard to cut. Keep the sections in diluted alcohol (20%) till ready to mount.

**BONE.**

Bone on account of its hardness requires special preparation. Beginners generally have good success in making a section of bone. The following process is probably the best for mounting a section of dry bone in which the lining mem-
brane of the Haversian canals and lacunæ has been destroyed and removed.

I. Preparing for Mounting.

(a) Get a long bone. With a bone saw saw off some transverse and longitudinal sections making them as thin as possible. Make the sections from the compact portion of the bone.

(b) Thin down the sections by means of an ordinary file.

(c) Place the section between two "Washita" or sand stones and rub till the section is so thin as to bend of its own weight when one end is raised. The grinding surfaces of the stones and section must be kept moist all the time. Grind carefully.

II. Mounting.

(a) Boil some Canada balsam till it is quite thick. When cool place a drop of this balsam on a cover glass and allow it to cool till it is of the consistency of putty or butter, then imbed in it the section of bone. Place cover glass with section downward on exact center of slide. By pressure get rid of as much superfluous balsam as possible; apply a little heat if necessary. If mounted in thin balsam the lacunæ will become filled up and spoil the section.

(b) Finish like any other permanent mount.

Note.—Rock sections can be made in a similar way. They, however, require more care and patience.
BIOLOGY.

INSECT MOUNTS.

Small insects can generally be mounted whole without any previous preparation since they are mostly transparent. Among these may be mentioned *Acarus domesticus*, young *Pulex irritans*, *Acarus scabies*, and especially the younger members of the genus *Pediculi*.

The larger insects, such as flies, bees, beetles, spiders, etc., require careful dissection in order to gain a correct insight into the relative structure of the insect economy. It would be impossible to describe how to proceed in each individual case. Experience comes by practice and the student will find that each subject becomes more and more easy, especially if, before commencing in haste with the needles and scissors, he will study the general arrangement of organs in his subject, by reference to some one or other of the many standard works in existence at any good library.

The student will have no trouble in finding insects for dissection. Put no insect to any unnecessary pain. Kill it as soon as possible by means of chloroform, ether, or the cyanide of potassium bottle which is now so often used.

Before beginning work be sure you have the necessary instruments such as dissecting case, dissecting microscope, dissecting needles and the necessary reagents. Now select some insect to begin with, for example the *Gryllus domesticus* or common cricket.

I.

Prepare for Dissecting.

(a) Carefully study the insect before you, referring to some standard work. Be sure you know what it is and can classify and name it rightly. Be sure you understand its mode of living and the structure of its organs. In fact find out all you can about it before beginning to dissect. Of course while doing this you will very dilligently use a good pocket lens and finally make a good drawing of the whole insect.
(b) By means of knife, scissors and forceps, detach wings, legs, antennae, eyes, tongue. Portions of these if transparent enough can be mounted, otherwise they can only be examined as opaque objects. For example never have a mount which shows the foot of an insect very beautifully and has attached to it those portions of the leg which are much too thick and opaque to show anything at all.

(c) Place the carcass of the insect back down on a slide containing a drop of hardened balsam. Allow it to become firmly fixed.

(d) With a pair of fine scissors carefully slit up the integument on both sides. Raise up the chitinous skeleton and clear away the attachments with a blunt needle. When this is tolerably well performed the whole of the organs may be seen in situ.

(e) The specimen should now be placed for twenty-four hours in a mixture of glycerine and water (one of glycerine and two of water). This softens it for better dissection.

Note.—In this operation it is supposed you are about to dissect out the digestive organs. If the nervous system were wanted it would not do to immerse it in a glycerine solution as that would only soften the already too delicate tissue more. Instead it would have to be immersed in dilute alcohol.

II.

Dissecting.

(a) Place the specimen, still imbedded on the slide, in a dissecting trough under the microscope. For dissecting trough you can use any low dish or pan. Keep the specimen moist with the glycerine solution.

(b) Brush away all loose tissues with a small camel's hair brush. With scissors, needles and brush separate and clear away all that does not belong to the digestive organs. Never allow the specimen to become dry.
(c) By means of the scissors lay open the gizzard and wash it out with wash bottle and brush.

III. Mounting.

(a) Place the different organs in their natural position on center of slide. By means of blotting paper remove as much moisture as possible. Do not allow the specimen to become dry.

(b) Mount in pure glycerine. Glycerine mounts require careful preparation. Care is required to prevent them from leaking.

(c) Attach cover glass to slide by making around it a ring of balsam. After some time finish with varnish, etc.

GENERAL ADVICE.

Some advice has already been given about finishing balsam mounts. By careful study and consideration the observing student will find the best way to finish any mount he may have.

The intrinsic value of a mount does not depend upon its artistic finish; but first, upon the fact that the section itself has real value. For example the digestive organs afford more interest than simply the chitinous skeleton, although it may be entire and look very beautiful. Secondly, upon the fact that it is well finished so that it can be kept as long as possible. If combined with these two qualities we can have beautiful finish so much the better.

Always label each slide carefully. It avoids confusion and much unnecessary labor. Labels are cheap, get a good supply and paste them on well. In labelling insects always put on the scientific name, giving genus and species. If there is room you may put on the common name also.

Do not throw mounted slides into any box like marbles. Such a procedure will soon ruin them if they were ever worth
any thing. Place them in order in slide boxes made for that purpose. Place slides so that when the box is opened the labels naming the mounts will appear on the right hand side.

Be sure that each box is properly labelled and classified and that all the boxes have a suitable case in which they can be kept. One box might be labelled as follows:

Series No. 5.
Digestive and Tracheal Systems.
Articulata, (Subkingdom).
Insecta, (Class).
Diptera, (Order).
Musca, (Family).

Genus and species are given on the label on slide. Or,

Series No. 8.
Animal Tissues.
Muscle and Tendon,
Needle Preparation.

Each slide box is made to hold twenty-five slides. In getting slides it is best to buy those with ground edges as they will not scratch your microscope.

Above all keep only good mounts. Poor ones are of no use to you or any one else. Do not become discouraged if you fail in the first dozen attempts. If you have any ability at all you will finally come out victorious with a good mount.

Study your slides thoroughly and carefully. Be sure you know what you have before you. Get the necessary books in some way. One thing that the beginner generally lacks is application. Keep your mind fixed on what is before you.

Get your drawing outfit and make drawings of what you examine. It will help wonderfully to bring out details and to fix them upon your mind.

BACTERIA.

In recent years much has been said and written about the role that the very innocent and harmless looking bacteria
is supposed to play in the animal economy. In some instances it has been proven with almost a certainty that they are capable of causing morbid changes in the natural cell function of the animal system, thus producing what is called disease.

Bacteria are very minute, consisting of protoplasmic matter devoid of chlorophyll, generally multiplying by transverse division. They are of different forms, oblong, globular, rod like, spiral, etc. Many exist in two kinds of conditions, a still and an active.

Like torulæ they are capable of exciting fermentative changes in substances in which they live. All the putrefactive changes in animal and vegetable bodies are brought about by these bacteria. Here again we find the truth verified that death of one organism means life to another.

Drying does not kill bacteria. In the dry state they are not active but as soon as they find a suitable nidus they will begin to be active and reproduce their kind. The air, water, and surface of the earth are supposed to be full of bacteria. The reasons why their evil influence on bodies is only felt at certain times are these: First, they may not be present in sufficient number; and second, the body upon which they are acting may not be in a suitable condition. Organic cells in a normal state have sufficient physiological resistance to withstand the attacks of these germs. But as soon as this physiological resistance is lowered, for example in the human body by improper diet, the germs are able to locate and feed upon such cells, thus producing a pathological condition of an organ or some disease, as diphtheria, that depending upon the majority of germs which attack the body at the proper moment.

On account of the small size of most bacteria the beginner is not able to accomplish very much.

Laboratory Work.

Infuse some hay in warm water for an hour. Filter and set the filtrate aside for twenty-four hours. Note changes.
Examine the infusion with ¼-inch objective and B ocular. 

Bacteria.

1\(^{st}\) Form.
   1\(^{st}\) Rodlike or elliptic.

2\(^{nd}\) Size.
   1\(^{st}\) Several times longer than broad.

3\(^{rd}\) Structure.

1\(^{st}\) Not much to be made out with such low power. An external transparent layer and the internal protoplasmic fluid containing darker substances.

4\(^{th}\) Movements.
   1\(^{st}\) Some active, some passive.
   2\(^{nd}\) Some imbedded motionless groups.

Bacillus.

1\(^{st}\) Longer than bacteria.

Spirochæta.

1\(^{st}\) Form.
   1\(^{st}\) Like a spiral thread.

2\(^{nd}\) Motion.

1\(^{st}\) Very active. Spiral movement upon its longitudinal axis.

3\(^{rd}\) Uncommon form, often found in decaying teeth.

Place some hay infusion in three flasks. Boil two of them for a few minutes and hermetically seal one. Set all three aside in a warm place. Compare the three flasks. Explain.
RECIPES.

No. 1.
Davis' Solution.

\[ R \]
\[ \text{Acacia Gummi} \quad \text{gr. LX.} \]
\[ \text{Glycerine} \quad \text{gtt. V.} \]
\[ \text{Alcoholi} \quad \text{gtt. X.} \]
\[ \text{Aquæ, ad} \quad 5\text{ii.} \]
Allow all the gum arabic to dissolve, then filter carefully.

No. 2.

\[ R \]
\[ \text{Sulphite of Sodium} \quad 5\text{ii.} \]
\[ \text{Aquæ, ad} \quad 5\text{iv.} \]
Allow all of the No. 2 \( \text{SO}_3 \) to dissolve, then filter.

No. 3.
Ohlmacher's Medium.

\[ R \]
\[ \text{Canada balsam} \quad 5\text{i.} \]
\[ \text{Chloroform} \quad 5\text{i.} \]
Mix and shake well. If too thick add more chloroform.

No. 4.
Corrosive Sublimate Solution.

\[ R \]
\[ \text{Aquæ} \quad \text{OI.} \]
\[ \text{Hydrargiri Chloridi cor. q.s.} \]
Make a saturated solution and filter carefully. It is a very powerful poison. As an antidote give albumen, the white of an egg, flour, milk, etc. Give an active emetic.

No. 5.
Iodine Solution.

\[ R \]
\[ \text{Iodine} \quad \text{gr. XL.} \]
\[ \text{Iodine Pottasium,} \quad \text{gr. LX.} \]
\[ \text{Water ad} \quad \text{Oi.} \]
Dissolve the two first named substances in \( 5\text{iv.} \) of water, then add the remainder, filter.

No. 6.

\[ R \]
\[ \text{Gum Arabic} \quad 5\text{iv.} \]
\[ \text{Glycerine} \quad \text{gtt x.} \]
\[ \text{Carbolic Acid} \quad \text{gtt v.} \]
\[ \text{Aquæ, ad} \quad 5\text{iv.} \]
This is an excellent medium for attaching labels to glass.

No. 7.
Picro Carmine.

\[ R \]
\[ \text{Carmine Powder,} \quad \text{gr. XV.} \]
\[ \text{Liquor Ammonia,} \quad 5\text{i.} \]
\[ \text{Distilled Water,} \quad 5\text{VI} \frac{1}{4} \]
Mix and add Picric-acid Powder \( 5\frac{1}{4} \). Shake well and filter. Now set aside for several days to evaporate. The powdered residue must be kept in a well stopped bottle. When ready for use take of the above Picro-Carmine powder \( 30 \text{ gr.} \) and distilled water \( 3\frac{1}{2} \) ounces, shake and filter.
No. 8.  
Ammonia Carmine.

R  
Carmine Powder ...... 3i.  
Liquor Ammonia ...... 3ss.

While stirring add distilled water 3 XV., filter and keep in a well closed bottle.

No. 9.  
Preservative Fluid for Insects.

R  
Chloral Hydrate ...... 3i.  
Sodium Chloride ...... gr. xv.  
Pottassium Nitrate, gr. xxx.  
Glycerine and Alcohol aa ....... 05iss.  
Water ................ oz. v.  

Dissolve the chloral in the water and the remainder separate. Mix and filter.

No. 10.  
Culture Fluid for Torulae.

R  
Potass. Phosphate, gr. X.  
Magnesium Sulph., gr. V.  
Ammonium Tartarate, 3i.  
Cane Sugar .......... 3iss.  
Water ............... 3iv.  

Mix and filter.

No. 11.  
Acid Alcohol.

R  
Alcohol .............. 3ii.  
H. Cl ................ gtt X.

No. 12.  
Finishing Varnishes.  
(For colored rings.)

They are made by mixing the various colors with the vehicle in a mortar.

VEHICLE.

Dammar Gum ...... oz. iii.  
Mastic Gum ...... oz. i.  
Benzine .......... oz. vi.

COLORS.

White.......... Oxide of Zinc.  
Blue........... Ultramarine.  
Red............. Carmine.  
Black........... Lamp-black.  
Green........... Verdigris.  
Yellow........... Chrome yellow.

When the benzine evaporates it leaves the colors in a powder. Either use more benzine or simply dip the brush in benzine.

It is best to buy the staining fluids all ready prepared, especially where only a small quantity is required. The remaining formulae the student will have no trouble in preparing for himself.
VEGETABLE HISTOLOGY.

Having considered the process of making sections for the microscope we shall now describe somewhat the general histology of vegetable tissue. Distinct tissue are not found in the lower plants, not till we arrive at the pteridophyta. (ferns, cycads.) The most important tissue is the vascular. This begins to develop in the highest bryophyta (moss) but can not be said to be fully developed till we get to the ferns and flowering plants. Epidermal tissues is first to be differentiated. It constitutes the primary covering of the plant, consisting of one, but sometimes of two or three layers of cells. In it are found the stomata and trichome elements, which are simply modified epidermal cells. Sclerenchyma or sclerotic tissue consists of cells whose walls are very much thickened, commonly called stone cells. Collenchyma is a tissue whose cells have very much thickened angles; the cells themselves are generally prismatic in form and always found in close proximity to epidermal tissues. Cork tissue is also found beneath the epidermal tissue; its cells are thin walled, there are no intercellular spaces and at maturity lose all their protoplasm and become filled with air.

All these tissues, no matter how much they may differ, originated from a single parent cell. A general description of the cell is now in order. Heretofore the cell was considered the unit of structure in living organisms, this is probably not so, as I shall explain later on. Generally the cell is
defined as a nucleated mass of protoplasm. Sometimes even the nucleus may be absent so far as we know. In such cells it is supposed that the nucleus is finely divided and distributed through the protoplasm. Cell, is an unlucky term since it conveys the idea of an enclosure. The early histologists supposed all cells to be simply closed sacs and the very subordinate nature of the cell wall was not understood. We now know that the protoplasm and not the cell wall constitutes the essential part of the cell. In most cells we find suspended in the protoplasm a more highly refractive body, the nucleus. It consists of a delicate network of fibres suspended in a more clear substance surrounded by a delicate membrane. The clear portion is called achromatin and the net work chromatin. The readiness with which the nucleus stains is due to the chromatin. The achromatin does not stain as readily, some staining fluids do not stain it at all. In the chromatin is imbedded a highly refractive body, the nucleolus. It is simply a more dense collection of chromatin. As a rule there is but one, but several may be found in some cases. Sometimes a nucleus is found within the nucleolus. McMillan has discovered imbedded in the nucleus certain highly refractive bodies very difficult to stain. Their function and presence is not yet accounted for. The fact is there are yet many mysteries of cell structure to be unraveled and many more will be discovered.

The cell wall is secreted by the protoplasm and consists principally of cellulose in the vegetable kingdom. It is an amyloid carbohydrate having the same formula as starch.

The thickness of the cell wall varies greatly. Sometimes peculiar regular markings are formed by this thickening process going on unevenly, depositing the cellulose in heaps as we find in pollen. Sometimes the deposits are formed on the inner surface of cells as in ring, spiral and pittet vessels. In cells that become free just before maturity (as in pollen) these markings are formed on the outer surface of cell wall; when cells unite to form tissues the markings occur on inner
surface as in the different vessels of the vascular bundles. Sometimes the cell wall becomes otherwise changed in appearance and chemical behavior as in cork and lignin (wood). It may become infiltrated with coloring matter and mineral salts. The outer portion of wall may become converted into mucilage or gum as in the quince seed or flax. Sometimes the wall becomes partially or entirely absorbed due to pressure of cells upon each other as in the formation of laticiferous tubes for example. These changes in the cell walls are of considerable commercial importance, yielding gums and resins besides other useful substances. Crystals of various kinds also occur in the cell wall, yet these crystals are mostly found in the cell contents. Infiltration of mineral matter, especially Si O₂, for the purpose of strengthening the cell wall often occurs, especially in grasses.

Pfeffer claims that the cell wall, in fact nearly all tissues, are made up of small particles which he terms "micellæ"; they are very minute crystalloidal particles, each one consisting of many molecules, yet too small to be seen with the aid of the best microscope. These particles are not in contact, but separated from each other by a layer of water. This water is taken up and held in place by capillary force. The increase in size of tissues on the addition of water is due to the fact that the layer of water is increased thus forcing the "micellæ" further apart; when the water evaporates the micellæ approach each other and cause the cell to shrink. Starch granules, coloring bodies, etc., are likewise said to be made up of these micellæ. Pfeffer's assumptions are so far purely hypothetical. I have simply mentioned it to let the student know that there is such a hypothesis maintained by one of the greatest botanists.

Protoplasm is the most important part of the cell. It is the basis of all living matter. Yet in spite of its importance but little is known concerning it. Typical protoplasm is a transparent, semifluid or viscid, granular substance. It con-
tains the elements C, O, H, N, some S & P. These combine to form very complex proteid compounds whose percentage composition is not known. These compounds are quite unstable and can readily be broken up into simpler compounds.

The properties of protoplasm may be divided into four kinds, namely,

1. Chemism.
2. Metabolism.
3. Motility.

These properties are found in all living protoplasm and distinguish it from dead matter. All the phenomena of life action are dependent upon these properties. Chemism may be defined as the property which protoplasm has of producing within itself spontaneous chemical action thereby changing its chemical equilibrium. This chemism continues during the whole life period of every particle of protoplasm. Cessation of chemism means death to the protoplasm. The cause of this chemism is not known.

Metabolism is the process of assimilation and the excretion of waste products. It is the result of chemism. Through this metabolic process protoplasm increases in amount and forms the many bi-products, such as cellulose, starch, chromatophores (coloring bodies), aleuron grains, etc., and the waste products which are no longer of service to the cell.

Motility is that property which protoplasm has of producing within itself amœboid and other movements. This is also dependent upon chemism. Berthold made a careful study of protoplasmic motion and explains it wholly mechanically. In order to understand him a careful study of surface tension is necessary. (The student is referred to any standard college text on physics). Before a liquid or semi-liquid, free or suspended in another liquid, can come to rest or as-
sume a fixed form, surface tension must be equalized or counteracted on all sides. Movements of oil globules suspended in liquids, which are quite common, are due to a difference of surface tension between the oil globule and the liquid. As soon as surface tension is equalized movements of all kinds cease. If by some means the surface tension is continually changed motion is continuous. In living protoplasm chemism is the property which continually produces a difference in surface tension and hence movements of various kinds are the result. The movements of amœba, white blood corpuscle, bacteria, most infusoria, desmidia, algae, and streaming movements in vegetable cells are explained on this basis.

Reproduction is the property which one particle of protoplasm has of spontaneously separating into two independent masses. This will be more fully discussed under cell division.

R. Hartig has recently advanced a hypothesis which if correct will explain the source of protoplasm. By treating protoplasm with $\text{K}_2\text{H}_2\text{O}$ or $\text{Na}_2\text{H}_2\text{O}$ it is dissolved and leaves behind minute highly refractive bacterioid bodies which he terms "Zell Granula" or "Elementar Organismen." He claims that they are living organisms and by their life action secrete the protoplasm in which they live. This secreted protoplasm is not a waste product but is really a part of these organisms, as much so as the gelatinous covering of bacteria or the shell of molusca. If this hypothesis be true then the cell is not the unit of structure but each cell consists of a multitude of simpler units, the "Zell Granula," which produce protoplasm.

Cell division takes place by two methods, direct and indirect. The direct method is rare and occurs only in the lowest organisms. Here the nucleus constricts and separates into two, finally the whole cell is divided into two. In the indirect method the nucleus undergoes a peculiar transformation before it divides, called karyokinesis. It is but very re-
cently that karyokinesis has been studied and explained. Roughly it might be described as follows: (1) Nucleoli disappear. (2) Chromatin threads break up into U-shaped pieces. (3) Cross striations, which are present in the chromatin, disappear, (4) U-shaped pieces arrange themselves so that the closed ends are placed perpendicular to the equatorial plane of nucleus. (5) Appearance of two achromatin poles diametrically opposite and at right angles to equator. (6) U-shaped pieces each separate into two, one part passes to one pole the second part passes to other pole. (7) Reappearance of cross striations in chromatin. (8) Reappearance of nucleoli and cell division is complete. While this process has been going on in the nucleus the protoplasm and cell wall also became constricted through the middle and finally divided.

In the cell are also found cell sap, leucoblasts or amyloblasts which are supposed to form starch, aleuron grains containing crystalloid bodies, starch, acids, fixed oils, volatile oils, gums, resins, sugar, ferments, crystals, especially of calcium oxalate, coloring matter of which chlorophyll is most common, aromatic compounds and many other substances.

TISSUES.

As already stated all tissues develop from a single cell. Even after cell division has gone on to considerable extent no noticable differentiation of structure takes place. Sooner or later three primary meristematic tissues can be seen, namely, dermatogen, periblem and plerome. These can be studied in very young growing rootlets of ferns and angiosperms. Select the smallest fern rootlet obtainable and mount whole in water. It will show a structure something like that in. Fig. 4, lower right hand corner. c, is the triangular apical cell from which all tissues arise; a, is the root cap which serves to protect the growing point of roots; b, indicates the dermatogen, the primary epidermis, from which
all epidermal structures develop: e, represents the periblem from which the ground tissue or parenchyma proper develops; d, is the plerome cylinder or primary vascular bundle system. In the dicotyledonous angiosperms tissues develop from a group of apical cells. Study these primary tissues in the rootlets of ferns, monocotyledons and dicotyledons.

The principal tissues are—

(a) Vascular tissue or ducts.
   (1) Ringed vessels.
   (2) Spiral vessels.
   (3) Pitted vessels.
   (4) Reticulated vessels.
(b) Parenchyma or ground tissue.
(c) Collenchyma or thick angled tissue.
(d) Sclerenchyma or stony tissue.
(e) Liber or wood tissue. (Xylem.)
(f) Tracheids or vasiform tissue.
(g) Sive tissue with sive plates.
(h) Super or corky tissue. (Lenticels).
(i) Laticiferous or milk tissue.
(j) Epidermal tissue.
   (1) Stomata, water pores.
   (2) Trichomes, wax, warts.

We shall first describe the vascular bundle system. This constitutes the frame work of plants. It serves to strengthen and also to conduct fluids utilized by plants. The cells composing it generally have thickened walls and are much elongated in the direction of growth. The ducts or vessels constitutes the xylem or woody portion of the vascular bundle, the remainder consists of comparatively soft walled cells called phloem. The whole bundle is separated from the surrounding tissue by a sheath made up of cells having their walls thickened (xylem).

There are three kinds of vascular bundles according to the arrangement of the xylem and phloem, namely, collateral,
concentric and radical. In the collateral the xylem and phloem are placed side by side, the xylem toward the interior and phloem toward the exterior. Sometimes there is but one mass of xylem to two of phloem. This is called a bi-collateral bundle. When the growing line is between the xylem and phloem as in woody dicotyledons, thus causing the bundle to grow in thickness it is called an open collateral bundle. When the bundle soon reaches a definite size, as in most monocotyledons, it is called a closed collateral bundle. The concentric vas. bundle has either xylem or phloem located centrally and surrounded by the other. Sometimes the xylem is located centrally as in ferns. In many of the monocotyledons the reverse is true.

In the radical vascular bundle the xylem tissues or plates are arranged radially and separated from each other by phloem. The whole is surrounded by a bundle sheath. Sometimes the xylem plates meet in the center and sometimes they are connected by a pithy central cylinder of parenchyma.

The common corn stalk is a good object in which to study the closed vascular bundle. Cut the stalk across at the internode. The vascular bundles can be seen by the naked eye as dots distributed through the stalk. This is a peculiarity of the monocotyledons. Now make a thin cross section and stain with chloriodide of zinc and examine first with low power. The sheath, 6 in fig. 1, consists of lignified parenchyma cells. (Fig. 1 shows only one bundle.) These take a red-brown stain.
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VASCULAR BUNDLE OF CORN STALK.

1, Pitted vessels; 2, ringed vessels; 3, intercellular passage; 4, parenchyma; 5, reticulated cells; 6, sheath or endoderm; 7, sieve plate; 8, conducting cells. x 140.

The intercellular spaces, as at 3, may be formed by two ways, either by the rupturing of cells or by their separation from each other. The first may be called the "lysignian" and the second the "schizoginian" method. The ring vessels are the first elements formed in the vascular system. 1, represents pitted vessels. Sometimes a projection is seen on the inner wall of these vessels, it is all that remains of the division wall between the cells. Surrounding these ringed and pitted vessels are reticulated, thin walled cells, 5, these take a yellow-brown stain. The various vessels constitute the xylem portion of the bundle.

The remaining portion containing the sieve tubes, 7, and conducting cells, 8, is called the bast or phloem portion.
of the bundle. This takes a distinct violet stain with chloro-
dioxide of zinc. Sive tubes are never wanting. They are some-
what large, long, thin-walled cells whose partition walls are
perforated. Since the cells are quite long a cross section
may show but few of these perforated cell walls, called sive
plates. Notice that the xylem portion of bundle is toward
the interior of stem and phloem toward exterior. Also to-
ward outer side of stem the vascular bundles are more nu-
umerous and the intercellular passages are no longer found
and the sheath is very much enlarged. Sometimes several
bundles unite laterally.

After having carefully studied the vascular bundles next
examine the epidermis. Just beneath the extreme outer layer
which contains the stomata is found a stout ring of ligneous
(xylem, woody) tissue, this takes the same stain as the bundle
sheath. The vas. bundles with their sheaths are so placed as
to give the greatest possible strength to the stem. They con-
stitute a system of compound pillars.

Now make longitudinal sections, both radial and tangen-
tial. A radial section is made by cutting through circum-
ference and center of stem; a tangential section is made in
any direction excepting through or toward center. Fig. 2
represents a portion of vascular bundle of Zea mays. The
numberings are the same as in fig. 1. 4 is the parenchyma; 6, the sheath whose cells are generally more elongated than those shown in cut. 9, is a pitted vessel. Study carefully the sive tubes 7. 10, represents a sive plate; 11, a mucilage string found in all sive tubes. Sive tissue constitutes the nerve system of plants; it plays an important part in the irritable movements of plants as shown by the investigations of Frank and others. Stain both transverse and longitudinal sections with coralline. This is an excellent stain to bring out the walls of vessels and rings. It stains xylem and phloem different tints; xylem a bright coralline red and phloem a rose color. Tinct. of iodine stains ligneous tissue quite readily but does not stain bast fibres. It will also show whether starch be present.

Next make a cross section of outer part of cucumber stem. If you are lucky the section will show all the structures shown in fig. 3. More likely, however, you will find it necessary to make several sections before all the different tissues can be found. Use the same stains used in the corn stalk sections. 1, represents the epidermis consisting of one layer of cells devoid of chlorophyll; 2, is the collenchyma layer made up of thick angled cells. The cells themselves are prismatic in form. Collenchyma is always found in close proximity to epidermis.

It serves principally to give strength and resistance to the outer portion of stem. Sometimes it forms a continuous ring beneath the epidermis, sometimes only in bands as in the stem of Yellow Dock for example. The lines of demarcation between the different tissues are not so well marked as a rule as shown in the figure. 3, represents chlorophyll bearing rind parenchyma. 4, is sclerenchyma tissue. The walls of its cells are very much thickened. e, in fig. 4, repre-

The student is expected to make careful drawings of what he sees under the microscope. Use hard lead pencils on good unruled paper.
SECTION OF PART OF CUCUMBER STEM.

1, Epidermis; 2, collenchyma; 3, rind parenchyma; 4, sclerenchyma; 5, parenchyma; 6, trichomes (hair cells); 7, wart; 8, enlarged hair cell showing protoplasmic movement, a, chromatophores, b, nucleus, c, protoplasmic strings, arrows indicate direction of protoplasmic current; 9, air space beneath stomata; 10, stoma, guard cells; B, surface view of stoma.

presents typical sclerenchyma cells as found in the shell of nuts, here the cell cavity is almost obliterated. 5, is the true parenchyma consisting of large thin walled cells. 6, shows two hair cells (trichomes), one has a pointed end the other knobbed. These hair cells are very numerous in some plants and are quite characteristic in certain orders and families. 7, is a warty growth on the epidermis, they are generally abnormal developments produced by some irritation. 8, is an enlarged hair cell to show the streaming motion in vegetable
protoplasm. To study this use a \( \frac{1}{4} \)-inch obj. and B ocular. This motion can only be studied while the hair cells are alive. It is very interesting to study this movement in protoplasm since it gives ocular proof that it has the power of motion. The only reasonable theory to account for this motion is Berthold's based on chemism as already explained. The arrows indicate the direction of currents but these directions are not fixed, they may change and the currents flow in opposite directions. Study these movements in hair cells of Primrose and other plants. 9, is an air space found beneath all stomata. The two guard cells, 10, are modified epidermal cells. They, however, contain chlorophyll and an elongated clear nucleus. Their function is to regulate the evaporation of moisture from plants. Stomata are structures peculiar to the under side of leaves, but are also found less abundantly on upper side and on stem, petiole and other parts of plants. All the structures in fig. 2, are to be studied in other plants and compared with that of the cucumber. Water pores are found in many plants. They resemble stomata somewhat but differ from them in the fact that the guard cells are immovable and the opening therefore is constant in size, also it is found that water instead of gas oozes from them. They are found at the extremities of veins near the upper margin of leaves.

In fig. 3, the rind parenchyma 3, should be represented as extending to the epidermis wherever the stomata are found. Often it is found that the rind parenchyma cells just beneath the stomata begin to divide into oblong cells; this division extends over into the adjoining collenchyma. Soon a meniscus shaped layer of cells is formed called the cambium of lenticel. From this cambium are developed oblong, thin-walled, corky cells without chlorophyll. Finally these become so numerous as to rupture the epidermis at the stomata. These structures are called lenticels and appear to the naked eye as whitish spots distributed over the bark of
*Sambebus niger* for instance. To study these make careful surface and radial sections of these white spots and mount in water. Look for the cambium and superimposed loosely connected corky cells protruding through the rupture in the epidermis. The spaces between the loosely connected cells are filled with air thus admitting it to the inner tissue of the stem. Lenticels thus takes the place of stomata in the older stem where cork formation has begun.

True cork tissues can be studied in the bark of many plants. Make a cross section of a small stem of *Quercus* of any cork bearing stem.

![Fig 11](image)

a, epidermis; b, cork cells; c, cork cambium; d, rind parenchyma; e, typical sclerenchyma cells; f and g, method of forming laticiferous tubes; h, calcium oxalate crystals; a, b, c, d, e, tip of fern rootlet; x 180.

The cork cells are formed from the cork cambium shown at c, fig. 4. The youngest cork cells are colorless, the older yellow, and the oldest yellow-brown. Chloriodide of zinc stains them a yellow-brown, the younger darker than the
There are no intercellular spaces; cells appear rectangular, filled with air. Cork is also formed over the surface of wounds there serving to prevent the escape of cell sap. Cork is formed from collenchyma. c and upper layer of b in fig. 4, represents the under and upper parts of original collenchyma cells. The layer of cork cells just beneath the epidermis is called the "phelloderm," and the cork cambium is generally called the "phellogen." Make a section through a this year's stem of Ribes rubrum in which cork formation has just begun. In it you can seen the first formation of the phelloderm from the upper original layer of collenchyma.

Many plants when wounded give out a milky fluid. It is only milky so far as consistency is concerned; it may differ greatly in color and chemical composition in the different plants. This milky fluid is contained in a special tissue, the laticiferous tissue. This tissue is mostly found in the true parenchyma, especially on the sides of vascular bundles. Two kinds of milk tubes are distinguished, simple and complex. In the simple variety the tube consists of a single much elongated sometimes branching cell as in the Euphorbias. The complex milk tube is formed by the coalescence of many cells as shown at f and g in fig. 4. This variety occurs in the Dandelion. Make longitudinal sections to study milk tubes. At h, fig. 4, are shown a few oxalate of calcium crystals. These are quite common though others may found.

Tracheids are intermediate in structure between lignin cells and ducts. They differ from wood in having their walls less thickened, thus giving rise to pitted, spiral or ring like markings. Pitted tracheids are peculiar to pines. Make a longitudinal section of young stem, soak in alcohol to dissolve resin, and mount in water or dilute alcohol. Tracheids differ from ducts in that they do not become confluent end to end to form tubes; each tracheid consists of a single elongated cell. Carefully study the pitted tracheids in
both cross and longitudinal sections of pine stem. The pits appear as circular dots on the cell wall in the longitudinal section, facing toward the radial surface of section.

This article on Vegetable Histology is only intended to give the student a start in the study of plant structure. Sufficient has been indicated to enable the student to study tissues in different plants and make comparisons.

*Finis.*
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